CEEDO-TR-77-38

FOR FURTHER TRAN

CERL-IR-E-129

FIELD TEST OF BUILDING ENERGY ANALYSIS TOOLS AND PROCEDURES

BY D.C. HITTLE

U.S. ARMY CONSTRUCTION ENGINEERING RESEARCH LABORATORY, CHAMPAIGN, ILLINOIS

SPONSORED BY:

AIR FORCE CIVIL AND ENVIRONMENTAL ENGINEERING DEVELOPMENT OFFICE, AIR FORCE SYSTEMS COMMAND, TYNDALL AIR FORCE BASE, FLORIDA

AND

DEPARTMENT OF THE ARMY, OFFICE OF THE CHIEF OF ENGINEERS, WASHINGTON, D.C.

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: CERL-IR-E-129 (14)

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): (6) FIELD TEST OF BUILDING ENERGY ANALYSIS TOOLS AND PROCEDURES

5. TYPE OF REPORT & PERIOD COVERED: (9) INTERIM rept.

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): D. C. Hittle

(10) Douglas C./Hittle

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS: CONSTRUCTION ENGINEERING RESEARCH LABORATORY, P.O. Box 4005, Champaign, IL 61820

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: (16) 4A762731AT41-06-021 (17) 06

11. CONTROLLING OFFICE NAME AND ADDRESS

12. REPORT DATE: (11) May 1978

13. NUMBER OF PAGES: 86

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (12) 88 p.

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

(18) CEEDO (19) TR-77-38

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service
Springfield, VA 22151

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

building energy analysis
BLAST
field test

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the results of the field test of three building energy analysis tools: (1) the Building Loads Analysis and System Thermodynamics (BLAST) program, (2) Predicting the Performance of Solar Energy Systems, and (3) Use of the Building Loads Analysis and System Thermodynamics Program to Perform Total Energy System Analysis.

405 279

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Block 20 continued.

The BLAST program was tested for usability by the Corps of Engineers' Fort Worth District, Chanute Air Force Base, Base Civil Engineering personnel, and by personnel from the Air National Guard Bureau. Projects to which BLAST was applied included a flight simulator training facility, administrative buildings, and a hangar-administration building. Reports on program usability were received from each user and are summarized.

CERL Reports E-98 and E-108 were used in conjunction with BLAST by the Fort Worth District. Their evaluation of these tools is also summarized. Results showed that these tools can be effectively and usefully applied to the analysis and design of energy-conservative buildings. However, extensive revision of the draft BLAST *User's Manual* was recommended. The recommended revisions were accomplished prior to the publication of the *User's Manual* in December 1977. Widespread dissemination and use of these energy analysis tools is recommended.

*D. C. Hittle, *The Building Loads Analysis and Systems Thermodynamics (BLAST) Program, Vol I: User's Manual, Vol II: Program Reference Manual*, Technical Report E-119/ADA048734, ADA048982 (Construction Engineering Research Laboratory [CERL], December 1977), Technical Report 77-35 (Air Force Civil and Environmental Engineering Development Office [CEEDO], December, 1977).

†D. C. Hittle, G. N. Walton, D. F. Holshouser, and D. J. Leverenz, *Predicting the Performance of Solar Energy Systems*, Interim Report E-98/ADA035608 (CERL, January 1977).

+D. C. Hittle, *Use of the Building Loads Analysis and System Thermodynamics Program to Perform Total Energy Analysis*, Interim Report E-108/ADA040744 (CERL, June 1977).

FOREWORD

This research was conducted by the U.S. Army Construction Engineering Research Laboratory (CERL) for the Air Force Civil Engineering Center (AFCEC), Tyndall AFB, FL, under RDT&E Program 63723, Project 2102, "Mission Support"; Task 01, "Aerospace Structures"; and Work Unit 03, "Optimization of Energy Usage in Military Facilities"; and for the Directorate of Military Construction, Office of the Chief of Engineers, Department of the Army, under RDT&E program 6.27.31A, Project 4A762731AT41, "Design, Construction, and Operation and Maintenance Technology for Military Facilities"; Task 06, "Energy Systems"; Work Unit 012, "Development of Total Energy Systems for Military Facilities"; Work Unit 021, "Solar Energy for Heating and Cooling of Buildings"; and Work Unit 022 "Building Thermal Loads Analysis and System Simulation." The Air Force portion of this effort was accomplished under the auspices of AFCEC. On 8 April 1977, AFCEC was divided into two organizations. AFCEC became part of the Air Force Engineering and Services Agency (AFESA). The R&D Function remains under Air Force Systems Command as Det 1 (CEEDO), HQ ADTC. Both units remain at Tyndall AFB, FL.

Mr. F. Beason was the Air Force Technical Monitor, and Messrs. H. Maschke, S. Hiratuska, and E. Zulkofske were the OCE Technical Monitors. Mr. Douglas C. Hittle was the CERL Principal Investigator. Administrative support provided by Dr. D. J. Leverenz and by Mr. R. G. Donaghy, Chief of the CERL Energy and Habitability Division, is acknowledged.

COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

FIELD TEST OF BUILDING ENERGY
ANALYSIS TOOLS AND PROCEDURES

1 INTRODUCTION

Background

This report covers the field testing of three products of research and development efforts:

1. The Building Loads Analysis and System Thermodynamics (BLAST) energy analysis computer program and its user's manual[1]

2. *Predicting the Performance of Solar Energy Systems*[2]

3. *Use of the Building Loads Analysis and System Thermodynamics Program to Perform Total Energy System Analysis*.[3]

The Building Loads Analysis and System Thermodynamics (BLAST) program is a comprehensive building energy analysis computer program for estimating the hourly space heating and cooling requirements of the building, the hourly performance of building fan systems, and the hourly performance of conventional heating and cooling plants, total energy plants, and/or solar energy systems. Apart from its comprehensiveness, this program differs in four key respects from similar programs used in the past.

1. The BLAST program uses extremely rigorous and detailed algorithms in its computations.

2. The program employs its own input language, which permits rapid input preparation in a completely unformatted, English-like (as opposed

---

[1] D. C. Hittle, *The Building Loads Analysis and System Thermodynamics (BLAST) Program, Vol I: User Instructions; Vol II: Program Reference Manual*, Technical Report E-119/ADA048734, ADA048982 (Construction Engineering Research Laboratory [CERL], November 1977).

[2] D. C. Hittle, G. N. Walton, D. F. Holshouser, and D. J. Leverenz, *Predicting the Performance of Solar Energy Systems*, Interim Report E-98/ADA035608 (CERL, January 1977).

[3] D. C. Hittle, *Use of the Building Loads Analysis and System Thermodynamics Program to Perform Total Energy Analysis*, Interim Report E-108/ADA040744 (CERL, June 1977).

to computer-like) style. This language contains a library of all materials, wall sections, and roof sections and their properties that are listed in the ASHRAE *Handbook of Fundamentals*.[4] The capability of referring to these components by name frees the user from the tedious task of inputting scores of numbers for each space or building; similarly, the use of default equipment performance parameters permits the user to investigate generic systems easily and rapidly.

3. The program execution time is extremely brief, making the study of many alternative concepts relatively inexpensive.

4. The program is not proprietary and is therefore open to inspection by its users and those who rely on the results it generates.

BLAST is not the first public energy analysis program. Several programs dating over the past decade preceded BLAST; however, in the development of BLAST, the emphasis shifted from defining the technical feasibility of energy calculation programs to making these programs usable by design engineers. It was an objective of the BLAST program development effort to take energy analysis tools out of the laboratory and present them in a form which could be used easily by field engineers. Thus, the field test was the next logical step to determine whether this objective of usability had been achieved. Usability was considered to be a principal criterion for the potential future success of building energy analysis programs.

CERL Report E-38 (*Predicting the Performance of Solar Energy Systems*) resulted from a defined need to analyze the performance of building solar heating and cooling systems easily and quickly. The first section of the report presents a graphical method which, when combined with simple hand calculations, provides a first estimate of the potential performance of solar energy systems when applied to meet building hot water, heating, or heating and cooling demands. This manual procedure for estimating the performance of solar systems provides a first estimate of the potential fuel savings and a starting point for more detailed studies if solar energy systems are determined to be feasible.

The second section of this solar energy report deals with the detailed simulation of solar energy systems using the BLAST program. This section presents a step-by-step approach to analyzing solar energy systems for heating, cooling, or heating and cooling applications. This approach permits the user to apply BLAST and select the optimum collector area to maximize energy savings and cost avoidance.

---

[4] *Handbook of Fundamentals* (American Society of Heating, Refrigerating, and Air Conditioning Engineers [ASHRAE], 1972).

The emphasis of this report was on providing technology to the field in a form usable by field engineers. Consequently, it was necessary to test the methods presented and establish whether they served this purpose.

CERL Report E-108, *Use of the Building Loads Analysis and System Thermodynamics Program to Perform Total Energy System Analysis* supplements the BLAST program in the area of total energy systems evaluation and design. Estimating the annual energy savings possible with total energy systems currently requires that such analysis be performed using computer programs. This report provides a step-by-step approach to computer-aided total energy system performance evaluation. The purpose of field testing this product was to establish its usefulness in combination with the BLAST program for performing total energy system studies.

Purpose

The purpose of this field test was to determine the usability of these three building energy analysis tools, to expose them to users outside the laboratory, and to gather information for inclusion in the BLAST program implementation plan.

Approach

The approach to meeting the objectives of this field test consisted of the following steps:

1. Developing a test plan which included steps 2 through 6.

2. Providing a user's manual and user training to personnel involved in the field test.

3. Selecting, for each of the field test participants, one or more projects for study using the BLAST program.

4. Providing necessary user assistance and user support during the analysis of the selected projects by the field users.

5. Requesting user evaluation of the BLAST program and related reports.

6. Using the experience of the field test as an information guide for developing implementation plans for the BLAST program.

The evaluation of BLAST by the users occurred at two points: (1) after the training seminar, and (2) after the use of the BLAST program with emphasis on the BLAST input language and on the reports produced from BLAST simulations.

After using the BLAST program to evaluate the several projects included in the field test, the users were again asked to evaluate the BLAST *User's Manual* and the BLAST program input language. In addition, they were asked to identify the problems encountered in the daily use of the program and to provide suggestions for revising both the program and the *User's Manual*. Any deficiencies in the BLAST program in terms of its ability to realistically simulate field projects were to be identified.

Army personnel participating in the field test were requested to use CERL Reports E-98 and E-108 in addition to the BLAST program and to provide the indicated feedback on the adequacy of each. No special training was provided in the use or application of the methods and procedures described in these documents, because it was believed that these documents should stand on their own and that users should be able to apply them without special training.

Mode of Technology Transfer

The results of this work will be included in a new Appendix to TM 5-810, *Heating, Ventilating and Air Conditioning*, and published as a U.S. Air Force and Environmental Engineering Development Office technical report.

2 FIELD TEST PARTICIPANTS

Field test participants included personnel from the following organizations:

1. For the BLAST program:

   a. The U.S. Air Force Civil and Environmental Engineering Development Organization (CEEDO) and the U.S. Air Force Civil Engineering Center (AFCEC), both at Tyndall AFB, FL

   b. Base Civil Engineering personnel, Chanute Air Force Base, IL

   c. Fort Worth District, Corps of Engineers

   d. Air National Guard Bureau

2. For CERL Reports E-98 and E-108, the Corps of Engineers' Fort Worth District personnel were the only participants.

Other personnel from Federal and state agencies participated in the first BLAST training seminar to help evaluate the training session. Appendix A provides a list of the participating organizations in the training seminar.

3 EVALUATION CRITERIA

Since the objective of the field test was to establish the usability of the tools being tested, user evaluation focused on features relevant to usability. Users were asked to respond specifically to the following evaluation criteria.

1. BLAST training seminar evaluation criteria:

a. User's manual adequacy. Was the draft BLAST Program *User's Manual* readable, understandable, and complete?

b. Input language, program flexibility, output reports. Was the input for the BLAST program easy to use and clear? Was it easy to determine the type of building described and the type of systems and central plants to be simulated? Was the program flexible enough to permit analysis of many real buildings? Were the output reports generally self-explanatory and easy to interpret?

c. Training methods. Was the training seminar necessary, effective, and adequate as a supplement to the *User's Manual*?

2. The BLAST field test:

a. Program portability and accessibility. Could the program be moved from the computers on which it was developed to other computers where it might be used? Could the program be accessed by field users without difficulty?

b. User's Manual adequacy. The same questions about readability, understandability, and completeness were asked, recognizing that the field test provided a much more severe test of the *User's Manual*, since users were "on their own" in applying the program to a complicated field project.

c. Input language program flexibility and output reports. Ease of use and clarity were the evaluation criteria.

d. Impact of BLAST on the design and decision-making process. Were the results of the BLAST program useful and meaningful in terms of the project's design? Did the results provide additional information which affected the decisions made during design?

e. Manpower and funding requirements. What were the manpower requirements for preparing input, executing, and interpreting results of the BLAST program? What were the funding requirements and computer charges required to fully study a field project?

3. CERL Report E-98, *Predicting the Performance of Solar Energy Systems*:

a. Clarity of the procedure. Could the procedures described be understood and used without prior training?

b. Usefulness. Was the manual procedure for predicting the performance of solar energy systems useful as a preliminary feasibility assessment tool? Was the step-by-step procedure outlined for applying BLAST helpful in the design of solar energy systems?

4. CERL Report E-108, *Use of the Building Loads Analysis and System Thermodynamics Program to Perform Total Energy System Analysis*:

a. Clarity of the procedure. Was the step-by-step procedure for applying the BLAST program to perform total energy studies understandable and clearly presented?

b. Usefulness. Did the report provide useful supplementary guidance in using BLAST to perform total energy studies?

4 THE BLAST PROGRAM TRAINING SEMINAR

Training the field participants in the use of the BLAST program was accomplished by conducting a 3-day training seminar at CERL. The seminar provided an introduction to the BLAST program and introduced users to the BLAST input language, the BLAST simulation techniques, and the reports produced during BLAST simulations. In addition to lectures, this training involved actual use of the BLAST program on a sample class problem. The training seminar covered the following topics:

1. The BLAST program overview. This topic acquainted future users with the program's capabilities and the relationship between the various elements of the BLAST program.

2. The Load-Predicting Subprogram. The methods used to compute hourly space loads were reviewed, with emphasis on the relationship between user input and the space loads calculated.

3. The Air Distribution System Simulation Subprogram. The air distribution system simulation capabilities of the BLAST program and the methods used to perform the simulations were reviewed.

4. The Central Plants Simulation Subprogram. The capabilities and methods used to simulate boiler/chiller plants, total energy plants, and solar energy systems were discussed.

5. The BLAST program input language. A detailed review of the BLAST program input language was provided.

6. Sample problem. Participants ran the BLAST program on a sample problem. The class was divided into groups and each group was given a sample computer card input deck prepared prior to the training seminar, which insured that the sample problem in its original configuration could be successfully run on the BLAST program. Groups were instructed to modify the sample deck to study the effects of the various building architectural features, effects of air distribution system design and selection of air handling systems, and the effects of the central energy plant component selection on building energy use.

7. Forum on hints for effectively using BLAST. This forum discussed procedures for successively examining the architectural impact, the air distribution system impact, and the central energy plant impact on energy consumption in buildings.

8. Results of group problem solving. Each group presented its results for the sample problem.

9. User critique. At the end of the training seminar, each participant completed a questionnaire, evaluating the BLAST computer program, the BLAST seminar, and the BLAST *User's Manual*.

5 FIELD TEST PROJECTS

For the field test, the users applied BLAST and CERL reports E-98 and E-108 to selected real projects. An attempt was made to select projects which were sufficiently difficult to be typical of the routine design work accomplished, but not so large in scope as to place an unacceptable burden on the field test personnel.

The BLAST test project selected for use by Chanute Air Force Base personnel was the Base Civil Engineering Headquarters building, which is a small, one-story office building of approximately 8000 sq ft (72 m^2), divided into roughly 14 separate zones. This building had also been the subject of a previous design analysis for a heating and cooling system modernization project. A floor plan of this building is shown in Figure 1.

The project selected for study by the Fort Worth District personnel was the Laughlin Air Force Base Flight Simulator Training Facility. This building is a one- and two-story building of approximately 100,000 sq ft (9000 m^2) and is divided into approximately 19 thermodynamically separate zones. Since this project had been considered during its design as candidate for a total energy system, a considerable amount of data relevant to the building construction, building fan system design, and boiler/chiller plant were available. Floor plans of this building are shown in Figures 2 and 3.

The Air National Guard Bureau personnel studied a hangar/administration complex and an operations and training building, a building type found at several locations around the country. The hangar/administration building consists of a central hangar bay surrounded on three sides by two-story office spaces. The operations and training facility is a one-story, 19,000-sq ft (1710-m^2) building of masonry and metal panel wall construction. The principal reason for selecting these typical Air National Guard buildings was to study possible energy conservation options at various geographical locations.

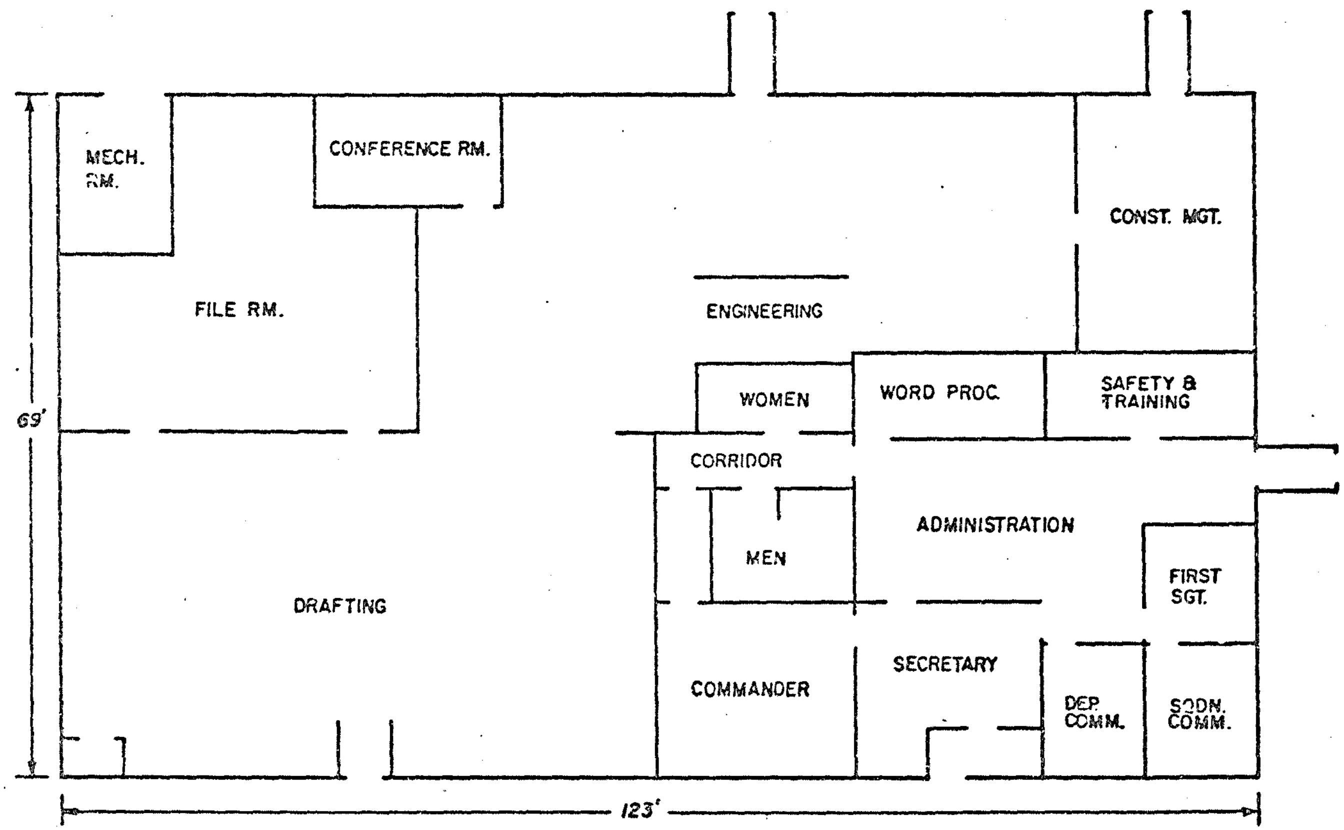


Figure 1. Base Civil Engineering Headquarters Building.

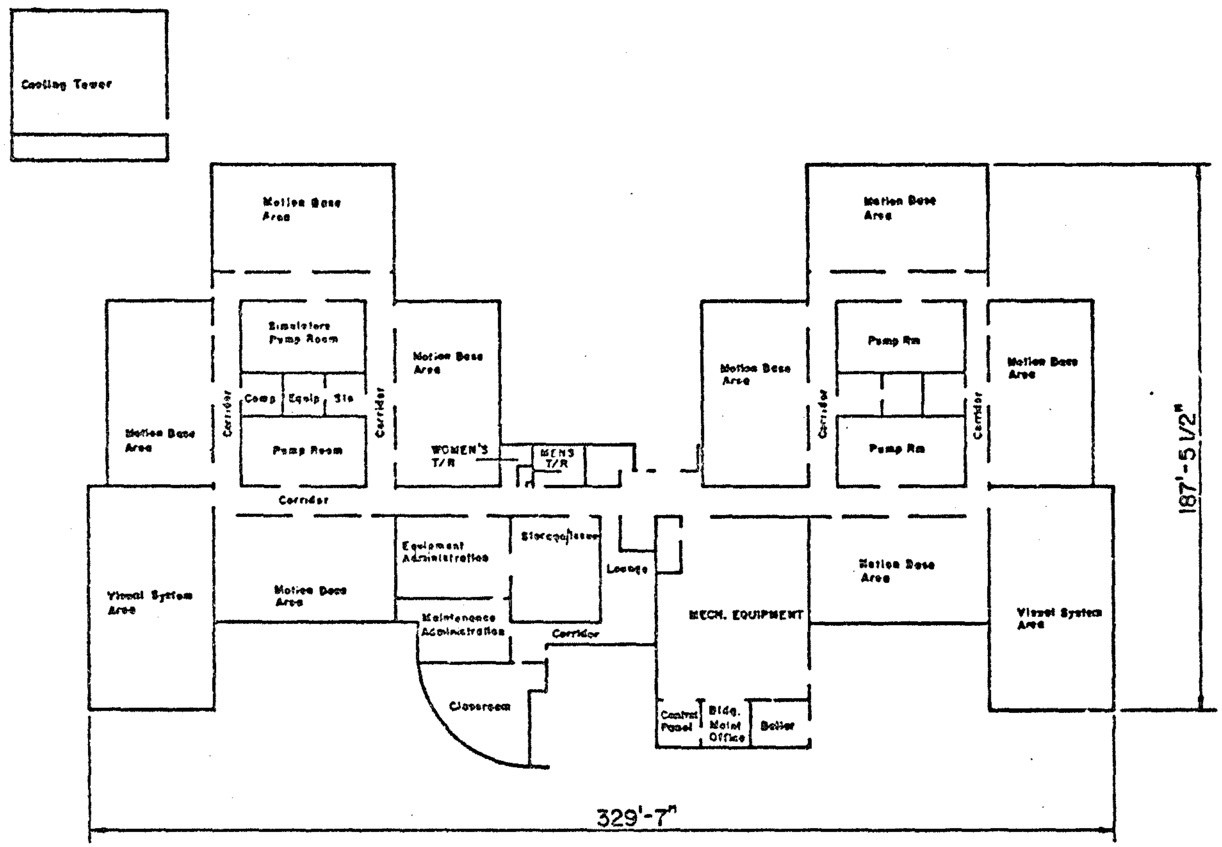


Figure 2. Laughlin Air Force Base Flight Simulator Training Facility (first floor).

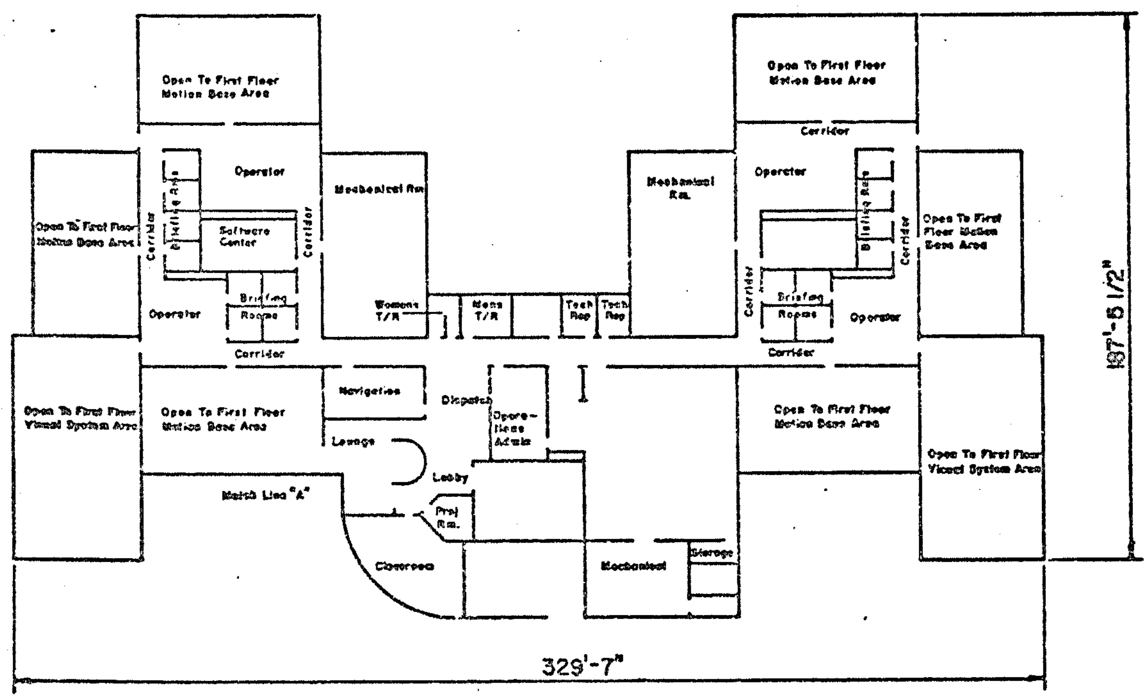


Figure 3. Laughlin Air Force Base Flight Simulator Training Facility (second floor).

6 THE BLAST PROGRAM FIELD TEST RESULTS

Results of User Questionnaires

Results of the user questionnaires completed at the end of the training seminar provided a mechanism for obtaining a preliminary evaluation of (1) the clarity, readability, and understandability of the BLAST *User's Manual*, (2) the adequacy of the input language, program flexibility, and output reports, and (3) the effectiveness of the BLAST training seminar. The results were as follows.

BLAST Program User's Manual

The draft BLAST Program *User's Manual* received considerable substantive criticism. The most frequently identified deficiency was its inadequate description of the procedures for inputting the geometric description of building spaces. Users had particular problems in describing roofs and floors and in determining the method by which to describe overhang and wing shading features. Users also felt that the discussion of reports and the meaning of the various numbers printed on the reports was insufficient. Another frequent criticism was that the manual did not clearly delineate which input items were mandatory and which could be optionally supplied by the user (the optional items would assume default values if not specified by the user). Users felt that more discussion was required concerning heating and cooling control strategies and the link between the load-predicting and system simulation control phases. The description for simulating specific central energy plant components was also thought to be inadequate and confusing.

The BLAST Program Input Language, Program Flexibility, and Output Reports

User response to the BLAST program and the BLAST input language in particular was almost universally favorable. The BLAST input language, because of its similarity to frequently used architectural and engineering terminology was considered to be extremely natural and to provide for easy input preparation and detection of errors in the input.

The flexibility of the BLAST program was the second most favorable reviewed feature. Users recognized the importance of being able to simulate both new and existing buildings and the need to use BLAST in both concept and final design phases. BLAST was frequently noted to be extremely flexible in comparison to other energy analysis programs.

Another important feature was the user's ability to simulate actual equipment by using BLAST. This feature was considered to be extremely important, particularly in the application of BLAST to existing buildings and systems.

Participants indicated a need for increased capability to simulate more air handling systems, specifically some of the more recently developed systems (for example, a dual-duct variable air volume system). The capability to account for miscellaneous nonelectrical thermal loads in building spaces and for miscellaneous latent space loads was considered to be an important feature to be added to the BLAST program.

Users identified substantial benefits which could be derived from being able to prepare the BLAST input data in an interactive mode. The users want to be able to sit at a desk-top computer terminal and immediately determine that their input data was syntactically correct. Such interactive input data processing would avoid the current problem of submitting a deck and receiving the output much later, only to find that a simple keypunch error prevented the program from performing the desired simulations. Interactive terminals are more commonly available than card reader/line/printer "batch" terminals and are relatively inexpensive ($2000 to $4000).

The reports produced by the BLAST program were generally considered to be adequate; however, users frequently mentioned that it would be desirable to produce more detailed "design day" reports to aid in the selection of air-handling system coils. More substantive criticism of the BLAST reports resulted from the field test of the program on actual projects, however.

The BLAST Training Seminar

It was universally agreed that the rapid assimilation of the BLAST input language and the rapid acquisition of the skills necessary for using the BLAST program required user participation in a training seminar. The participants also agreed that the application of the BLAST program on a sample problem was an important part of the training. In contrast to the rather critical comment by the users on the BLAST Program *User's Manual*, the trainees generally evaluated the training seminar as a clear presentation of what should be input to the BLAST program, what the output means, how to use the output for design and energy analysis, and what the BLAST program can and cannot do. Users also considered the forum on hints for using the BLAST program to be an important and beneficial interchange of ideas and procedures.

There were two major suggestions for improving the training. The first was that users should prepare their own input decks for a sample problem. Many users felt that a prepunched deck detracted from the benefit of the sample problem. The second suggestion was that the users should have more time before the training seminar to read and review the *User's Manual*. BLAST users also suggested that a slightly longer training seminar would have provided an opportunity to discuss the program's capabilities in more detail and that an additional day would be required if users prepare their own input decks. Finally, users suggested that the original class size of 23 participants was too large for training effectiveness to be optimal. Such a large group limited the "hands on" experience in using BLAST for each participant. In addition, the informal interaction between individual trainers and the training staff was limited because of the group's size.

Evaluation of Field Test Projects

The evaluation criteria for the field test included program portability and accessibility, adequacy of the *User's Manual*, adequacy of the input language and output reports, the impact of BLAST on design and decision-making processes, and the manpower and dollar requirements for using BLAST.

Program Portability and Accessibility

A measure of the program's portability was established when the program was loaded at the Eglin Air Force Base computer, and the Lawrence Berkeley Laboratory computer in San Francisco. Participants from the Fort Worth District accessed the BLAST program at the Lawrence Berkeley Laboratory Computer Center through their own batch terminal facilities.* Personnel from Chanute Air Force Base used the batch facilities at CERL to access the same computer center. Participants from the Air Force Civil Engineering Center at Tyndall Air Force Base and the Air National Guard Bureau used the remote batch facilities at Tyndall Air Force Base to access the program at the Eglin computer.

When CERL loaded the BLAST program on the two computer sites, the first problems were identified. These problems, which related to the BLAST program's portability, basically involved the computer hardware/software at the computer sites instead of the BLAST program itself. The problems encountered included (1) nonstandard and "evolving" operating systems (that is, the operating systems were not standard Control Data Corporation operating systems similar to the one on which BLAST was developed), (2) poor job turnaround, and (3) limited access to the computer facilities. It appears that the Government-owned computer

*A batch terminal is a high-speed card reader/line printer which can be connected to the remote computer via telephone lines.

centers have been purchased to meet specific mission requirements and are not general-purpose computer resources. Consequently, the BLAST program development staff received much lower priority for computer resources than did persons engaged in work involving the site's mission. As a result, the task of transferring the program from the computer on which it was developed to the computers to be used by the field test personnel was tedious. At the same time, the nonstandard operating systems made some reprogramming necessary.

Just as the BLAST program development staff received lower priority at the computer centers during loading of the BLAST program, BLAST program users also frequently experienced slow turnaround in using the BLAST program at these sites. In addition to the poor turnaround time, BLAST users at the Fort Worth District also found that the local batch terminal through which cards were input to the computer and from which printouts were obtained was also fully utilized. Thus, users were able to "log in" to the Lawrence Berkeley Lab computer typically no more than once a day. This further delayed the turnaround time between input and output, and was particularly frustrating when users who made minor syntax errors in the input had to wait as long as a day to find that the simulation had aborted. Interactive terminals were available, as they are in most Districts. However, they could not be used effectively during the field test since procedures for their use had not been developed.

As another measure of portability, studies were conducted to determine the feasibility of using BLAST on the Air Force's many Burroughs 3500 and Honeywell 6000 computers. Use of BLAST on these computers appears impractical (see Appendix B for details of this study).

The BLAST Program User's Manual

The adequacy of the draft BLAST *User's Manual* was more severely tested during the field test. Here, users did not have the benefit of the BLAST training staff during the preparation of input decks. Consequently, omissions and ambiguities in the *User's Manual* were readily identified as a result of the field test projects.

Generally, Chapters 1 through 5 of the draft *User's Manual* were considered to be fairly complete and, with the exception of typographical errors, caused minimal confusion; however, Chapters 6 and 7, which describe the input for air distribution system simulation and central energy plant simulation, respectively, confused the users as to the types of systems and central plant components being described in preparing the input. Users indicated a desire for a detailed description or figures illustrating the types of fan systems simulated in the BLAST program and essential information about each system (such as placement of coils, fans, humidifiers, etc.). The discussion of air distribution system control strategies, both optional and default, was considered to be inadequate. Similarly, in Chapter 7, which describes how to prepare input for central energy plant simulations, users suggested that the models used in simulating central plant components should be explained in detail and contain examples of methods for obtaining individual equipment performance parameters. A more detailed explanation of life cycle cost calculation procedures was also requested.

The BLAST Input Language and Output Reports

Field test participants were asked to evaluate the BLAST program input language and output reports again after they had used the program on an actual project. These evaluations were similar to those provided immediately after the training session. It was pointed out, however, that in practice, users will not be using the BLAST program on a continuous basis; it was therefore considered even more important to clearly identify and provide a checklist for the commands and language. Special coding forms were suggested as an aid to program use.

During the field test, a much more critical review of the reports produced by BLAST was provided, since users had more time to review and interpret them. In this regard, the reports produced by the Load-Predicting and Systems Simulation Subprograms, once explained, could be interpreted without confusion. However, the Energy Utilization Summary report produced by the Central Plant Simulation Subprogram caused considerable confusion. Suggested alternate formats were provided by participants.

Impact of the BLAST Program on the Design and Decision-Making Process

During the course of the field test there was considerable discussion with the Fort Worth District personnel regarding the impact of BLAST simulation results on their design and decision-making process. For example, during the early load calculation phase, it was determined that the results of the BLAST simulation indicated considerable lower peak demands for cooling capacity than the original project design calculations. Regardless of which calculational procedure was correct, it was agreed that the application of BLAST to this particular project and the low peak loads produced by BLAST simulation compared to the original design peak loads could cause, at the least, a careful review of the original calculations. If it was determined that the BLAST results were correct, the capacity of the required chiller could be reduced substantially.

The Fort Worth District personnel evaluated two conventional plants (compression chiller plants and an absorption chiller plant), several total energy plants, and a series of solar-heated and -cooled central plant configurations. Again the BLAST results provided important decision-making information. For example, BLAST revealed that the lowest life-cycle cost system was a compression air-conditioning system and a conventional boiler. All other options, including the total energy plant options and all the solar options, were discovered to be more expensive on a life-cycle cost basis. Therefore, if the objective of a design and analysis process was to minimize life-cycle cost, the choice of the conventional system would have been indicated by the BLAST simulations. On the other hand, if either minimizing energy consumption or maximizing the efficiency of the fuel energy used were objectives, other choices would have been made. In any case, the results of the BLAST simulations would have provided the information necessary to make a decision. Appendix C summarizes the analysis of the project by Fort Worth District personnel.

The Air National Guard Bureau applied BLAST to the study of retrofit energy conservation options for an operation and training building and a large hangar with two-story office wings on three sides of the main bay (total area was 63,500 sq ft [5715 m^2]). Simulations were performed for eight locations for both buildings. Four conservation options were studied for the hangar and two for the Operations and Training Building. Results of each option studied were graphed against degree days to permit extension of the results to sites other than the sites studied. Appendix D provides the results of the Air National Guard's work.

The Air National Guard Bureau used the simulation results to support requests for construction and operation and maintenance funds to implement energy conservation programs in more than 60 buildings around the country.

The ability to quantify the potential energy conservation of various retrofit options by using BLAST makes the Guard's energy conservation program a defensible one. In this case, the use of BLAST will probably directly influence future allocation of funds for energy conservation.

The application of the BLAST program provided much more information for the design and decision-making process than was previously available from other energy analysis tools. This additional information adds to the options which can realistically be considered in the analysis phase. Prior to the development of comprehensive energy analysis programs, it was technically difficult to perform the many detailed calculations required for an energy analysis. The BLAST program performs the many detailed calculations (simulations) routinely, thereby greatly increasing the information available for decision-making. As the information available increases, the options available from which to make a selection increase, and the design and decision-making process expands. The designer, freed from the tedious task of making calculations which are better performed by a computer, can apply his/her engineering skills and judgment to a wider range of design options. This will inevitably lead to more energy-conservative and cost-effective building energy systems.

Manpower and Funding Requirements

Field test personnel at both Fort Worth District and Chanute Air Force Base kept records of the time required to prepare the input data and to examine the results of each simulation performed using BLAST. The project on which the field test was performed at the Fort Worth District was somewhat larger than that performed at Chanute; therefore, much more analysis was perfomed on the Fort Worth District project, and, as expected, more time was spent analyzing the Flight Simulator Training Building.

According to the Fort Worth District field test personnel, 517 hours were spent in performing the total analysis of the Flight Simulator Training Building (see Appendix C). Its analysis included the preparation of input to perform the hourly load analysis for 19 zones, input necessary to simulate the air-handling systems in the building (in many cases, there was a single air-handling system serving one zone only), and input to simulate the various central plant system options studied.

The computer cost associated with all these simulations was approximately \$350. The total cost, including overhead for the entire analysis, was approximately \$8750. This is in contrast to \$28,600 cost for the performance of the original total energy study for the facility (of which \$7100 was for computer costs). While the original study may have been slightly more detailed than that performed by the Fort Worth District, the less costly study performed by the Fort Worth District using BLAST was just as conclusive as the original.

The much smaller building analyzed by the Chanute Air Force Base Civil Engineering personnel was divided into 13 zones; only the hourly load calculation and air distribution simulations were performed, with one simulation performed for the conventional boiler/chiller plant. Their partial records indicate that approximately 72 man-hours were required to describe the buildings and to perform the desired simulations. It is believed that the small amount of time spent in preparing the input for BLAST by Chanute personnel was partly because a conventional calculation had been performed on this building by the same person performing the BLAST simulations (his office was also in the building) and consequently, his familiarity with the building reduced the amount of time required to prepare the input. Also, the Chanute personnel obtained more frequent consulting service at CERL.

All the field test participants indicated that considerably less time would be required to perform subsequent design analysis using BLAST once the first analysis had been performed. However, it was also pointed out that unless analyses are performed frequently, a certain amount of retraining or "start up" time would probably be required for the users to become familiar again with the BLAST input language.

7 FIELD TEST OF SOLAR ENERGY AND TOTAL ENERGY ANALYSIS AND DESIGN PROCEDURES

CERL Report E-98 *(Predicting the Performance of Solar Energy Systems)*

With the exception of typographical errors and numerical errors in the examples, Fort Worth District personnel found this procedure to be both clear and usable. They applied the graphical techniques of this report to obtain a preliminary analysis which was used as a starting point for BLAST simulations of solar energy systems. Results of their preliminary assessment and the BLAST simulation results are shown in Table C1 and Appendix C.

The Fort Worth District suggested that the universal curves in the report be enlarged and plotted on cross-hatched paper to improve their usability. It was also suggested that an example be provided for applying BLAST to the final design of solar systems.

CERL Report E-108 *(Use of the Building Loads Analysis and System Thermodynamics Program to Perform Total Energy System Analysis)*

Again, several errors in the numerical examples were found which caused some initial confusion. Otherwise, the simple procedures in this report were understandable and clear.

The usefulness of this report was demonstrated by its application to the field test project. By applying the step-by-step procedures, Fort Worth District was able to estimate the performance and cost of various conventional and total energy system options and rank them on the basis of cost and energy savings. On the basis of this ranking, the users at the Fort Worth District concluded that total energy systems were not appropriate for the field test project (see Appendix C). Also, the user determined that the conventional boiler/chiller plant originally specified was too large. Thus, the procedures in the report proved useful both in eliminating nonfeasible options and in determining near-optimal plant configurations for the type of plant selected.

8 CONCLUSIONS

Conclusions--BLAST Program

The field test of the BLAST program tested the program's usability as applied to real design problems. Evaluation of the BLAST program by participants in the BLAST training seminar led to the following general conclusions:

1. Considerable revision of the draft BLAST *User's Manual* was required prior to publication. The necessary revisions were accomplished prior to publication of the BLAST *User's Manual* in December 1977.

2. The BLAST program input language is extremely natural, easy to learn, and easy to use.

3. The flexibility of the BLAST program is unique and important to its users.

4. Expansion of the BLAST program to include the capability to simulate new types of air distribution systems (and certain conventional systems not now part of BLAST) will further enhance its usefulness.

5. Interactive input processing will enhance the usability of BLAST.

6. Formal training in the use of BLAST is required and the "hands on" application of BLAST to a sample problem should be part of the training program. A small class size (10 to 15 persons) will be more effective.

The application of the BLAST program to the field test projects and evaluation of BLAST by the field test participants led to additional conclusions:

7. The use of the BLAST program on mission-oriented Government computer facilities is cumbersome. Maintenance of BLAST at more than one computer site is not cost-effective at this time. Use and maintenance of BLAST at a single commercial computer site will permit widespread access, facilitate implementation, and minimize maintenance efforts. Implementation plans should incorporate this single computer site approach.

Routine use of the BLAST program by District designers, Air Force designers, and architect-engineers would be considerably easier if an interactive input language were developed for the program. Existing batch terminals at CE Districts are already heavily utilized, and very few such terminals are available to Air Force personnel. Many architect-engineers (who do a large portion of Army and Air Force designs) also do not have ready access to batch terminal facilities. In contrast, interactive terminals are readily available to most CE designers and many architect-engineers, and these terminals are sufficiently inexpensive ($2000 to $4000) to justify their purchase for Air Force designers. Interactive input processing therefore can enhance BLAST implementation by making the program easier to use. Provisions have already been made to permit BLAST input to be entered (but not processed) interactively. BLAST output can also be printed at interactive terminals that print 132 characters per line. Interactive input processing would permit user errors to be caught as soon as they are typed; "on the spot" corrections could be made and users would be assured that simulations would be successful the first time the program is run.

8. Revision of central plant simulation output reports to provide more detailed summaries of energy used by each plant component is required.

9. Results of BLAST simulations provide a basis for review of project designs and equipment selection and for the evaluation of various design options.

10. The additional information provided by using BLAST provides quantitative means for evaluating many design options. This information should lead to improved building and system design.

Finally, using the field test results as a whole, it can be concluded that:

11. The BLAST program can be used by field personnel. Its usefulness has been demonstrated by its application to real design problems.

12. It is an effective tool for analyzing energy effectiveness of new and retrofit projects at a time when such a tool is needed.

Conclusions--CERL Report E-98 *(Predicting the Performance of Solar Energy Systems)*

Results of the application of the procedures in this report to an actual field project indicate that they were relatively easy to use and were valuable tools for preliminary analysis and final design of solar energy systems for buildings.

Conclusions--CERL Report E-108 *(Use of the Building Loads Analysis and System Thermodynamics Program to Perform Total Energy System Analysis)*

The procedures in this document were applied without difficulty and provided a useful "road map" for conducting analysis of both conventional and total energy systems.

9 RECOMMENDATIONS

The BLAST program should be implemented in the CE military construction Districts and the Air Force. Recommended implementation plans for the BLAST program have been developed and are shown in Appendices E and F.

As recommended, the BLAST Program *User's Manual* was revised and expanded prior to its publication.

Development of additional simulation capabilities recommended by the field test users and the development of an interactive input processor for the BLAST program should be pursued. Certain output reports should also be revised.

The necessary revisions to CERL Reports E-98 and E-108 suggested by field test users should be accomplished, and these documents should be forwarded for publication as Engineer Technical Letters.

APPENDIX A:

ORGANIZATIONS REPRESENTED AT FEBRUARY 1977
BLAST TRAINING SESSION

HQ Army - Air Force Exchange Service
Engineering Division, EN-C
Dallas, TX 75222

U.S. Army Ft. Worth District
Corps of Engineers
P.O. Box 17300
Fort Worth, TX 76102

Department of Mechanical Engineering
Texas A&M University
College Station, TX 77843

Air Force Institute of Technology/DEE
WPAFB, Ohio 45433

Air Force Civil Engineering Center
AFCEC/DE/21
Tyndall AFB, FL 32403

Center for Building Technology
National Bureau of Standards
Washington, D.C. 20234

DEVCT
USAF Academy, CO 80840

Naval Civil Engineering Laboratory
Code L-80
Port Hueneme, CA 93030

Air National Guard/FSC/DE
Bldg E4435 Edgewood Area
Aberdeen, MO 21010

Argonne Labs
Bldg 221, A.M.D.
9700 S. Cass Avenue
Argonne, IL

U.S. Army Facilities Engineering
  Support Agency (FESA)
Research and Technology Division
Fort Belvoir, VA 22060

Headquarters, Department of the Army
(DAEN-MCE-U)
WASH DC 20314

Base Civil Engineer
(DEEED)
Chanute AFB, IL 61868

HQ Air Training Command
HQ ATC/DEEEM
Randolph AFB, TX 78148

Department of Mechanical Engineering
University of Illinois
Urbana, IL 61801

Energy and Environment Division
Lawrence Berkeley Laboratory
Berkeley, CA 94720

APPENDIX B:

BURROUGHS AND HONEYWELL FEASIBILITY STUDY

Introduction

At the request of AFCEC and under the scope of FY77 work under AFCEC sponsored "Optimization of Energy Usage in Military Facilities," a determination was made as to the feasibility of running the Building Loads Analysis and System Thermodynamics (BLAST) program on Burroughs B3500 and Honeywell 6000 computers. This study was required since these computers are available at many Air Force installations but are not similar to the Control Data Corporation (CDC) computer on which the BLAST program was developed and now operates.

The BLAST program is a large (about 50,000 lines of FORTRAN) highly numerical program. It uses large, randomly accessible files during execution and uses 150 to 300 central processor seconds on a CDC 6600 computer for a typical run.

Approach

To determine if the BLAST program could be successfully and conveniently used on the B3500 and Honeywell 6000 computers, contacts were made with software specialists from both companies. The following questions were addressed:

a. Could BLAST be modified and loaded on these machines?

b. What would be the expected execution times for typical BLAST runs?

c. What conversion problems would be likely?

d. What other constraints, if any, would influence the decision to use BLAST on the B3500 or Honeywell 6000?

Results

Burroughs B3500

It is not feasible to load and run the BLAST program on the B3500 computer.

This computer is a relatively small COBOL-oriented machine with limited FORTRAN capability. While a complete determination as to the convertibility of BLAST to run on the B3500 was not possible without actually attempting to convert the program, the B3500's limited FORTRAN is likely to present substantial conversion problems. Given that the 3500 is not FORTRAN-oriented, consultant support for FORTRAN is virtually non-existent. Consequently any attempt to convert BLAST to run on the B3500 would be extremely costly.

Even if BLAST could be converted, the estimated run time for a typical job on the B3500 was 3 to 3 1/2 hours. BLAST would, therefore, impose a completely unacceptable burden on the operation of the B3500 centers. This alone makes the implementation of the BLAST program on the Burroughs B3500 impractical.

Honeywell 6000

In contrast to the B3500, the Honeywell 6000 is considerably more powerful and supports FORTRAN to a much greater extent. No severe problems could be identified in converting BLAST to run on the Honeywell 6000. Even so, 3 to 6 man-months would be required to make the software conversion.

Estimates of central processor times for typical BLAST runs were also not nearly as long for the Honeywell 6000. Depending on the configuration, the Honeywell might run a BLAST job in 900 to 3000 seconds. This execution time is still rather lengthy (15 to 50 minutes) and would have a significant impact on any Honeywell 6000 installation whose resources are already fully utilized.

The principal disadvantage of the Honeywell 6000 computer sites in the Air Force is that most run classified jobs and consequently are only infrequently available for general purpose calculations. Substantial delays in getting output from BLAST simulations can therefore be expected. For this reason, implementation of the BLAST program on Honeywell 6000 computers is considered *highly undesirable*.

Government Versus Commercial, Multiple Versus Single-Site Implementation

In the specific cases considered above, and as a general rule for most Goverment-owned or operated computer sites, implementation and use of the BLAST program conflicts with the site mission. Implementation of BLAST on two Government-owned CDC sites (Eglin AFB and the Lawrence Berkeley Laboratory) has already demonstrated the problems that result from this conflict. Aside from the often non-standard operating systems and procedures found at Government installations, the low priority and restricted computer resource allocations given to BLAST users as compared to users directly supporting the site's mission considerably reduces the usability and effectiveness of the BLAST program as a tool for energy conservation studies and designs.

Experience at CERL in attempting to maintain current versions of the BLAST program and support program use at more than one site has shown that considerable costly and *unnecessary* effort is required.

In contrast, implementation of BLAST on a single commercial time-sharing system will provide nationwide access to the program, equal priority for BLAST users, guaranteed quick turnaround, and superior user support, and will minimize program maintenance efforts and cost.

Summary

It is not feasible to implement the BLAST program on the Burroughs B3500 computer because the hardware and software resources of the B3500 sites are inadequate to support a computer program of this size and type.

While it appears that there are no insurmountable programming obstacles to implementing the BLAST program at Honeywell 6000 sites, this approach will severely reduce the usability of the program. A significant amount of time and effort would be required to load and maintain the BLAST program on the several Honeywell computers in the Air Force. Experience has shown that attempting to maintain current versions of the program at more than one site is undesirable. Implementation on Honeywell 6000 sites is therefore strongly discouraged.

On the basis of experience acquired during the BLAST program field test, implementation of the program on a single time-sharing CDC computer system appears to offer many advantages. This approach will be pursued in detail as recommended implementation plans are developed at CERL.

APPENDIX C

ANALYSIS OF FLIGHT SIMULATOR TRAINING FACILITY*

The Flight Simulator Training Facility at Laughlin Air Force Base, TX, was selected as a typical District design project. A simplified floor plan of this facility is illustrated by Figure C1 Zones 1 through 4 are Visual System rooms containing very high intensity light banks which are cooled with outside air below 82°F (28°C) and return air otherwise. Zones 5 and 6 are second floor offices over equipment rooms and under mechanical rooms. Zones 8 through 14 are Motion Base rooms. Zone 15 is first- and second-floor offices and classrooms. Zone 32 is a large area over a mechanical room, and Zone 33 is another area under a mechanical room.

The high-intensity light banks had to be simulated as interior lighting with 25 percent of the 50 percent convective portion as return air heat gains. The ceilings under, floors over, and walls adjacent to mechanical or equipment rooms could only be treated as roofs, exposed floors, and walls to uncooled spaces, respectively. The bypass multizone cooling with zone duct heating coil system of Zone 15 (15, 16, and 17 in the data) was simulated as a three-deck multizone system, and the single-station heating/cooling system for each of the remaining zones was simulated as a terminal reheat system.

The BLAST program was first used to predict hourly zone loads and simulate the air-handling systems with winter and summer design day criteria as weather data. This established approximate zone heating/cooling capacities, zone supply air volume flow rates, and system heating/cooling coil capacities. Next the BLAST program was used to refine this data by using 365 days of weather information from a 1960 San Antonio, TX, weather tape. Then, together with the established zone heating/cooling coil capacities, zone air volume flow rates, and system heating/cooling coil capacities, and the San Antonio weather tape, the BLAST program was used to again predict the annual building energy consumption and simulate the performance of the air-handling systems, saving the air handling system energy demands to tape. Finally, with the air-handling system energy demands as input, the BLAST program was used to simulate the performance of, and perform life cycle cost studies for, the several central plants.

* Written by Dan Ellis, Fort Worth District, U.S. Army Corps of Engineers, and reproduced with his permission.

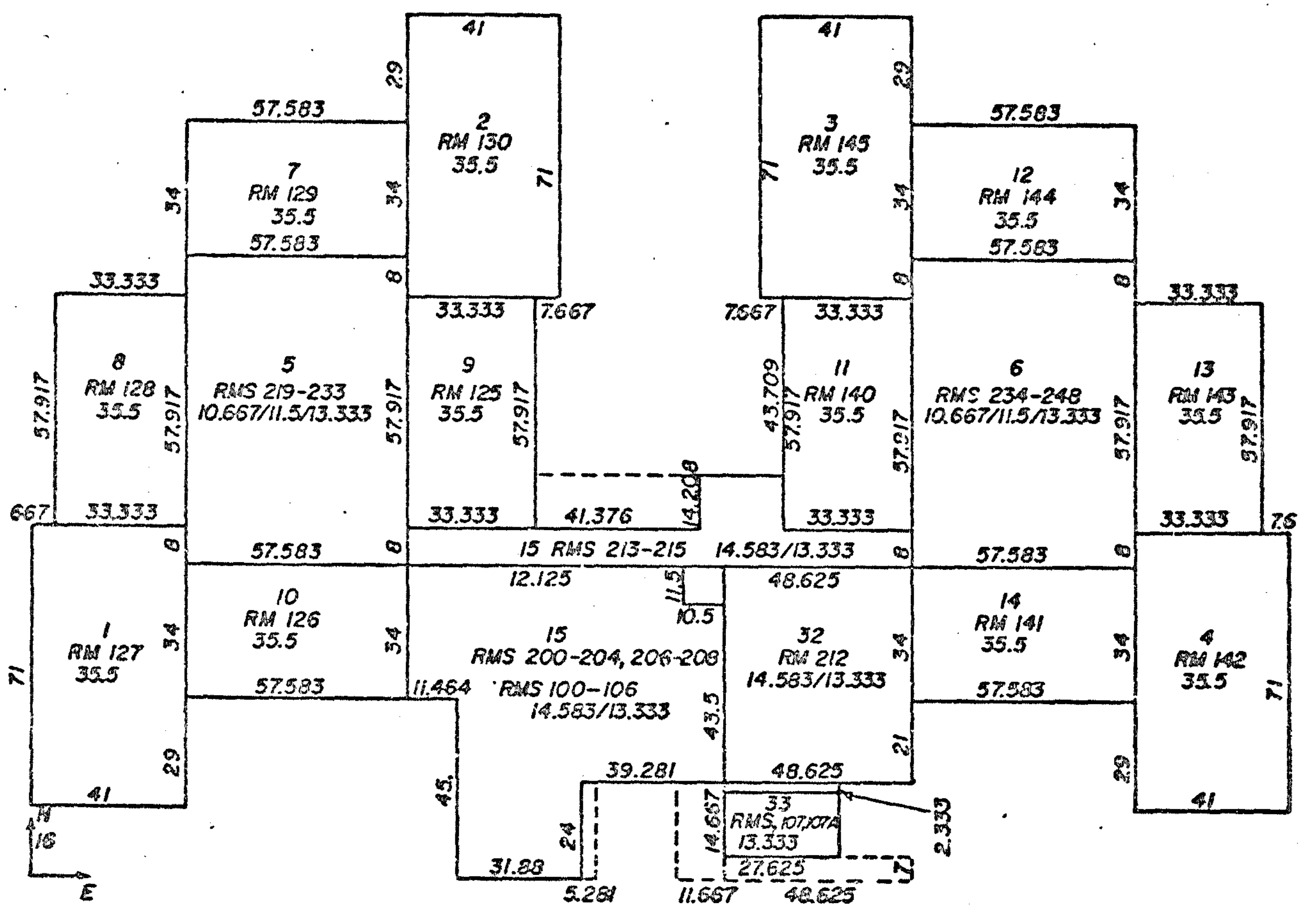


Figure C1. Simplified floor plan of Flight Simulator Training Facility.

Design Project Analysis

After several central plant simulations, 10 designs were selected for comparison:

1. One 3250-KBtu/hr* cooling tower, two 1308-KBtu/hr electric chillers, and two 325-KBtu steam boilers;

2. Two 1300-KBtu diesel generators, one 6500-KBtu cooling tower, two 1308-KBtu one-stage absorption chillers, two 1200-KBtu steam boilers;

3. Two 1300-KBtu gas turbine generators, one 6500-KBtu cooling tower, two 1308-KBtu one-stage absorption chillers, two 325-KBtu steam boilers;

4. One 6500-KBtu cooling tower, two 1308-KBtu one-stage absorption chillers, two 2400-KBtu steam boilers;

5. One 6500-KBtu cooling tower, two 1308 KBtu electric chillers, two 1308-KBtu absorption chillers, two 325-KBtu steam boilers, 250 32-sq-ft (2.88 m^2) solar collectors:

6. Same as 5, but with 500 solar collectors;

7. Same as 5, but with 750 solar collectors;

8. Same as 5, but with 1000 solar collectors;

9. Same as 5, but with 1250 solar collectors;

10. Same as 5, but with 1500 solar collectors.

These sizes and combinations of central plant equipment were selected to yield reasonably high average operating efficiencies. The 25-year life cycle cost of each design is illustrated in Table C1.

Prior to performing the central plant simulations, the graphical techniques of CERL Technical Report E-98 were applied to the results of the air system simulations to predict the expected performance of the solar energy plant designs. The air system simulations indicated yearly demands of 118,474 KBtu of hot water (Q_{HW}) and 4,872,833 KBtu of chilled water (Q_{CW}). It was also known that a demand of 213,953 KBtu of domestic hot water (Q_{DW}) was required. From Figure A1, page 26, of CERL Report E-98:

*1 KBtu = .293 kW

H_ν = 450 Langleys/Day = 450(365)(0.00369) = 606 KBtu/sq ft-yr,

V_L = 29°.*

Therefore,

$V_C = V_L - 10^\circ = 19^\circ$,

$Q_L = Q_{HW} + Q_{DW} + Q_{CW}/.65$ = 7,829,093 KBtu/yr,

$Q_{C/} = H_\nu \cos(V_L-7-V_C)/\cos(V_L-7)$ = 653 KBtu/sq ft-yr,

$A_c/P_{s/} = Q_L/Q_{c/}$ = 11,989 sq ft ≈ 12,000 sq ft**

Then, by selecting various collector areas, A_c, and applying the Universal Curve for Solar Heating and Cooling, Figure 2, page 14, of CERL Report E-98, the predicted values of expected performance, p_s, illustrated in Table C2, were obtained.

*H_ν = The annual of monthly radiation flux density on a horizontal surface
V_L = Latitude in degrees
**V_C = Optimum tilt angle
Q_L = Annual energy consumption in Btu
Q_c = Annual or monthly incident solar radiation flux density
A_c = Collector area
p_s = Solar system performance parameter

Table C1

25-Year Life Cycle Costs
(10^3 Dollars)

Design	1	2	3	4	5	6	7	8	9	10
First	246.5	1441.4	1135.9	490.0	712.2	1016.0	1319.7	1623.5	1927.2	2231.0
O&M	1161.0	2447.3	3224.9	1384.9	1620.6	1641.1	1655.2	1659.9	1663.8	1665.6
Energy	2897.7	4283.7	3362.7	3484.0	2886.3	2845.3	2822.6	2796.2	2764.3	2737.0
Total	4305.3	8172.4	7723.5	5359.0	5219.2	5502.4	5797.5	6079.6	6355.3	6633.6
% Diff	0.0	+89.8	+79.4	+24.5	+21.2	+27.8	+34.7	+41.2	+47.6	+54.1

Table C2

Predicted Values of Expected Performance

Design	5	6	7	8	9	10
A_c (sq ft)	8,000	16,000	24,000	32,000	40,000	48,000
P_s	.667	1.333	2.000	2.667	3.333	4.000
p_s	.182	.354	.488	.613	.710	.779
p_B	.223	.397	.548	.678	.782	.849
% Difference	-18.4	-10.8	-10.9	-9.6	-9.2	-8.2

For comparison, the predicted values of expected performance, p_B, were also computed from the results of each of the solar energy plant simulations and included in Table C2. Some of the difference can be attributed to the higher average annual solar radiation flux density determined from the San Antonio weather tape and the use of high-efficiency solar collectors in the computer simulations. Even then, particularly for relatively small collector areas, the graphical technique produced rather conservative estimates of solar system performance.

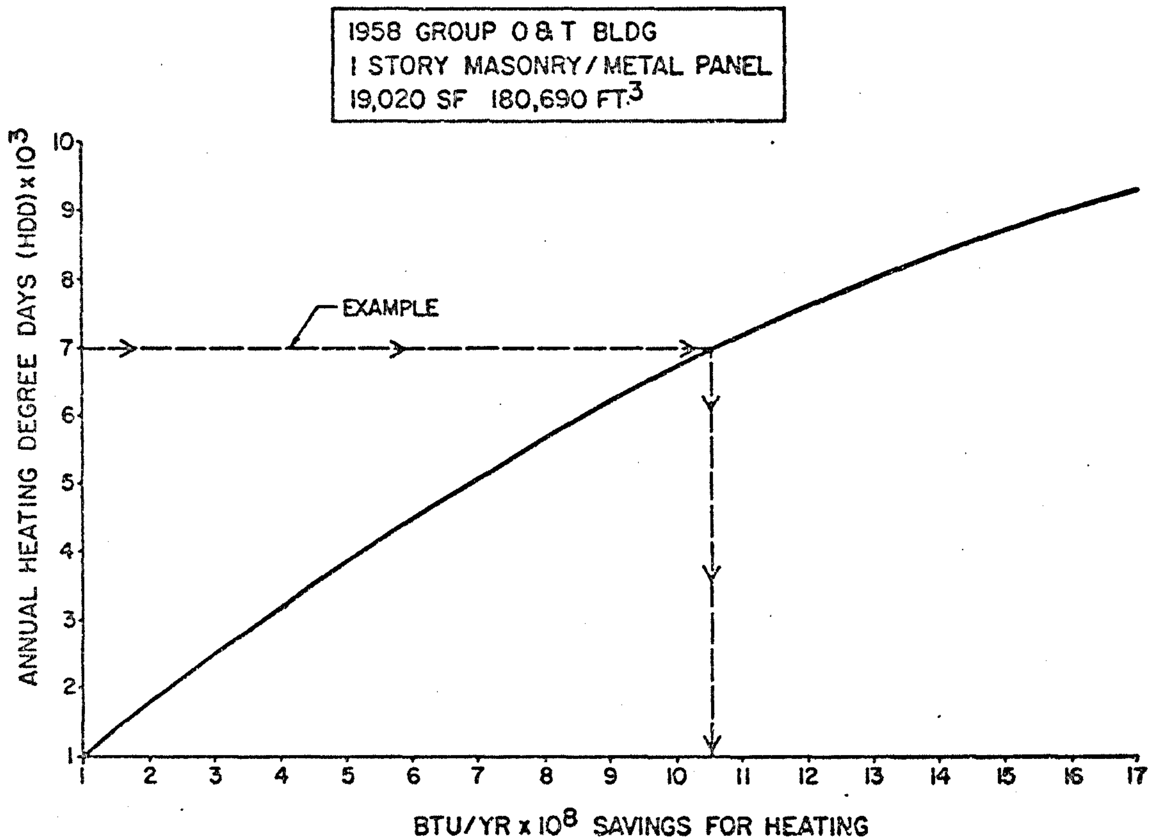
Based upon this study and the resulting life cycle costs illustrated in Table C1, the most economical system would be the conventional electric chiller, boiler central plant (Design 1). Switching to more costly absorption chillers requires additional boiler capacity (Design 4). This increases the use of uncertain supplies of natural gas as well as overall energy costs. Addition of some solar collectors (Design 5) deletes the need for additional boiler capacity but requires auxiliary electric chillers. And, although natural gas consumption and total energy costs are reduced and the system is an improvement over the conventional absorption chiller boiler design, the increased first and operation/maintenance costs far outweigh the reduced energy costs as compared to the conventional electric chiller boiler plant. Increasing solar collector area (Designs 6 through 10) does not reduce the energy costs sufficiently to offset the increased first and operation/maintenance costs. Apparently because of noncoincident cooling/heating loads and collected solar energy, heat rejected to the cooling tower increases with solar collector area.

This rejected heat exceeds the cooling tower capacity in the last four systems (Designs 7 through 10). Thus all costs are incorrect by the additional costs associated with the required tower capacity. The noncoincident cooling/heating demands and available waste heat in the two total energy plants (Designs 2 and 3) also cause rejected heat to exceed cooling tower capacity. It is doubtful whether the addition of thermal storage tanks could reduce the rejected heat and energy costs sufficiently to offset the already high first costs--thus additional study of total and solar energy systems is not warranted.

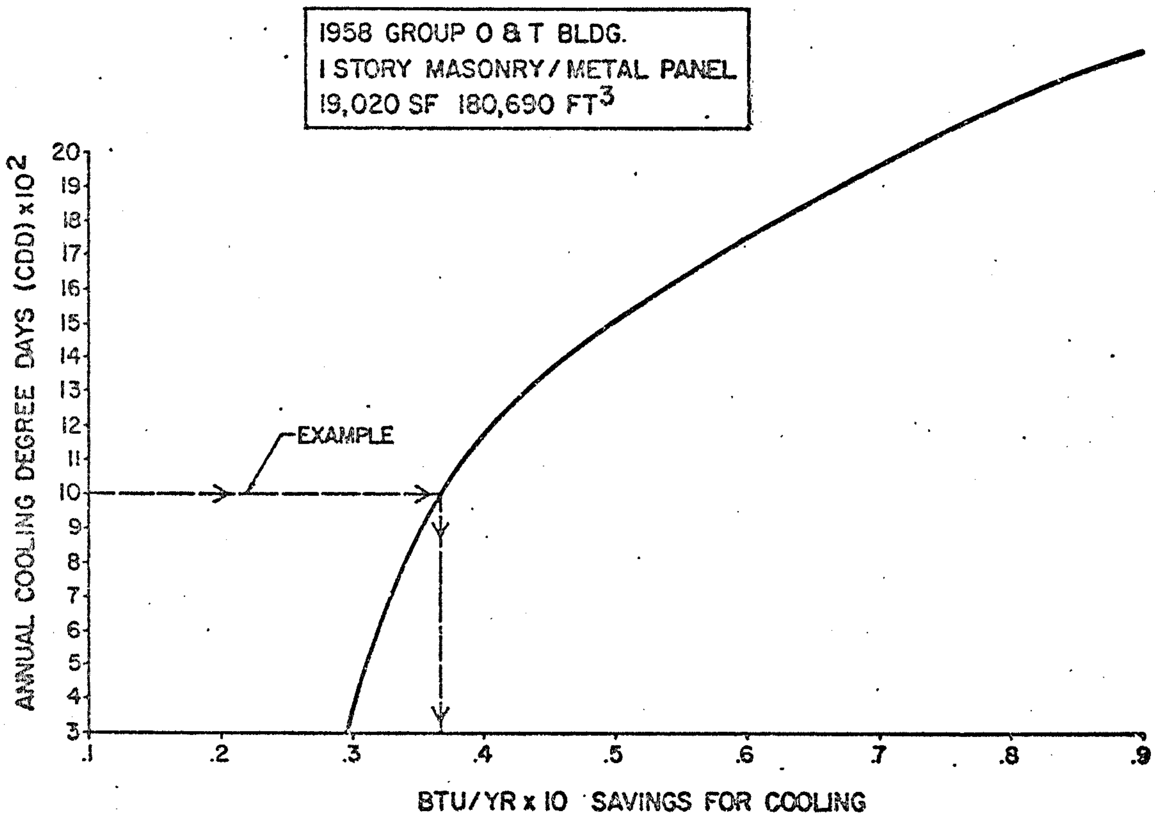
It is interesting to note that while this study indicates requirements for two 1308-KBtu electric chillers and two 325-KBtu boilers, the architect selected three electric chillers with a total capacity of 5568 KBtu and an 1848-KBtu steam boiler.

APPENDIX D:

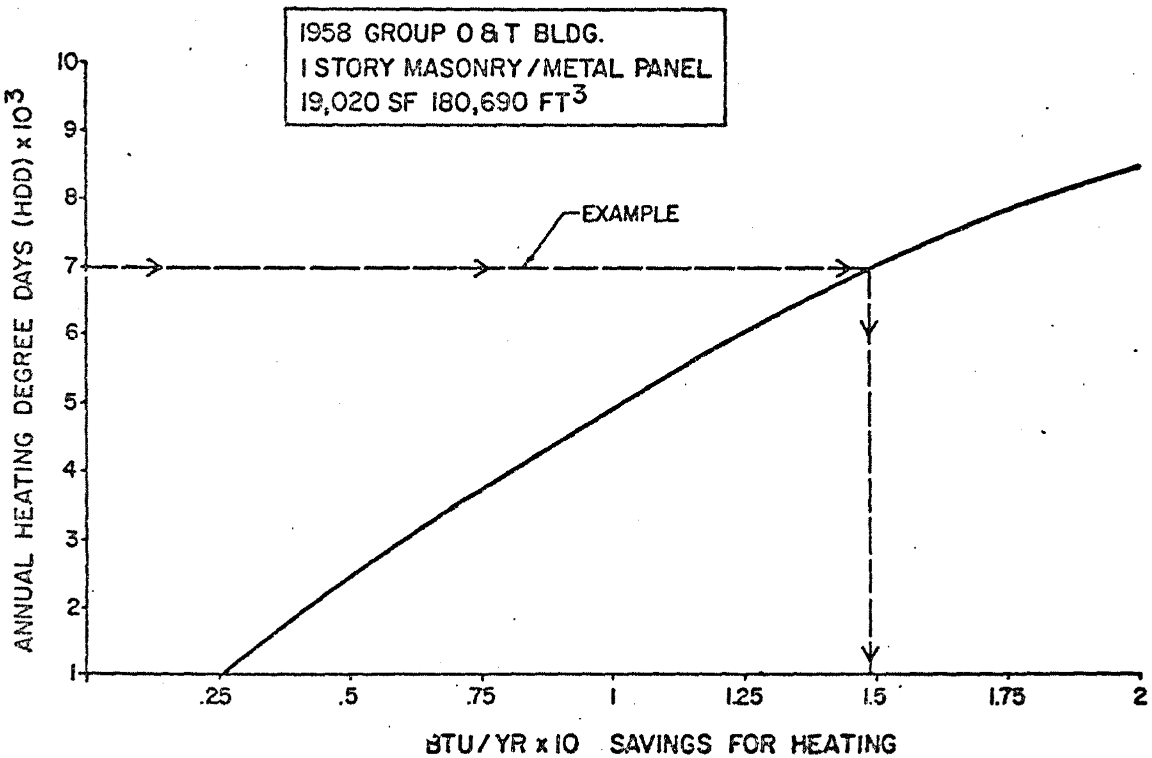
SUMMARY OF RESULTS--USE OF BLAST BY NATIONAL GUARD BUREAU



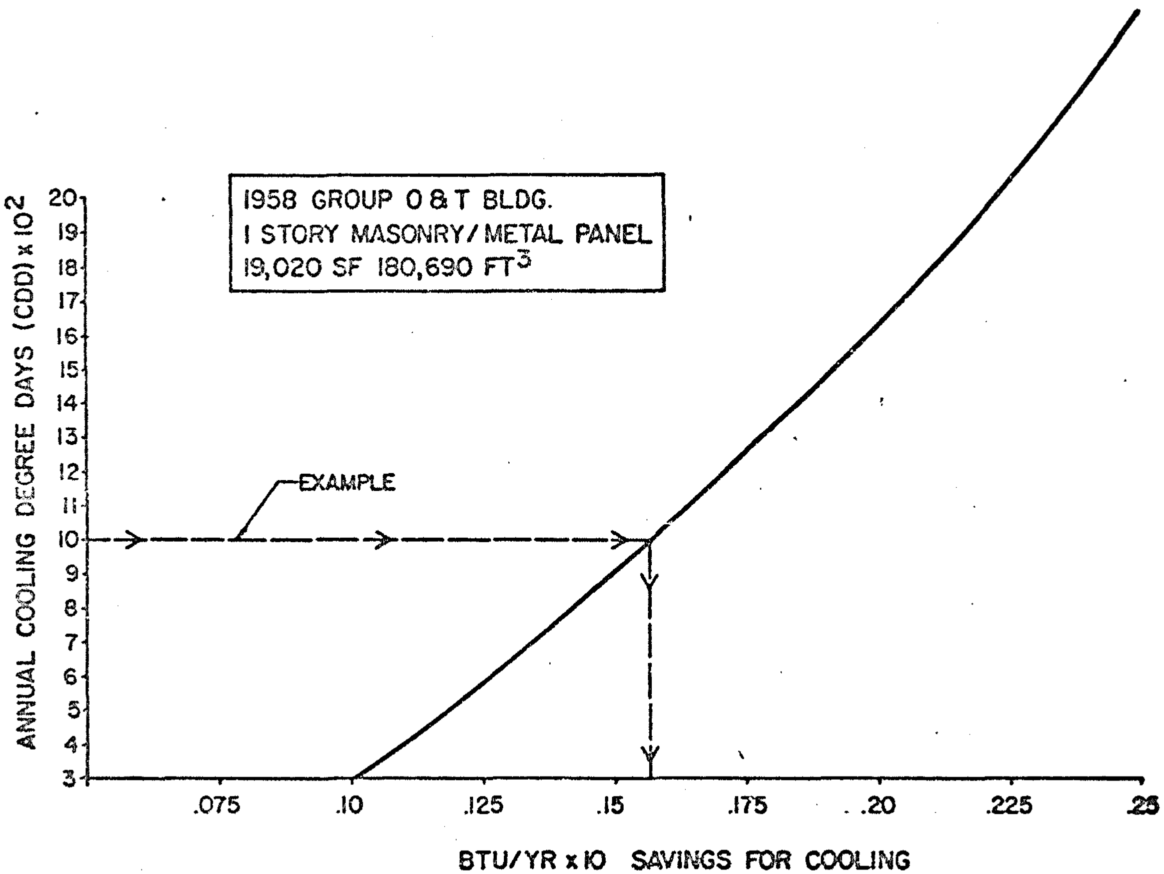
Install Additional 3-in. TK. Roof Insulation (19,020 SF)



Replace 1750 SF Single-Pane Windows with 88 Percent Insulated Metal Panels and 12 Percent Double-Pane Tinted Windows.



Install Additional 3-in. TK. Roof Insulation (19,020 SF)



Replace 1750 SF Single-Pane Windows with 88 Percent 2-in. TK. Insulated Metal Panels and 12 Percent Double-Pane Tinted Windows.

LOADS SUMMARY - O & T BLDG: HOUSTON, TX

HDD = 1434
CDD = 2889

		EXISTING BUILDING (DECK #1)	MODIFIED WALLS & RED. WINDOWS (DECK #2A)	SAVINGS DUE TO WALL PAN. & WINDOWS (#1 - #2A)	MODIFIED WALLS & ADD'L CLG. INSUL. (DECK #2B)	SAVINGS DUE TO ADD'L CLG. INSUL. (#2A - #2B)	OVERALL SAVINGS (#1 - #2B)	ALLOWABLE ENERGY CONSERVATION EXPENSES
ANNUAL HEATING LOAD (BTU/YR)		2.768×10^8	9.443×10^7	1.824×10^8 (65.9% Dec)	6.596×10^7	2.847×10^7 (30.1% Dec)	2.108×10^8 (76.2% Dec)	$9,165.
MAXIMUM HEATING LOAD (BTU/HR)		6.437×10^5	2.939×10^5	3.498×10^5 (54.3% Dec)	2.547×10^5	3.920×10^4 (13.3% Dec)	3.890×10^5 (60.4% Dec)	
ANNUAL COOLING LOAD (BTU/YR)		3.349×10^8	2.553×10^8	7.960×10^7 (23.8% Dec)	2.298×10^8	2.550×10^7 (10.0% Dec)	1.051×10^8 (31.4% Dec)	$4,570.
MAXIMUM COOLING LOAD (BTU/HR)		4.742×10^5	3.120×10^5	1.622×10^5 (34.2% Dec)	2.625×10^5	4.950×10^4 (15.9% Dec)	2.117×10^5 (44.6% Dec)	
MAX ZONE TEMPS	1							
	2							
	3							
MIN ZONE TEMPS	1							
	2							
	3							

LOADS SUMMARY - O & T BLDG: FRESNO, CA

HDD= 2650
CDD= 1671

	EXISTING BUILDING (DECK #1)	MODIFIED WALLS & RED. WINDOWS (DECK #2A)	SAVINGS DUE TO WALL PAN. & WINDOWS (#1 - #2A)	MODIFIED WALLS & ADD'L CLG. INSUL. (DECK #2B)	SAVINGS DUE TO ADD'L CLG. INSUL. (#2A - #2B)	OVERALL SAVINGS (#1 - #2B)	ALLOWABLE ENERGY CONSERVATION EXPENSES
ANNUAL HEATING LOAD (BTU/YR)	4.488×10^{8}	1.693×10^{8}	2.795×10^{8} (62.3% Dec)	1.192×10^{8}	5.010×10^{7} (29.6% Dec)	3.296×10^{8} (73.4% Dec)	$14,[illegible]32.
MAXIMUM HEATING LOAD (BTU/HR)	5.346×10^{5}	2.753×10^{5}	2.[illegible]93 x 10^{5} (48.5% Dec)	2.388×10^{5}	3.653×10^{4} (13.3% Dec)	2.958×10^{5} (55.3% Dec)	
ANNUAL COOLING LOAD (BTU/YR)	2.741×10^{8}	1.943×10^{8}	7.980×10^{7} (29.1% Dec)	1.629×10^{8}	3.140×10^{7} (16.2% Dec)	1.112×10^{8} (40.6% Dec)	$4,835[illegible]
MAXIMUM COOLING LOAD (BTU/HR)	5.860×10^{5}	3.411×10^{5}	2.449×10^{5} (41.8% Dec)	2.751×10^{5}	6.600×10^{4} (19.3% Dec)	3.109×10^{5} (53.0% Dec)	
MAX ZONE TEMPS 1							
MAX ZONE TEMPS 2							
MAX ZONE TEMPS 3							
MIN ZONE TEMPS 1							
MIN ZONE TEMPS 2							
MIN ZONE TEMPS 3							

LOADS SUMMARY - O & T BLDG: RICHMOND, VA

HDD = 3939
CDD = 1353

	EXISTING BUILDING (DECK #1)	MODIFIED WALLS & RED. WINDOWS (DECK #2A)	SAVINGS DUE TO WALL PAN. & WINDOWS (#1 - #2A)	MODIFIED WALLS & ADD'L CLG. INSUL. (DECK #2B)	SAVINGS DUE TO ADD'L CLG. INSUL. (#2A - #2B)	OVERALL SAVINGS (#1 - #2B)	ALLOWABLE ENERGY CONSERVATION EXPENSES
ANNUAL HEATING LOAD (BTU/YR)	1.018×10^9	4.409×10^8	5.771×10^8 (56.7% Dec)	3.455×10^8	9.540×10^7 (21.6% Dec)	6.725×10^8 (66.1% Dec)	$29,239.
MAXIMUM HEATING LOAD (BTU/HR)	7.416×10^5	3.807×10^5	3.609×10^5 (48.7% Dec)	3.325×10^5	4.820×10^4 (12.7% Dec)	4.091×10^5 (55.2% Dec)	
ANNUAL COOLING LOAD (BTU/YR)	1.603×10^8	1.187×10^8	4.160×10^7 (26.0% Dec)	1.005×10^8	1.820×10^7 (15.3% Dec)	5.980×10^7 (37.3% Dec)	$2,600.
MAXIMUM COOLING LOAD (BTU/HR)	4.484×10^5	2.597×10^5	1.887×10^5 (42.1% Dec)	2.093×10^5	5.040×10^4 (19.4% Dec)	2.391×10^5 (53.3% Dec)	
MAX ZONE TEMPS 1							
MAX ZONE TEMPS 2							
MAX ZONE TEMPS 3							
MIN ZONE TEMPS 1							
MIN ZONE TEMPS 2							
MIN ZONE TEMPS 3							

LOADS SUMMARY - O & T BLDG: LOUISVILLE, KY

HDD = 4640
CDD = 1268

		EXISTING BUILDING (DECK #1)	MODIFIED WALLS & RED. WINDOWS (DECK #2A)	SAVINGS DUE TO WALL PAN. & WINDOWS (#1 - #2A)	MODIFIED WALLS & ADD'L CLG. INSUL. (DECK #2B)	SAVINGS DUE TO ADD'L CLG. INSUL. (#2A - #2B)	OVERALL SAVINGS (#1 - #2B)	ALLOWABLE ENERGY CONSERVATION EXPENSES
ANNUAL HEATING LOAD (BTU/YR)		1.111×10^9	4.784×10^8	6.326×10^8 (56.9% Dec)	3.788×10^8	9.960×10^7 (20.8% Dec)	7.322×10^8 (65.9% Dec)	$31,835.
MAXIMUM HEATING LOAD (BTU/HR)		1.119×10^6	5.090×10^5	6.100×10^5 (54.5% Dec)	4.408×10^5	6.820×10^4 (13.4% Dec)	6.782×10^5 (60.6% Dec)	
ANNUAL COOLING LOAD (BTU/YR)		1.547×10^8	1.176×10^8	3.710×10^7 (24.0% Dec)	1.021×10^8	1.550×10^7 (13.2% Dec)	5.260×10^7 (34.0% Dec)	$2,287.
MAXIMUM COOLING LOAD (BTU/HR)		4.425×10^5	2.693×10^5	1.732×10^5 (39.1% Dec)	2.245×10^5	4.480×10^4 (16.6% Dec)	2.180×10^5 (49.3% Dec)	
MAX ZONE TEMPS	1							
	2							
	3							
MIN ZONE TEMPS	1							
	2							
	3							

LOADS SUMMARY - O & T BLDG: SPRINGFIELD, OH

HDD=5100
CDD=1050

		EXISTING BUILDING (DECK #1)	MODIFIED WALLS & RED. WINDOWS (DECK #2A)	SAVINGS DUE TO WALL PAN. & WINDOWS (#1 - #2A)	MODIFIED WALLS & ADD'L CLG. INSUL. (DECK #2B)	SAVINGS DUE TO ADD'L CLG. INSUL. (#2A - #2B)	OVERALL SAVINGS (#1 - #2B)	ALLOWABLE ENERGY CONSERVATION EXPENSES
ANNUAL HEATING LOAD (BTU/YR)		1.228×10^9	5.416×10^8	6.862×10^8 (55.9% Dec)	4.332×10^8	1.084×10^8 (20.0% Dec)	7.946×10^8 (64.7% Dec)	$34,548.
MAXIMUM HEATING LOAD (BTU/HR)		1.257×10^6	5.841×10^5	6.733×10^5 (53.5% Dec)	5.083×10^5	7.580×10^4 (13.0% Dec)	7.491×10^5 (59.6% Dec)	
ANNUAL COOLING LOAD (BTU/YR)		1.298×10^8	9.222×10^7	3.758×10^7 (29.0% Dec)	7.612×10^7	1.610×10^7 (17.4% Dec)	5.368×10^7 (41.4% Dec)	$2,334.
MAXIMUM COOLING LOAD (BTU/HR)		4.072×10^5	2.374×10^5	1.698×10^5 (41.7% Dec)	1.855×10^5	5.190×10^4 (21.9% Dec)	2.217×10^5 (54.4% Dec)	
MAX ZONE TEMPS	1							
	2							
	3							
MIN ZONE TEMPS	1							
	2							
	3							

LOADS SUMMARY - O & T BLDG: BOISE, ID

HDD = 5833
CDD = 714

		EXISTING BUILDING (DECK #1)	MODIFIED WALLS & RED. WINDOWS (DECK #2A)	SAVINGS DUE TO WALL PAN. & WINDOWS (#1 - #2A)	MODIFIED WALLS & ADD'L CLG. INSUL. (DECK #2B)	SAVINGS DUE TO ADD'L CLG. INSUL. (#2A - #2B)	OVERALL SAVINGS (#1 - #2B)	ALLOWABLE ENERGY CONSERVATION EXPENSES
ANNUAL HEATING LOAD (BTU/YR)		1.306×10^9	5.965×10^8	7.115×10^8 (54.4% Dec)	4.728×10^8	1.237×10^8 (20.7% Dec)	8.352×10^8 (63.8% Dec)	$36,311.
MAXIMUM HEATING LOAD (BTU/HR)		9.706×10^5	4.775×10^5	4.931×10^5 (50.8% Dec)	4.127×10^5	6.478×10^4 (13.6% Dec)	5.579×10^5 (57.5% Dec)	
ANNUAL COOLING LOAD (BTU/YR)		1.132×10^8	7.167×10^7	4.153×10^7 (36.7% Dec)	5.594×10^7	1.573×10^7 (21.[illegible]% Dec)	5.726×10^7 (50.6% Dec)	$2,4[illegible].
MAXIMUM COOLING LOAD (BTU/HR)		4.609×10^5	2.438×10^5	2.171×10^5 (47.1% Dec)	1.835×10^5	6.030×10^4 (24.7% Dec)	2.774×10^5 (60.2% Dec)	
MAX ZONE TEMPS	1							
	2							
	3							
MIN ZONE TEMPS	1							
	2							
	3							

LOADS SUMMARY - O & T BLDG: NIAGARA FALLS, NY

HDD = 6927
CDD = 437

		EXISTING BUILDING (DECK #1)	MODIFIED WALLS & RED. WINDOWS (DECK #2A)	SAVINGS DUE TO WALL PAN. & WINDOWS (#1 - #2A)	MODIFIED WALLS & ADD'L CLG. INSUL. (DECK #2B)	SAVINGS DUE TO ADD'L CLG. INSUL. (#2A - #2B)	OVERALL SAVINGS (#1 - #2B)	ALLOWABLE ENERGY CONSERVATION EXPENSES
ANNUAL HEATING LOAD (BTU/YR)		1.912×10^9	8.562×10^8	1.056×10^9 (55.2% Dec)	7.000×10^8	1.562×10^8 (18.2% Dec)	1.212×10^9 (63.4% Dec)	$52,696.
MAXIMUM HEATING LOAD (BTU/HR)		1.151×10^6	5.585×10^5	5.925×10^5 (51.5% Dec)	4.905×10^5	6.800×10^4 (12.2% Dec)	6.605×10^5 (57.4% Dec)	
ANNUAL COOLING LOAD (BTU/YR)		5.439×10^7	4.073×10^7	1.366×10^7 (25.1% Dec)	3.356×10^7	7.170×10^6 (17.6% Dec)	2.083×10^7 (38.3% Dec)	$906.
MAXIMUM COOLING LOAD (BTU/HR)		2.931×10^5	1.676×10^5	1.255×10^5 (42.8% Dec)	1.346×10^5	3.300×10^4 (19.7% Dec)	1.585×10^5 (54.1% Dec)	
MAX ZONE TEMPS	1							
	2							
	3							
MIN ZONE TEMPS	1							
	2							
	3							

LOADS SUMMARY - O & T BLDG: GREAT FALLS, MT

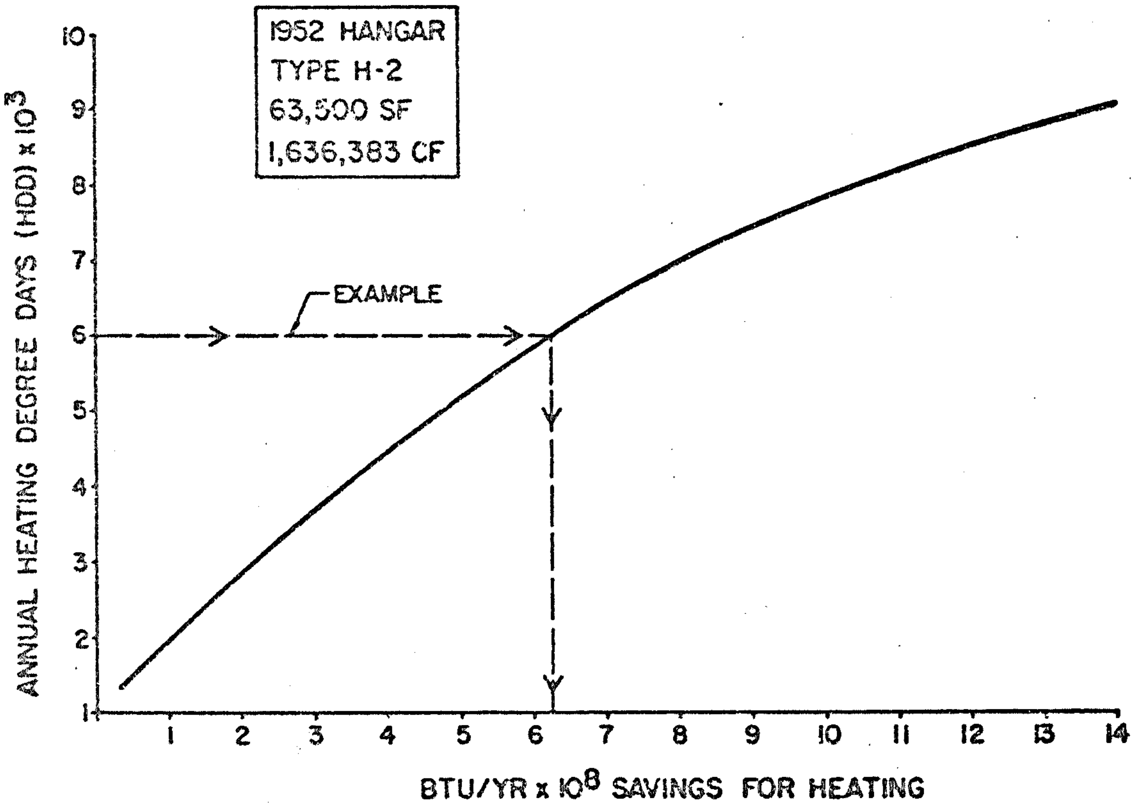
HDD=7652
CDD=339

		EXISTING BUILDING (DECK #1)	MODIFIED WALLS & RED. WINDOWS (DECK #2A)	SAVINGS DUE TO WALL PAN. & WINDOWS (#1 - #2A)	MODIFIED WALLS & ADD'L CLG. INSUL. (DECK #2B)	SAVINGS DUE TO ADD'L CLG. INSUL. (#2A - #2B)	OVERALL SAVINGS (#1 - #2B)	ALLOWABLE ENERGY CONSERVATION EXPENSES
ANNUAL HEATING LOAD (BTU/YR)		2.172×10^9	9.786×10^8	1.193×10^9 (54.9% Dec)	8.058×10^8	1.728×10^8 (17.6% Dec)	1.366×10^9 (62.9% Dec)	$59,391.
MAXIMUM HEATING LOAD (BTU/HR)		1.745×10^6	7.830×10^5	9.620×10^5 (55.1% Dec)	6.868×10^5	9.620×10^4 (12.3% Dec)	1.058×10^6 (60.6% Dec)	
ANNUAL COOLING LOAD (BTU/YR)		6.245×10^7	3.390×10^7	2.855×10^7 (45.7% Dec)	2.311×10^7	1.079×10^7 (31.8% Dec)	3.934×10^7 (63.0% Dec)	$1,710.
MAXIMUM COOLING LOAD (BTU/HR)		3.728×10^5	1.836×10^5	1.892×10^5 (50.8% Dec)	1.359×10^5	4.770×10^4 (26.0% Dec)	2.369×10^5	
MAX ZONE TEMPS	1	92.0	84.9		83.5			
	2	95.6	86.0		85.1			
	3	96.2	89.3		88.8			
MIN ZONE TEMPS	1	62.0	62.0		62.0			
	2	62.0	62.0		62.0			
	3	62.0	62.0		62.0			

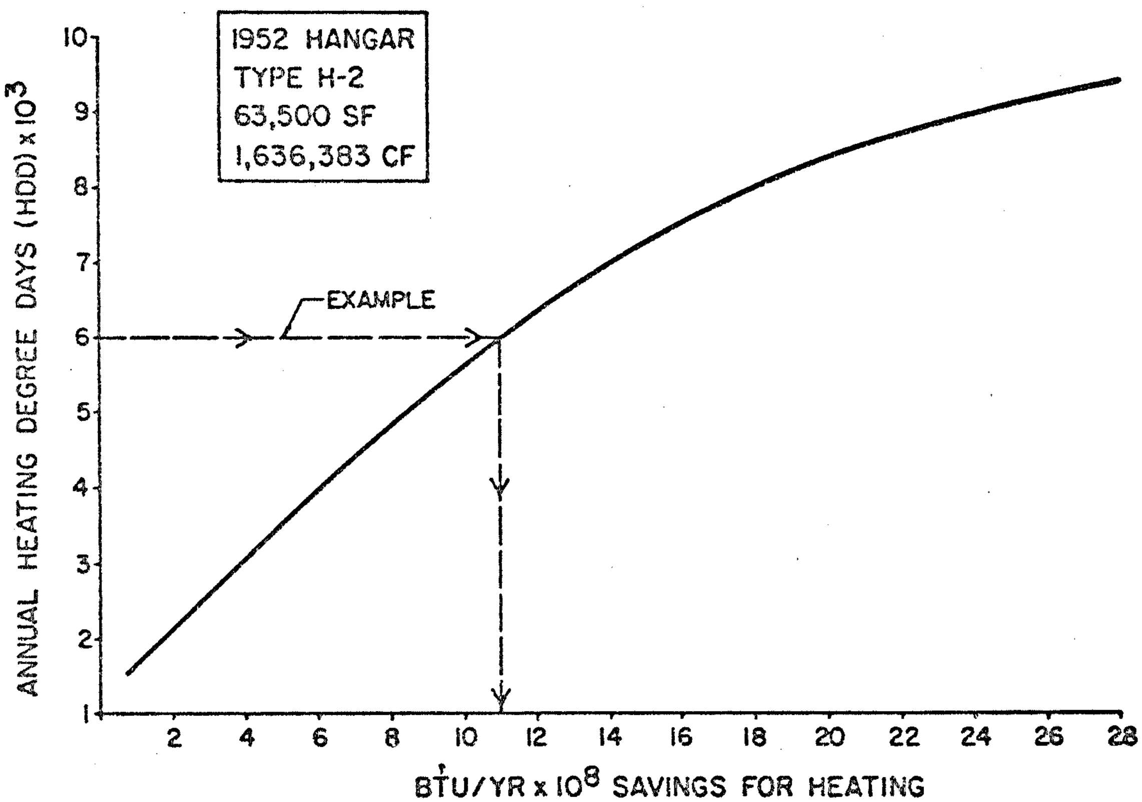
LOADS SUMMARY - O & T BLDG: FARGO, ND

HDD= 9044
CDD= 487

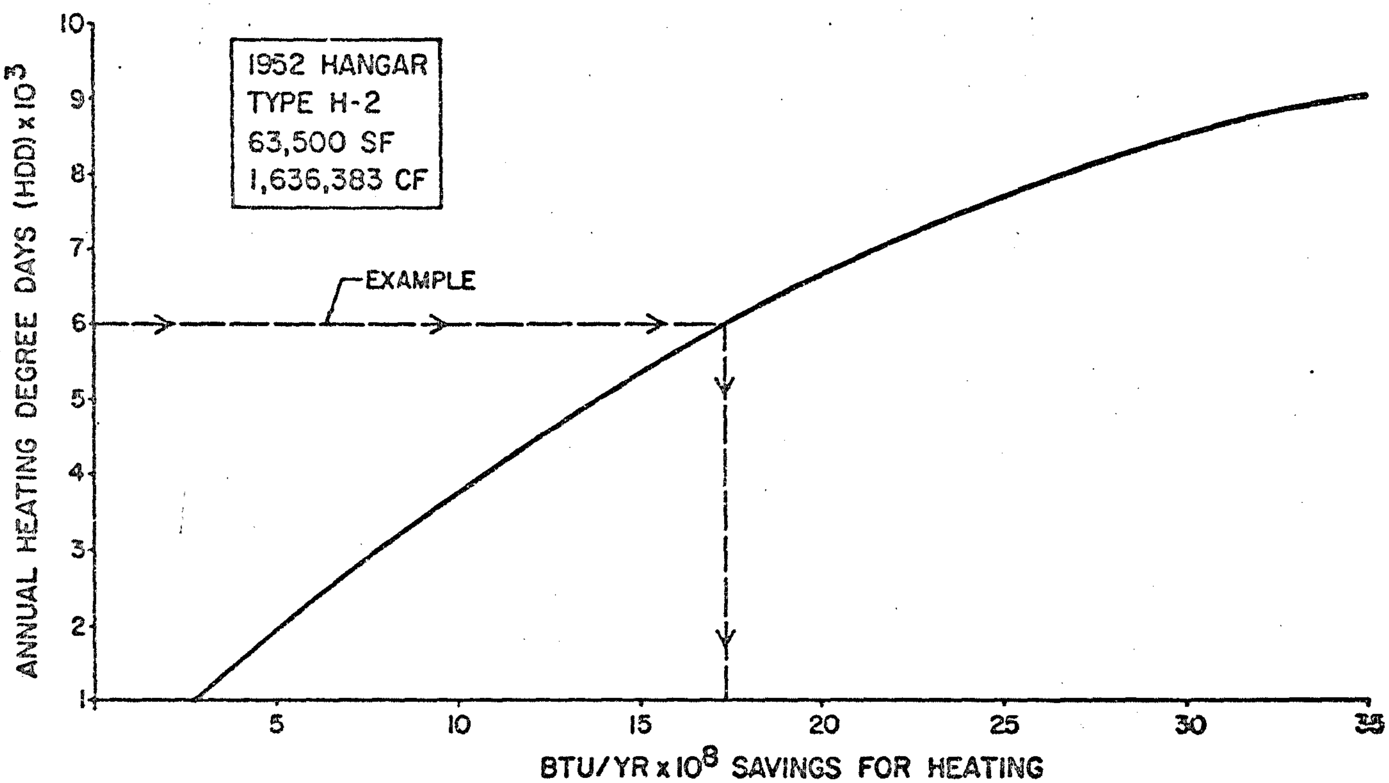
		EXISTING BUILDING (DECK #1)	MODIFIED WALLS & RED. WINDOWS (DECK #2A)	SAVINGS DUE TO WALL PAN. & WINDOWS (#1 - #2A)	MODIFIED WALLS & ADD'L CLG. INSUL. (DECK #2B)	SAVINGS DUE TO ADD'L CLG. INSUL. (#2A - #2B)	OVERALL SAVINGS (#1 - #2B)	ALLOWABLE ENERGY CONSERVATION EXPENSES
ANNUAL HEATING LOAD (BTU/YR)		2.920×10^9	1.320×10^9	1.600×10^9 (54.8% Dec)	1.089×10^9	2.310×10^8 (17.5% Dec)	1.831×10^9 (62.7% Dec)	$79,609.
MAXIMUM HEATING LOAD (BTU/HR)		1.758×10^6	7.666×10^5	9.914×10^5 (56.4% Dec)	6.685×10^5	9.810×10^4 (12.8% Dec)	1.090×10^6 (62.0% Dec)	
ANNUAL COOLING LOAD (BTU/YR)		8.053×10^7	4.872×10^7	3.181×10^7 (39.5% Dec)	3.813×10^7	1.059×10^7 (21.7% Dec)	4.240×10^7 (52.6% Dec)	$1,843.
MAXIMUM COOLING LOAD (BTU/HR)		4.347×10^5	9.705×10^7	-9.661×10^7	1.688×10^5	2.65	2.659×10^5 (61.2% Dec)	
MAX ZONE TEMPS	1							
	2							
	3							
MIN ZONE TEMPS	1							
	2							
	3							



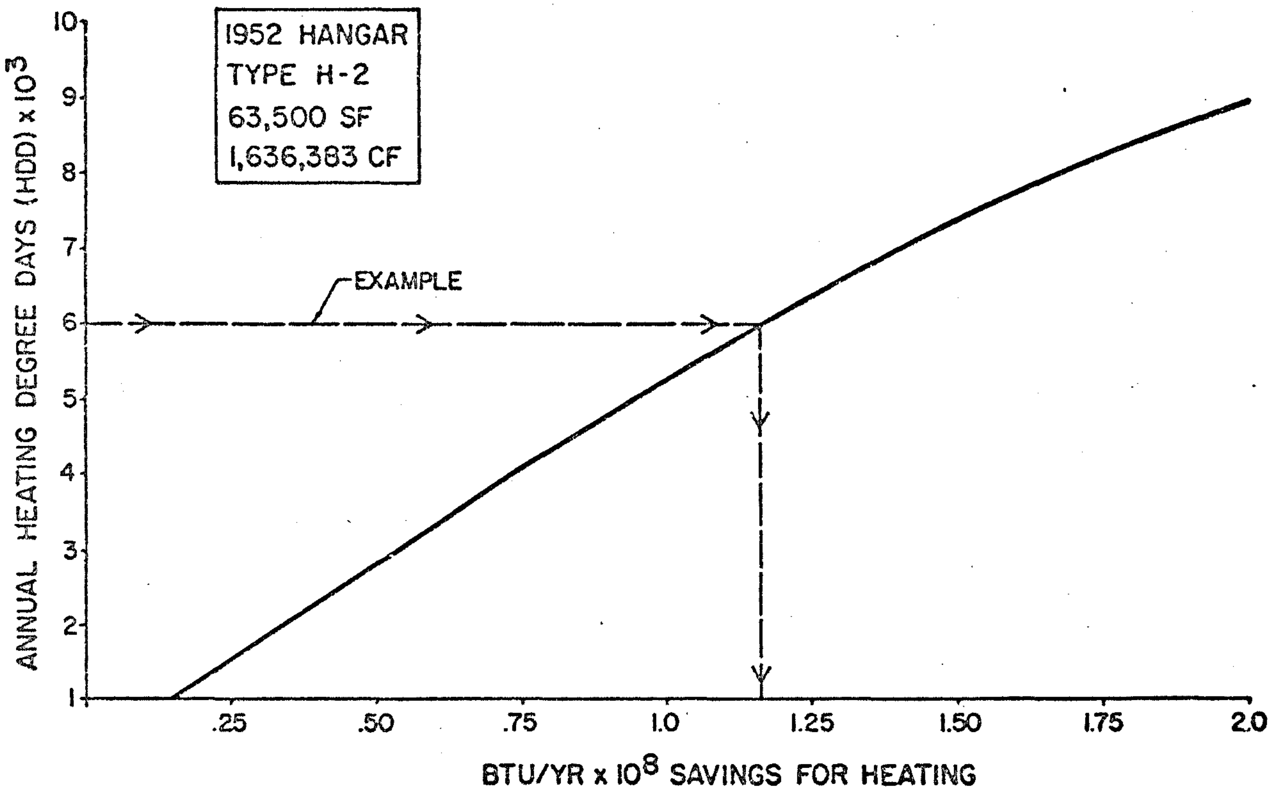
Insulate Hangar Door and End Wall with 3 1/2-in. TK. Insulation.



Install Suspended Ceiling with 6-in. TK. Insulation at 26 ft, 8 in Height in Hangar Bay.



Replace 7000 SF Single-Pane Windows in Two-Story Lean-to Areas with 75 Percent 2-in. TK. Insulated Metal Panels and 25 Percent Double-Pane Windows.



Install 16,000 SF 3 1/2 in. TK. Insulation on Second-Story Lean-to Ceiling.

LOADS SUMMARY - H-2 HANGAR: HOUSTON, TX

HDD = 1434
CDD = 2887

		EXISTING BUILDING (DECK #1)	MODIFIED LEANTO WALL & INSUL BAY DOOR (DECK #2)	ADD'L LEANTO CLG INSUL & BAY SUSP CLG (DECK #3)	SAVINGS DUE TO LEANTO TO PNL WIND (#1-#2)	SAVINGS DUE TO HANGAR DOOR INSUL (#1-#2)	SAVINGS DUE TO LEANTO CLG INSUL (#2-#3)	SAVINGS DUE TO HANGAR BAY SUSP (#2-#3)	TOTAL SAVINGS	
ANNUAL HEATING LOAD (BTU/YR)		5.828 x 10^8	1.957 x 10^8	1.708 x 10^8	3.871 x 10^8 (66.4%) [$16,830.]		2.490 x 10^7 (12.7%) [$1,083.]		4.120 x 10^8 (70.7%)	LEANTO
		4.644 x 10^8	3.743 x 10^8	2.076 x 10^8		9.010 x 10^7 (19.4%) [$3,917]		1.667 x 10^8 (44.5%) [$7,248]	2.568 x 10^8 (55.3%)	BAY
		1.047 x 10^9	5.700 x 10^8	3.784 x 10^8					6.686 x 10^8 (63.8%)	TOTAL
MAXIMUM HEATING LOAD (BTU/HR)		1.407 x 10^6	5.643 x 10^5	4.900 x 10^5	8.427 x 10^5 (59.9%)		7.430 x 10^4 (13.2%)		9.170 x 10^5 (65.2%)	LEANTO
		3.302 x 10^6	2.706 x 10^6	1.645 x 10^6		5.960 x 10^5 (18.0%)		1.061 x 10^6 (39.2%)	1.657 x 10^6 (50.2%)	BAY
		4.709 x 10^6	3.270 x 10^6	2.135 x 10^6					2.574 x 10^6 (54.7%)	TOTAL
ANNUAL COOLING LOAD (BTU/YR)		3.722 x 10^8	1.987 x 10^8	1.927 x 10^8	1.735 x 10^8 (46.6%) [$7,543.]		6.000 x 10^6 (3.0%) [$261.]		1.795 x 10^8 (48.2%)	LEANTO
		4.858 x 10^8	4.017 x 10^8	2.047 x 10^8						BAY
		8.580 x 10^8	6.004 x 10^8	3.974 x 10^8						TOTAL
MAXIMUM COOLING LOAD BTU/HR		6.970 x 10^5	3.442 x 10^5	4.264 x 10^5	3.528 x 10^5 (50.6%)		-8.220 x 10^4 (-23.9%)		2.706 x 10^5 (38.8%)	LEANTO
		1.619 x 10^6	1.309 x 10^6	6.845 x 10^5						BAY
		2.316 x 10^6	1.653 x 10^6	1.111 x 10^6						TOTAL
MAX ZONE TEMP	1				EXISTING = 10,684 gal/yr	MODIFIED =3,861 gal/yr	SAVINGS = 6,823 gal/yr			
	2									
	3									
	4									
MIN ZONE TEMP	1									
	2									
	3									
	4									

LOADS SUMMARY - H-2 HANGAR: FRESNO, CA

HDD = 2650
CDD = 1671

		EXISTING BUILDING (DECK #1)	MODIFIED LEANTO WALL & INSUL BAY DOOR (DECK #2)	ADD'L LEANTO CLG INSUL & BAY SUSP CLG (DECK #3)	SAVINGS DUE TO LEANTO TO PNL WIND (#1-#2)	SAVINGS DUE TO HANGAR DOOR INSUL (#1-#2)	SAVINGS DUE TO LEANTO CLG INSUL (#2-#3)	SAVINGS DUE TO HANGAR BAY SUSP (#2-#3)	TOTAL SAVINGS	
ANNUAL HEATING LOAD (BTU/YR)		8.885×10^8	3.262×10^8	2.831×10^8	5.623×10^8 (63.3%) [$24,448]		4.310×10^7 (13.2%) [$1,874]		6.054×10^8 (68.1%)	LEANTO
		6.015×10^8	4.871×10^8	2.761×10^8		1.144×10^8 (19.0%) [$4,974]		2.110×10^8 (43.3%) [$9,174]	3.254×10^8 (54.1%)	BAY
		1.490×10^9	8.133×10^8	5.592×10^8					9.308×10^8 (62.5%)	TOTAL
MAXIMUM HEATING LOAD (BTU/HR)		1.122×10^6	5.505×10^5	4.760×10^5	5.715×10^5 (50.9%)		7.450×10^4 (13.5%)		6.460×10^5 (57.6%)	LEANTO
		2.500×10^6	2.044×10^6	1.262×10^6		4.560×10^5 (18.2%)		7.820×10^5 (38.2%)	1.238×10^6 (49.5%)	BAY
		3.622×10^6	2.594×10^6	1.738×10^6					1.884×10^6 (52.0%)	TOTAL
ANNUAL COOLING LOAD (BTU/YR)		3.040×10^8	1.370×10^8	1.308×10^8	1.670×10^8 (54.9%) [$7,261]		6.200×10^6 (4.5%) [$270]		1.732×10^8 (57.0%)	LEANTO
		4.242×10^8	3.357×10^8	1.442×10^8					2.800×10^8	BAY
		7.282×10^8	4.727×10^8	2.750×10^8					4.532×10^8	TOTAL
MAXIMUM COOLING LOAD BTU/HR		9.230×10^5	3.906×10^5	3.679×10^5	5.324×10^5 (57.7%)		2.270×10^4 (5.8%)		5.551×10^5 (60.1%)	LEANTO
		2.036×10^6	1.654×10^6	8.491×10^5					1.187×10^6	BAY
		2.959×10^6	2.044×10^6	1.217×10^6					1.742×10^6	TOTAL
MAX ZONE TEMP	1									
	2									
	3									
	4									
MIN ZONE TEMP	1				EXISTING = 15,204 gal/yr	MODIFIED = 5,706 gal/yr	SAVINGS = 7,498 gal/yr			
	2									
	3									
	4									

LOADS SUMMARY - H-2 HANGAR: RICHMOND, VA

HDD= 3939
CDD= 1353

		EXISTING BUILDING (DECK #1)	MODIFIED LEANTO WALL & INSUL BAY DOOR (DECK #2)	ADD'L LEANTO CLG INSUL & BAY SUSP CLG (DECK #3)	SAVINGS DUE TO LEANTO TO PNL WIND (#1-#2)	SAVINGS DUE TO HANGAR DOOR INSUL (#1-#2)	SAVINGS DUE TO LEANTO CLG INSUL (#2-#3)	SAVINGS DUE TO HANGAR BAY SUSP (#2-#3)	TOTAL SAVINGS	
ANNUAL HEATING LOAD (BTU/YR)		1.948×10^{9}	7.577×10^{8}	6.612×10^{8}	1.190×10^{9} (61.1%) [$51,739]		9.650×10^{7} (12.7%) [$4,196]		1.287×10^{9} (66.0%)	LEANTO
		1.932×10^{9}	1.588×10^{9}	9.061×10^{8}		3.440×10^{8} (17.8%) [$14,956]		6.819×10^{8} (42.9%) [$29,648]	1.026×10^{9} (53.1%)	BAY
		3.880×10^{9}	2.346×10^{9}	1.567×10^{9}					2.313×10^{9} (59.6%)	TOTAL
MAXIMUM HEATING LOAD (BTU/HR)		1.541×10^{6}	7.159×10^{5}	6.266×10^{5}	8.251×10^{5} (53.5%)		8.930×10^{4} (12.5%)		9.144×10^{5} (59.3%)	LEANTO
		3.560×10^{6}	2.904×10^{6}	1.768×10^{6}		6.560×10^{5} (18.4%)		1.136×10^{6} (39.1%)	1.792×10^{6} (50.3%)	BAY
		5.101×10^{6}	3.620×10^{6}	2.395×10^{6}					2.706×10^{6} (53.0%)	TOTAL
ANNUAL COOLING LOAD (BTU/YR)		1.545×10^{8}	6.293×10^{7}	6.683×10^{7}	9.157×10^{7} (59.3%) [$3,981]		-3.900×10^{6} (-6.2%)		8.767×10^{7} (56.7%)	LEANTO
		1.926×10^{8}	1.429×10^{8}	5.216×10^{7}						BAY
		3.471×10^{8}	2.058×10^{8}	1.190×10^{8}						TOTAL
MAXIMUM COOLING LOAD BTU/HR		6.882×10^{5}	2.804×10^{5}	2.690×10^{5}	4.078×10^{5} (59.2%)		1.140×10^{4} (4.1%)		4.192×10^{5} (60.9%)	LEANTO
		1.355×10^{6}	1.104×10^{6}	5.385×10^{5}						BAY
		2.043×10^{6}	1.384×10^{6}	8.075×10^{5}						TOTAL
MAX ZONE TEMP	1									
	2									
	3									
	4									
MIN ZONE TEMP	1				EXISTING = 39,592 gal/yr	MODIFIED = 15,990 gal/yr	SAVINGS = 23,602 gal/yr			
	2									
	3									
	4									

LOADS SUMMARY - H-2 HANGAR: LOUISVILLE, KY

HDD=4640
CDD=1268

		EXISTING BUILDING (DECK #1)	MODIFIED LEANTO WALL & INSUL BAY DOOR (DECK #2)	ADD'L LEANTO CLG INSUL & BAY SUSP CLG (DECK #3)	SAVINGS DUE TO LEANTO TO PNL WIND (#1-#2)	SAVINGS DUE TO HANGAR DOOR INSUL (#1-#2)	SAVINGS DUE TO LEANTO CLG INSUL (#2-#3)	SAVINGS DUE TO HANGAR BAY SUSP (#2-#3)	TOTAL SAVINGS	
ANNUAL HEATING LOAD (BTU/YR)		2.121×10^9	8.945×10^8	7.196×10^8	1.316×10^9 (62.1%) [$57,217]		8.490×10^7 (10.6%) [$3,691]		1.401×10^9 (66.1%)	LEANTO
		2.293×10^9	1.852×10^9	1.070×10^9		4.410×10^8 (19.2%) [$19,174]		7.820×10^8 (42.2%) [$34,000]	1.223×10^9 (53.3%)	BAY
		4.414×10^9	2.657×10^9	1.790×10^9					2.624×10^9 (59.4%)	TOTAL
MAXIMUM HEATING LOAD (BTU/HR)		2.349×10^6	8.870×10^5	7.961×10^5	1.462×10^6 (62.2%)		9.090×10^4 (10.2%)		1.553×10^6 (66.1%)	LEANTO
		7.415×10^6	6.036×10^6	3.633×10^6		1.379×10^6 (18.6%)		2.403×10^6 (39.8%)	3.782×10^6 (51.0%)	BAY
		9.764×10^6	6.923×10^6	4.429×10^6					5.335×10^6 (54.6%)	TOTAL
ANNUAL COOLING LOAD (BTU/YR)		1.521×10^8	7.142×10^7	7.008×10^7	8.068×10^7 (53.0%) [$3,508]		1.340×10^6 (1.9%) [$58]		8.202×10^7 (53.9%)	LEANTO
		1.968×10^8	1.496×10^8	5.728×10^7		4.720×10^7 (24.0%)		9.232×10^7 (61.7%)		BAY
		3.489×10^8	2.210×10^8	1.274×10^8						TOTAL
MAXIMUM COOLING LOAD BTU/HR		6.317×10^5	2.790×10^5	2.667×10^5	3.527×10^5 (55.8%)		1.230×10^4 (4.4%)		3.650×10^5 (57.8%)	LEANTO
		1.247×10^6	9.864×10^5	4.998×10^5						BAY
		1.879×10^6	1.265×10^6	7.665×10^5						TOTAL
MAX ZONE TEMP	1									
	2									
	3									
	4									
MIN ZONE TEMP	1				EXISTING = 45,041 gal/yr	MODIFIED = 18,265 gal/yr	SAVINGS = 26,776 gal/yr			
	2									
	3									
	4									

LOADS SUMMARY - H-2 HANGAR: SPRINGFIELD, OH

HDD = 5100
CDD = 1050

		EXISTING BUILDING (DECK #1)	MODIFIED LEANTO WALL & INSUL BAY DOOR (DECK #2)	ADD'L LEANTO CLG INSUL & BAY SUSP CLG (DECK #3)	SAVINGS DUE TO LEANTO TO PNL WIND (#1-#2)	SAVINGS DUE TO HANGAR DOOR INSUL (#1-#2)	SAVINGS DUE TO LEANTO CLG INSUL (#2-#3)	SAVINGS DUE TO HANGAR BAY SUSP (#2-#3)	TOTAL SAVINGS	
ANNUAL HEATING LOAD (BTU/YR)		2.319×10^9	8.910×10^8	7.980×10^8	1.428×10^9 (61.6%) [$62,087]		9.300×10^7 (10.4%) [$4,043]		1.521×10^9 (65.6%)	LEANTO
		2.506×10^9	2.031×10^9	1.180×10^9		4.750×10^8 (18.9%) [$20,652]		8.510×10^8 (41.9%) [$37,000]	1.326×10^9 (52.9%)	BAY
		4.825×10^9	2.922×10^9	1.978×10^9					2.847×10^9 (59.0%)	TOTAL
MAXIMUM HEATING LOAD (BTU/HR)		2.570×10^6	1.004×10^6	9.030×10^5	1.566×10^6 (60.9%)		1.010×10^5 (10.0%)		1.667×10^6 (64.9%)	LEANTO
		6.778×10^6	5.546×10^6	3.351×10^6		1.232×10^6 (18.2%)		2.195×10^6 (39.6%)	3.427×10^6 (50.6%)	BAY
		9.348×10^6	6.550×10^6	4.254×10^6					5.094×10^6 (54.5%)	TOTAL
ANNUAL COOLING LOAD (BTU/YR)		1.246×10^8	4.700×10^7	4.636×10^7	7.760×10^7 (62.3%) [$3,374]		6.400×10^5 (1.4%) [$28]		7.824×10^7 (62.8%)	LEANTO
		1.444×10^8	1.055×10^8	3.224×10^7						BAY
		2.690×10^8	1.525×10^8	7.860×10^7						TOTAL
MAXIMUM COOLING LOAD BTU/HR		6.050×10^5	2.410×10^5	2.274×10^5	3.640×10^5 (60.2%)		1.360×10^4 (5.6%)		3.776×10^5 (62.4%)	LEANTO
		1.265×10^6	1.005×10^6	4.815×10^5						BAY
		1.870×10^6	1.246×10^6	7.099×10^5						TOTAL
MAX ZONE TEMP	1									
	2									
	3									
	4									
MIN ZONE TEMP	1				EXISTING = 49,235 gal/yr	MODIFIED = 20,184 gal/yr	SAVINGS = 29,051 gal/yr			
	2									
	3									
	4									

LOADS SUMMARY - H-2 HANGAR: BOISE, ID

HDD=5833
CDD=714

		EXISTING BUILDING (DECK #1)	MODIFIED LEANTO WALL & INSUL BAY DOOR (DECK #2)	ADD'L LEANTO CLG INSUL & BAY SUSP CLG (DECK #3)	SAVINGS DUE TO LEANTO TO PNL WIND (#1-#2)	SAVINGS DUE TO HANGAR DOOR INSUL (#1-#2)	SAVINGS DUE TO LEANTO CLG INSUL (#2-#3)	SAVINGS DUE TO HANGAR BAY SUSP (#2-#3)	TOTAL SAVINGS	
ANNUAL HEATING LOAD (BTU/YR)		2.434×10^{9}	9.800×10^{8}	8.710×10^{9}	1.454×10^{9} (59.7%) [$63,217]		1.090×10^{8} (11.1%) [$4,739]		1.563×10^{9} (64.2%)	LEANTO
		2.494×10^{9}	2.021×10^{9}	1.175×10^{9}		4.730×10^{8} (19.0%) [$20,565]		8.460×10^{8} (41.9%) [$36,782]	1.319×10^{9} (52.9%)	BAY
		4.928×10^{9}	3.001×10^{9}	2.046×10^{9}					2.882×10^{9} (58.5%)	TOTAL
MAXIMUM HEATING LOAD (BTU/HR)		1.988×10^{6}	8.690×10^{5}	7.600×10^{5}	1.119×10^{6} (56.3%)		1.000×10^{5} (11.5%)		1.219×10^{6} (61.3%)	LEANTO
		5.269×10^{6}	4.288×10^{6}	2.596×10^{6}		9.810×10^{5} (18.6%)		1.692×10^{6} (39.4%)	2.673×10^{6} (50.7%)	BAY
		7.257×10^{6}	5.157×10^{6}	3.365×10^{6}					3.892×10^{6} (53.6%)	TOTAL
ANNUAL COOLING LOAD (BTU/YR)		1.158×10^{8}	3.620×10^{7}	3.532×10^{7}	7.960×10^{7} (68.7%) [$3,461]		8.800×10^{5} (2.4%) [$38]		8.048×10^{7} (69.5%)	LEANTO
		1.623×10^{8}	1.133×10^{8}	3.154×10^{7}						BAY
		2.781×10^{8}	1.495×10^{8}	6.686×10^{7}						TOTAL
MAXIMUM COOLING LOAD BTU/HR		7.100×10^{5}	2.660×10^{5}	2.596×10^{5}	4.440×10^{5} (62.5%)		6.400×10^{3} (2.4%)		$4.504 \times$ (63.4%)	LEANTO
		1.759×10^{6}	1.351×10^{6}	6.685×10^{5}						BAY
		2.469×10^{6}	1.617×10^{6}	9.281×10^{5}						TOTAL
MAX ZONE TEMP	1									
	2									
	3									
	4									
MIN ZONE TEMP	1				EXISTING = 50,286 gal/yr	MODIFIED = 20,878 gal/yr	SAVINGS = 29,408 gal/yr			
	2									
	3									
	4									

LOADS SUMMARY - H-2 HANGAR: NIAGARA FALLS, NY

HDD = 6927
CDD = 437

		EXISTING BUILDING (DECK #1)	MODIFIED LEANTO WALL & INSUL BAY DOOR (DECK #2)	ADD'L LEANTO CLG INSUL & BAY SUSP CLG (DECK #3)	SAVINGS DUE TO LEANTO TO PNL WIND (#1 - #2)	SAVINGS DUE TO HANGAR DOOR INSUL (#1 - #2)	SAVINGS DUE TO LEANTO CLG INSUL (#2 - #3)	SAVINGS DUE TO HANGAR BAY SUSP (#2 - #3)	TOTAL SAVINGS	
ANNUAL HEATING LOAD (BTU/YR)		3.564 x 10^9	1.389 x 10^9	1.240 x 10^9	2.175 x 10^9 (61.0%) [$94,565]		1.490 x 10^8 (10.7%) [$6,478]		2.324 x 10[illegible] (65.2%)	LEANTO
		4.171 x 10^9	3.370 x 10^9	1.966 x 10^9		8.010 x 10^8 (19.2%) [$34,826]		1.404 x 10^9 (41.7%) [$61,043]	2.205 x 10[illegible] (52.9%)	BAY
		7.734 x 10^9	4.759 x 10^9	3.206 x 10^9					4.528 x 10^9 (58.5%)	TOTAL
MAXIMUM HEATING LOAD (BTU/HR)		2.392 x 10^6	9.935 x 10^5	8.858 x 10^5	1.398 x 10^6 (58.5%)		1.077 x 10^5 (10.8%)		1.398 x 10^5 (58.5%)	LEANTO
		6.603 x 10^6	5.382 x 10^6	3.262 x 10^6		1.221 x 10^6 (18.5%)		2.120 x 10^6 (39.4%)	3.341 x 10^6 (50.6%)	BAY
		8.995 x 10^6	6.376 x 10^6	4.148 x 10^6					4.847 x 10^6 (53.9%)	TOTAL
ANNUAL COOLING LOAD (BTU/YR)		3.714 x 10^7	8.571 x 10^6	9.948 x 10^6	2.857 x 10^7 (76.9%) [$1,242]		-1.377 x 10^6 (-16.1%)		2.719 x 10^7 (73.2%)	LEANTO
		3.726 x 10^7	2.367 x 10^7	3.640 x 10^6						BAY
		7.440 x 10^7	3.224 x 10^7	1.359 x 10^7						TOTAL
MAXIMUM COOLING LOAD BTU/HR		3.941 x 10^5	1.319 x 10^5	1.295 x 10^5	2.622 x 10^5 (66.5%)		2.400 x 10^3 (1.8%)		2.646 x 10^6 (67.1%)	LEANTO
		7.084 x 10^5	5.551 x 10^5	2.172 x 10^5						BAY
		1.102 x 10^6	6.870 x 10^5	3.467 x 10^5						TOTAL
MAX ZONE TEMP	1									
	2									
	3									
	4									
MIN ZONE TEMP	1				EXISTING = 78,918 gal/yr	MODIFIED = 32,714 gal/yr	SAVINGS = 46,204 gal/yr			
	2									
	3									
	4									

LOADS SUMMARY - H-2 HANGAR: FARGO, ND

HDD = 9044

CDD = 487

		EXISTING BUILDING (DECK #1)	MODIFIED LEANTO WALL & INSUL BAY DOOR (DECK #2)	ADD'L LEANTO CLG INSUL & BAY SUSP CLG (DECK #3)	SAVINGS DUE TO LEANTO TO PNL WIND (#1-#2)	SAVINGS DUE TO HANGAR DOOR INSUL (#1-#2)	SAVINGS DUE TO LEANTO CLG INSUL (#2-#3)	SAVINGS DUE TO HANGAR BAY SUSP (#2-#3)	TOTAL SAVINGS	
ANNUAL HEATING LOAD (BTU/YR)		5.534×10^9	$2.1[illegible]2 \times 10^9$	1.349×10^9	3.432×10^9 (62.0%) [$149,217]	1.381×10^9 (19.2%) [$60,043]	7.540×10^8 (35.9%) [$32,783]	2.443×10^9 (42.0%) [$1[illegible]6,217]	$4.1[illegible]6 \times 10^9$ ([illegible])	LEANTO
		7.199×10^9	5.815×10^9	3.375×10^9					3.824×10^9 (53.1%)	BAY
		1.273×10^{10}	7.920×10^9	4.723×10^9					[illegible] (62.[illegible]%)	TOTAL
MAXIMUM HEATING LOAD (BTU/HR)		3.696×10^6	1.304×10^6	1.179×10^6	2.392×10^6 (64.7%)	2.231×10^6 (18.8%)	1.250×10^5 (9.6%)	3.860×10^6 (40.2%)	2.517×10^6 ([illegible])	LEANTO
		1.184×10^7	9.609×10^6	5.749×10^6					6.091×10^6 (51.4%)	BAY
		1.554×10^7	1.091×10^7	6.923×10^6					8.612×10^6 (55.[illegible]%)	TOTAL
ANNUAL COOLING LOAD (BTU/YR)		7.950×10^7	2.062×10^7	2.070×10^7	5.891×10^7 (74.0%) [$2,557]		-1.000×10^4 (-0.05%)		$5.8[illegible]0 \times 10^7$ (74.0%)	LEANTO
		1.223×10^9	[illegible]	2.301×10^7						BAY
		2.734×10^8	1.036×10^8	4.371×10^7						TOTAL
MAXIMUM COOLING LOAD BTU/HR		6.799×10^5	2.137×10^5	2.088×10^5	4.653×10^5 (68.5%)		4.900×10^3 (2.3%)		4.702×10^5 (69.2%)	LEANTO
		2.235×10^6	1.759×10^6	8.867×10^5						BAY
		2.914×10^6	1.972×10^6	1.096×10^6						TOTAL
MAX ZONE TEMP	1									
	2									
	3									
	4									
MIN ZONE TEMP	1				EXISTING = 129,898 gal/yr	MODIFIED = 48,194 gal/yr	SAVINGS = 81,704 gal/yr			
	2									
	3									
	4									

APPENDIX E:

PROPOSED BLAST IMPLEMENTATION PLAN FOR
CORPS OF ENGINEERS MILITARY CONSTRUCTION DISTRICTS

Background

Program Description

The Building Loads Analysis and System Thermodynamics (BLAST) program is a comprehensive computer program for estimating (1) hourly space heating and cooling requirements, (2) hourly performance of fan systems, and (3) hourly performance of a conventional heating and cooling system, total energy systems, and/or solar energy systems. Apart from its comprehensiveness, the program differs in five key respects from similar programs used in the past:

1. The BLAST program uses extremely rigorous and detailed algorithms to compute both building loads and system performance.

2. The program employs its own input language, which permits rapid input preparation in a completely unformatted English-like (as opposed to computer-like) style.

3. The program contains a library of all materials and wall, floor, and roof sections and their thermodynamic properties listed in the ASHRAE *Handbook of Fundamentals*.

4. The program execution time is extremely brief, making the study of many alternative concepts relatively inexpensive.

5. The program is not proprietary and is therefore open to inspection by its users and those who rely on the results it generates.

The BLAST program consists of three main computation sections. The first section of the BLAST program--the space load-predicting subprogram--computes hourly heating and cooling thermal loads for each building zone, taking into account conduction through the building envelope, solar heat gain, internal loads from occupants, and equipment and infiltration loads. The program can perform two types of analysis in this section:

1. Hourly energy analysis. This analysis uses actual hourly weather data to calculate hourly heating and cooling loads for each zone of the building. Output from the hourly energy analysis is used as input to the system simulation program, the second program section.

2. Design day analysis. This analysis uses user input design day data to calculate peak heating and cooling loads for each zone of the building.

The second section of the program--the air distribution system simulation subprogram--simulates air distribution systems as they respond to hourly space thermal loads and determines the hourly and total load placed on the central heating and cooling plant. This subprogram can analyze all major types of distribution systems and several combinations of mixed air and delivery air control strategies.

The third section of the program--the central energy plant simulation subprogram--can simulate all conventional heating and cooling equipment plus electrical generation and heat recovery equipment, solar collectors and storage tank systems, and utility power systems. The subprogram uses either the generic models for each component present in BLAST or user-specified equipment performance parameters, which allows for rigorous simulation of a particular manufacturer's product.

In addition to performance analysis of variously configured central plants, the BLAST program computes life cycle costs of each central energy plant option selected on the basis of user-supplied or default capital cost, maintenance cost, operating cost, and utility rate schedules.

Intended Users

The BLAST program is for use by CE Division and District Engineer Offices, OCE, and the A/E firms working for them. It can be used for analyzing the energy consumption impact of alternative design options in new facility designs and in major retrofit projects. The BLAST program can also be the main computational tool for assessing the performance of total energy and solar heating and cooling system options during the design phase.

OCE may also have requirements for using the BLAST program. Their major areas of need are anticipated to be in evaluating the energy savings potential of energy conservation alternatives and options, and for checking new facility designs for compliance with Executive Orders and DA/OCE energy conservation directives.

Status of Program

The development of the BLAST program is complete, and the User's and Reference Manuals are ready for publication. The program has been installed in the Eglin Air Force Base computer and the Lawrence Berkeley Laboratory computer at Berkeley, CA. A training session on the BLAST program for program sponsors and field test users was conducted and a field test completed at Fort Worth District. Documentation required under AR 18-1 has been initiated.

Computer Requirements

Programming Language

BLAST is a 60,000- to 80,000-line program written in CDC FORTRAN, version 4 extended, running under CDC's scope 3.4 and NOS operating systems. The program uses CDC mass storage files, but otherwise there is little nonstandard FORTRAN used.

Computer Capacity Required

The BLAST program uses approximately 70,000 decimal words of common and loads in six segments of 50,000 to 60,000 decimal words each, including some duplicated common and all linked system routines. The program generates large intermediate permanent files on the order of 12,000 PRU's (1 PRU = 64 words).

Desired Machine System Capabilities

The BLAST program performs large numbers of similar or identical calculations in calculating energy use and requires a large amount of memory and peripheral storage. Criteria for selecting the computer hardware on which BLAST will be installed for general use are as follows:

1. Equipment must be accessible to all classes of users through batch terminal.

2. Equipment must perform many repetitive calculations efficiently.

3. Calculations must be performed with high precision and minimum roundoff error.

4. Equipment must have large and efficiently used core memory and easily accessed peripheral storage.

5. Equipment must be capable of running the program in minimum calculational time and minimum job turnaround time.

Recommended Computer System

The computer equipment capability criteria dictate installation of BLAST on a large system. Use of a large system would also help insure that the program could be accessed by a large number of users, that some level of programming support would be available at the computer site, and that desired turnaround time and computer usage rates could be obtained. A survey of large hardware systems showed that BLAST could be operated most effectively on Control Data Corporation (CDC) equipment, specifically the 6000 and 7000 series computers. All criteria given in the Computer Requirements are satisfied by the CDC equipment.

In order to minimize the amount of effort required for program support and maintenance, it is desirable to maintain BLAST at one computer site, while insuring that the site can be effectively accessed by all users via terminals. A survey indicated that all Corps Military Construction Districts have access to CDC equipment at Lawrence Berkeley Laboratory (LBL), some have access to the Naval Ship Research and Development Centers (NSRDC), Carderock, MD, and most have accounts with or could easily arrange for accounts with one of the several CDC commercial networks under a General Services Administration multiple award computer services contract.

Implementation and use of the BLAST program at Government-owned or operated computer sites can often conflict with the site mission. Implementation of BLAST by CERL on two Government-owned CDC sites (Eglin AFB and Lawrence Berkeley Laboratory) has already demonstrated the problems that result from this conflict. Aside from the often non-standard operating systems and procedures found at Government installations, the low priority and restricted computer resource allocations given to BLAST users compared to users directly supporting the site's mission considerably reduces the usability and effectiveness of the BLAST program as a tool for energy conservation studies and designs.

Bench mark runs of BLAST show that while costs are somewhat higher on commercial computer systems, user convenience and turnaround time are considerably better than on Government-owned, mission-oriented systems. The BLAST program, therefore, should be installed and supported at one of the commercial CDC computer centers. Specific site selection will be based on additional bench marks which are nearly complete.

A batch terminal similar to the CDC 731, DATA 100, or COPE 1200 is desirable for using the BLAST program, because these terminals have a card reader and high-speed printer which will minimize input and output time. Wide-carriage (132 characters) interactive terminals can be used but are much slower (30 characters per second, compared to 480 characters per second for high-speed batch terminals).

Implementation Plan

The following steps should be taken to implement the BLAST program in Division and District Offices and OCE.

Instructions From OCE

The Directorate of Military Construction (DMC) should issue Engineering Instructions recommending and authorizing, but not requiring, the use of BLAST for evaluating all major retrofit and new design projects and studies for a period of 18 months.

Manuals

The User's and Reference Manuals for the BLAST program will be updated based on results of the field test and comments from OCE by October 1977 and distributed to Divisions and Districts and OCE during the first quarter of FY78.

Authorization and Documentation

DMC is the proponent agency for the BLAST program and will authorize CERL to prepare all documentation and obtain approvals required under AR 18-1. OCE assistance will be required. Documentation will be in the form of a "System Overview" (Modified GFSR) as shown in Annex 1. CERL will fund the development of the documentation.

User Training - First Year

DMC will provide and fund user training on a scheduled basis; CERL will assist as described in the following paragraph. Representatives from each Military Construction Division and District and OCE will require training. In addition, since benefits to be derived from the use of BLAST may not be fully realized without its use by A/E's working for the Corps, representatives of A/E firms selected by the Districts may also be trained. A training session of not less than 3 days is required and each class should be restricted to 20 students.

CERL will develop the training materials and provide training to the OCE Training Team. OCE will identify instructors for the OCE Training Team, identify students for each training session, and establish the funding sources to support the training preparation activities.

User Support - First Year

During the first year, CERL will provide necessary user support by providing answers to user questions over the telephone or by problem transmission to or from the computer, and by serving as a focal point for obtaining weather data tapes and keeping the *User's Manual* and documentation current. This support will be phased over from CERL to the DMC Support Contractor during the first year (see next paragraph).

User Support After First Year

User support after the first year of implementation will be the responsibility of a DMC Support Contractor, who will be trained by CERL during the first year. OCE will establish the funding source for the support contractor early enough to permit contract award in the second quarter of the first year and to maintain support thereafter.

Implementation Schedule

The proposed schedule for the implementation of BLAST is shown in Annex 2.

Maintenance Requirements

DMC will be responsible for providing maintenance for the BLAST program. It is expected that routine maintenance will be provided by a support contractor. CERL will provide technical backup and initial training to the contractor as required.

DMC support contractors will be responsible for making all changes to the BLAST program after consultation with CERL. This effort will include correcting errors found by users in the program, upgrading algorithms based on results of validation efforts, and enhancing input language and output reports. Changes should not be made more frequently than annually, unless they are necessary to overcome an immediate operational problem.

ANNEX 1:

SYSTEM OVERVIEW (MODIFIED GFSR FORMAT)

Chapters

1. Introduction:

    a. System identification

    b. Background

    c. Objectives

    d. Constraints

    e. Present status.

2. Description of Current System. Provide a clear description of the system or systems which the new system will replace. The system should be described not just in terms of the supporting ADP system, but all the structural components. In particular, any functional differences between the current and proposed system that raise special problems in conversion should be identified and discussed here.

3. Description of Proposed System. Identify and describe the basic functions to be performed by the proposed systems and the relationships among them. Describe how the ADP system is integrated into this proposed system. In particular, the points of interaction between the ADP and non-ADP system should be indicated.

4. Organizational Structure. Identify the organizational units to be performing or directly supporting the functions indicated in Chapter 3. This chapter should also designate who has the maintenance and training responsibility and the location of the operating Data Processing Installation DIP(S).

5. Interface with Other Systems. Identify and describe the organizations with which the proposed system must interface. Include the purpose of the interface and the manner by which such interface is to be achieved. For external interfaces that use machine-readable mediums, the input or output descriptions should be shown in Chapter 7.

6. System and Work Load Data.

a. Inputs. Identify all the system inputs and show their origin. In addition, the format and a sample of an input document should be shown.

b. Outputs. Describe the outputs from the system, indicating their content and frequency.

c. Data Retained. Describe the data which is to be retained for historical purposes or for backup.

7. Requirements for Backup. Identify the nature of the backup requirement, the files, or the data that should be saved, and identify how this data is to be used if a backup is required.

8. Installation and Conversion Concepts. Identify the requirements and general circumstances applicable to the period of transition from the current to the proposed system.

9. Communications Requirements. Identify all communications support requirements for the proposed system.

10. Economic Analysis. Provide details of the new system's economic benefits.

11. Training. Identify the requirements for training personnel who will manage and utilize the proposed system.

12. Control Methods and Audit Trails. Identify and define the automated decision-making functions of the system. The nature of the automated decision should be specified, and specific test data and criteria must be shown which can be used to validate all automated decisions prior to installation.

ANNEX 2:

PROPOSED IMPLEMENTATION SCHEDULE

ACTIVITY	1	2	3	4	5	6	7	8	9	10	11
				Months From Start							
1. DMC Engineering Instruction authorizing use of BLAST (OCE)*											
2. User's and Reference Manuals to Divisions, Districts, and OCE (CERL)	(1st Q FY78)										
3. Prepare AR 18-1 documentation (CERL)											
4. Develop training materials (OCE)											
5. Conduct training for training team (OCE)											
a. Initial training											
b. Team use of BLAST											
c. Follow-up training											
6. Support contractor selection and award (OCE)											
7. Training sessions for Divisions, Districts, and OCE personnel (OCE)											
8. User support by CERL (OCE)											
9. User support by contractor (OCE)											
10. First program update (CERL)											

*Funding responsibility shown in parentheses

COST GUIDELINES BY ACTIVITY

ACTIVITY

1. DMC Engineering Instructions to Divisions and Districts

   Prepare and distribute instructions at OCE.

2. User's and Reference Manuals to Divisions, Districts, and OCE

   Revised manuals will be distributed as part of FY78 RDT&E program

3. Prepare AR 18-1 Documentation

   Documentation will be prepared by CERL as part of FY78 RDT&E program.

   NOTE:

   OCE assistance will be required during preparation of the documentation and in obtaining the necessary approvals.

4. Develop Training Materials

Basic training aids have been developed. However, experience with past training sections indicates that a workbook containing several complete examples should be developed as an additional training aid and for use as a refresher.	$13,000

5. Conduct Training for BLAST team.

   a. Initial training (1-week seminar)

Training session cost - CERL cost	$ 6,000
Training salaries (10 trainees at GS-12)	$ 7,500
Travel and per diem	$ 4,300
Computer cost	$ 6,000

b. Initial use of BLAST

Assuming 8 of the 10 trainees from the initial training session (Activity 5a) devote one man-month each to use of BLAST, the cost projection is:

Salaries	$24,000
Computer	$ 6,000

c. Followup training (1-week refresher seminar)

Cost projections are the same as Activity 5a.	$23,800

6. Support Contractor Selection and Award

CERL assistance in developing scope of work and selecting contractor.	$ 4,000

7. Training Sessions for Division, Districts, and OCE Personnel

The session and computer costs for this activity will approximate those of Activity 5a. Salaries and per diem will depend on the number of trainees and the location of the seminar. Rough estimates are shown below based on bringing trainees to a central location:

Two training sessions - CERL cost	$12,000
Trainee salaries (30 trainees)	$22,500
Travel and per diem	$13,000
Computer cost	$14,000

8. User Support by CERL

Over a period of 7 months:

Labor	$ 8,000
Computer	$ 2,000

9. User Support by Contractor

The cost will be subject to the scope of work prepared under Activity 6 and to the number of users requiring support

10. First Program Update

This cost is included in the FY78 RDT&E and GSA-funded programs.

APPENDIX F:

PROPOSED BLAST IMPLEMENTATION
PLAN FOR THE AIR FORCE

Background

Program Description

The Building Loads Analysis and System Thermodynamics (BLAST) program is a comprehensive computer program for estimating (1) hourly space heating and cooling requirements, (2) hourly performance of fan systems, and (3) hourly performance of a conventional heating and cooling system, total energy systems, and/or solar energy systems. Apart from its comprehensiveness, the program differs in five key respects from similar programs used in the past:

1. The BLAST program uses extremely rigorous and detailed algorithms to compute both building loads and system performance.

2. The program employs its own input language, which permits rapid input preparation in a completely unformatted English-like (as opposed to computer-like) style.

3. The program contains a library of all materials and wall, floor, and roof sections and their thermodynamic properties listed in the ASHRAE *Handbook of Fundamentals*.

4. The program execution time is extremely brief, making the study of many alternative concepts relatively inexpensive.

5. The program is not proprietary and is therefore open to inspection by its users and those who rely on the results it generates.

The BLAST program consists of three main computation sections. The first section of the BLAST program--the space load predicting subprogram--computes hourly heating and cooling thermal loads for each building zone, taking into account conduction through the building envelope, solar heat gain, internal loads from occupants, and equipment and infiltration loads. The program can perform two types of analysis in this section:

1. Hourly energy analysis. Uses actual hourly weather data to calculate hourly heating and cooling loads for each zone of the building. Output from the hourly energy analysis is used as input to the system simulation program, the second program section.

2. Design day analysis. Uses user input design day data to calculate peak heating and cooling loads for each zone of the building.

The second section of the program--the air distribution system simulation subprogram--simulates air distribution systems as they respond to hourly space thermal loads and determines the hourly and total load placed on the central heating and cooling plant. This subprogram can analyze all major types of distribution systems and several combinations of mixed air and delivery air control strategies.

The third section of the program--the central energy plant simulation subprogram--can simulate all conventional heating and cooling equipment plus electrical generation and heat recovery equipment, solar collectors and storage tank systems, and utility power systems. The subprogram uses either the generic models for each component present in BLAST or user-specified equipment performance parameters, which allows for rigorous simulation of a particular manufacturer's product.

In addition to performance analysis of variously configured central plants, the BLAST program computes life cycle costs of each central energy plant option selected on the basis of user-supplied or default capital cost, maintenance cost, operating cost, and utility rate schedules.

Intended Users

The BLAST program is for use by Base Civil Engineers (BCE), Command Engineers (CE), Special Engineering Teams, and the A/E firms working for them. It can be used to analyze the energy consumption impact of alternative design options in new facility designs and in major retrofit projects. The BLAST program can also be the main computational tool for assessing the performance of total energy and solar heating and cooling system options during the design phase.

Status of Program

The development of the BLAST program is complete, and the User's and Reference Manuals are ready for publication. The program has been installed in the Eglin Air Force Base computer and the Lawrence Berkeley Laboratory computer at Berkeley, CA. A training session on the BLAST program for program sponsors and field test users was conducted and a field test completed at Chanute AFB, AFCEC, and the Air National Guard Bureau.

Computer Requirements

Programming Language

BLAST is a 60,000- to 80,000-line program written in CDC FORTRAN, version 4 extended, running under CDC's scope 3.4 and NOS operating systems. The program uses CDC mass storage files, but otherwise there is little non-standard FORTRAN used.

Computer Capacity Required

The BLAST program uses approximately 70,000 decimal words of common and loads in six segments of 50,000 to 60,000 decimal words each, including some duplicated common and all linked system routines. The program generates large intermediate permanent files on the order of 12,000 PRU's (1 PRU = 64 words).

Desired Machine System Capabilities

The BLAST program performs large numbers of similar or identical calculation in calculating energy use and requires a large amount of memory and peripheral storage. Criteria for selecting the computer hardware on which BLAST will be installed for general use are as follows:

1. Equipment must be accessible to all classes of users through batch terminals.

2. Equipment must perform many repetitive calculations efficiently.

3. Calculations must be performed with high precision and minimum round-off error.

4. Equipment must have large and efficiently used core memory and easily accessed peripheral storage.

5. Equipment must be capable of running the program in minimum calculational time and minimum job turnaround time.

Recommended Computer System

The computer equipment capability criteria dictate installation of BLAST on a large system. Use of a large system would also help insure that the program could be accessed by a large number of users, that some level of programming support would be available at the computer site, and that desired turnaround time and computer usage rates could be obtained. A survey of typical Air Force computer systems (see Appendix B) and of large hardware systems showed that BLAST could be operated most effectively on Control Data Corporation (CDC) equipment, specifically the 6000 and 7000 series computers. All criteria given in the previous paragraph are satisfied by the CDC equipment.

In order to minimize the amount of effort required for program support and maintenance, it is desirable to maintain BLAST at one computer site, while insuring that the site can be effectively accessed by all users via terminals.

Implementation and use of the BLAST program at Government-owned or operated computer sites can often conflict with the site mission. Implementation of BLAST by CERL on two Government-owned CDC sites (Eglin AFB and Lawrence Berkeley Laboratory) has already demonstrated the problems that result from this conflict. Aside from the often non-standard operating systems and procedures found at Government installations, the low priority and restricted computer resource allocations given to BLAST users as compared to users directly supporting the site's mission considerably reduces the usability and effectiveness of the BLAST program as a tool for energy conservation studies and designs.

Bench mark runs of BLAST show that while costs are somewhat higher on commercial computer systems, user convenience and turnaround time are considerably better than on Government-owned, mission-oriented systems. The BLAST program, therefore, should be installed and supported at one of the commercial CDC computer centers. Specific site selection will be based on additional bench marks which are nearly complete.

Using a batch terminal similar to the CDC 731, DATA 100, or COPE 1200 is desirable for the BLAST program, because these terminals have a card reader and high-speed printer which will minimize input and output time. Wide carriage (132 characters) interactive terminals can be used but are much slower (30 characters per second, compared to 480 characters per second for high-speed batch terminals).

Implementation Plan

The following steps should be taken to implement the BLAST program in BCE and CE offices and with special teams (if any).

Instructions from AFPRE

AFPRE should issue Engineering Instructions recommending and authorizing, but not requiring, the use of BLAST for evaluating all major retrofit and new design projects and studies.

Manuals

The User's and Reference Manuals for the BLAST program will be updated based on results of the field test and comments from AFCEC by October 1977 and distributed to BCE and CE offices and other personnel as required during the first quarter of FY78.

User Training - First Year

AFPRE will provide and fund user training on a scheduled basis; CERL will assist as described in the following paragraph. Representatatives from each CE and BCE office will require training. In addition, since benefits to be derived from the use of BLAST may not be fully realized without its use by A/E's working for the Air Force, representatives of A/E firms selected by the CE and BCE offices may also be trained. A training session of not less than 4 days is required, and each class should be restricted to 20 students.

CERL will develop the training materials and provide training to the Air Force Training Team. Subsequent training will be accomplished at the Air Force Civil Engineering School. AFPRE will identify students for each training session and establish the funding sources to support the training activities.

User Support - First Year

During the first year, CERL will provide necessary user support by providing answers to user questions over the telephone or by problem transmission to or from the computer, and by serving as a focal point for obtaining weather data tapes and keeping the *User's Manual* and documentation current. This support will be phased over from CERL to AFCEC or a support contractor during the first year (see next paragraph).

User Support After First Year

User support after the first year of implementation will be the responsibility of AFCEC or a support contractor, who will be trained by CERL during the first year. AFPRE will establish the funding source for the support contractor early enough to permit contract award in the second quarter of the first year and to maintain support thereafter.

Maintenance Requirements

AFPRE will be responsible for providing maintenance for the BLAST program. It is expected that routine maintenance will be provided by AFCEC or by a support contractor. CERL will provide technical backup and initial training to AFCEC or the contractor as required.

END

DATE

FILMED

7 – 78

DDC