

UNCLASSIFIED

NL

END
DATE
FILMED
0 8!
DTIC

LEVEL II

12

construction
engineering
research
laboratory



United States Army
Corps of Engineers
...Serving the Army
...Serving the Nation

TECHNICAL REPORT E-174

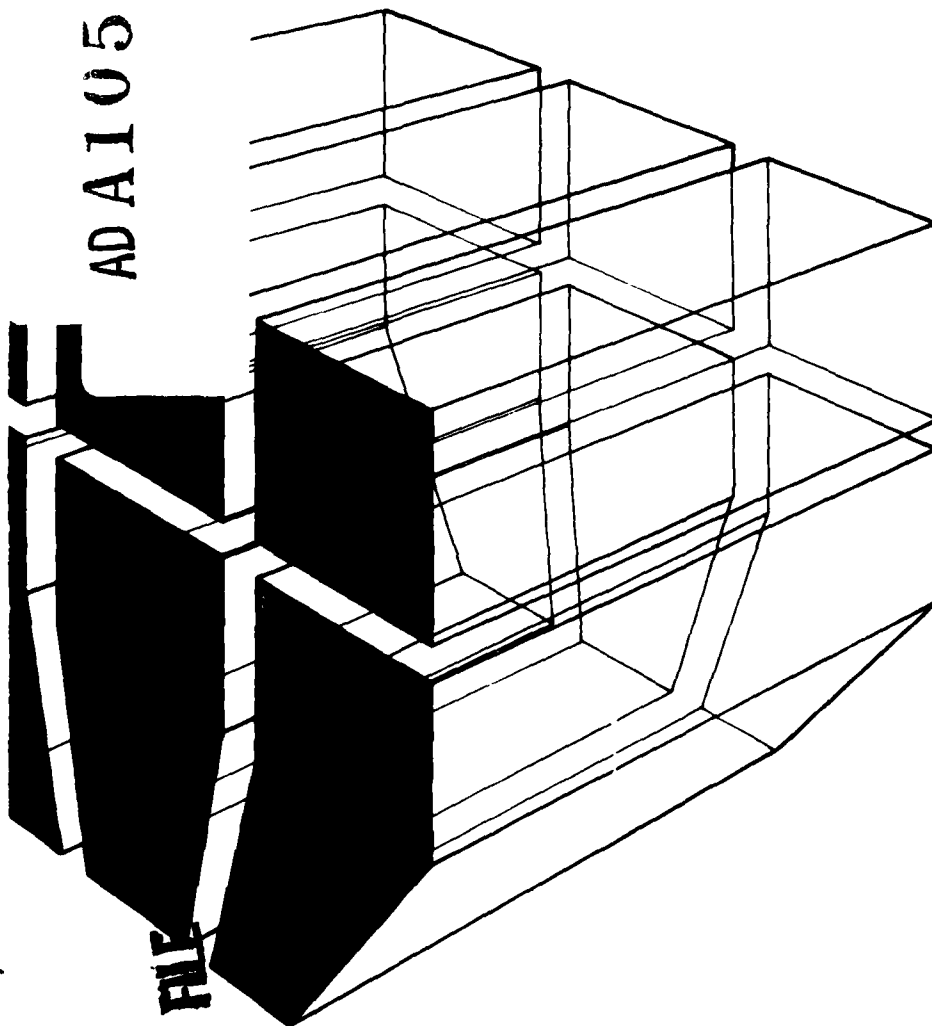
August 1981

(BLAST Validation)

COMPARISON OF BUILDING LOADS ANALYSIS AND SYSTEM THERMODYNAMICS
(BLAST) COMPUTER PROGRAM SIMULATIONS AND MEASURED
ENERGY USE FOR ARMY BUILDINGS

1085573

AD A105162



by
Dale Herron

DTIC
ELECTE
S OCT 6 1981 D

D



/ 81 10 5 073

Approved for public release; distribution unlimited.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official indorsement or approval of the use of such commercial products. The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

***DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED
DO NOT RETURN IT TO THE ORIGINATOR***

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 14 CERL-TR-E-174	2. GOVT ACCESSION NO. AD-A105162	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 COMPARISON OF BUILDING LOADS ANALYSIS AND SYSTEM THERMODYNAMICS (BLAST) COMPUTER PROGRAM SIMULATIONS AND MEASURED ENERGY USE FOR ARMY BUILDINGS.		5. TYPE OF REPORT & PERIOD COVERED FINAL rept.
7. AUTHOR(s) 10 Dale Herron		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. ARMY CONSTRUCTION ENGINEERING RESEARCH LABORATORY P.O. Box 4005, Champaign, IL 61820		8. CONTRACT OR GRANT NUMBER(s) 17G
11. CONTROLLING OFFICE NAME AND ADDRESS 11		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 16 4A762731AT41-G-001
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE August 1981
		13. NUMBER OF PAGES 52 12151
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Copies are obtainable from the National Technical Information Service Springfield, VA 22151		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) BLAST (computer program) buildings energy consumption		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes the results of study which compared actual energy-use data collected for two typical Army buildings by the Army's Fixed Facilities Energy Monitoring Project with energy-use data predicted by the U.S. Army Construction Engineering Research Laboratory's (CERL's) Building Loads Analysis and System Thermodynamics (BLAST) energy analysis computer program. 115-17 cont.		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Block 20 continued.

It was concluded that to compare actual building energy use with energy use predicted by BLAST, accurate, concurrent hourly measurements of weather data, energy-use data, occupancy-dependent parameters, and equipment operating parameters must be obtained. However, within the data collection restraints of this study, BLAST predicted building boundary energy consumption (including both electrical and gas consumption) to within 10 to 12 percent for two typical Army buildings. BLAST also accurately predicted electrical consumption of a chiller package for the same Army buildings.

It was also concluded that BLAST can be used to evaluate energy conservative design alternatives, since most of the hard-to-define effects of building occupants on building energy use are constant and therefore relatively unimportant. But when BLAST is used to predict actual energy performance, values for building geometry, materials, schedules, controls, and heating, cooling, and ventilating systems must be precise and the effects of occupants on building energy use must be carefully described.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

FOREWORD

This work was performed for the Directorate of Military Programs, Office of the Chief of Engineers (OCE), under Project 4A762731AT41, "Design, Construction, and Operation and Technology for Military Facilities"; Technical Area G, "Military Energy Technology"; Work Unit 001, "BLAST Validation." Mr. Ed Zulkofske, DAEN-MPE-E, was the Technical Monitor.

This work was performed by the Energy Systems (ES) Division of the U.S. Army Construction Engineering Research Laboratory (CERL). Mr. R. G. Donaghy is Chief of ES. Much work that contributed to this effort was performed under contract DACA 80-78-R-0004. Appreciation for their support during data collection is expressed to Yandell and Hiller, Inc., Fort Worth, TX.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	

DTIC
ELECTE
OCT 6 1981
S D

CONTENTS

	<u>Page</u>
DD FORM 1473	1
FOREWORD	3
LIST OF TABLES AND FIGURES	5
1 INTRODUCTION.....	7
Background	
Objective	
Approach	
Scope	
Mode of Technology Transfer	
2 DISCUSSION.....	9
Energy Conservative Design Rationale	
Building Selection	
Construction Drawings	
Building and HVAC System Data	
Computer Simulation for the Short Time Period	
Comparison of Actual and Simulated Results for the Short Time Period	
Computer Simulation for the Long Time Period	
Comparison of Actual and Simulated Results for the Long Time Period	
3 ANALYSES AND FINDINGS -- DENTAL CLINIC.....	19
BLAST Input Deck	
Computer Simulation -- Short Time Period	
Comparison of Data -- Short Time Period	
Computer Simulation -- Long Time Period	
Comparison of Data -- Long Time Period	
Summary	
4 ANALYSES AND FINDINGS -- BATTALION HEADQUARTERS AND CLASSROOM BUILDING.....	28
BLAST Input Deck	
Computer Simulation -- Short Time Period	
Comparison of Data -- Short Time Period	
Computer Simulation -- Long Time Period	
Comparison of Data -- Long Time Period	
Summary	
5 GENERAL RESULTS.....	35
6 CONCLUSIONS.....	36
APPENDIX A: Dental Clinic Simulation Model	37
APPENDIX B: Battalion Headquarters and Classroom Building Simulation Model	45
APPENDIX C: Statistical Formulas	52
DISTRIBUTION	

TABLES

<u>Number</u>		<u>Page</u>
1	BLAST Validation Input Data	16
2	Fan System Parameters -- Dental Clinic	21
3	Dental Clinic Comparison -- Short Time Period Electrical Data Comparison	23
4	Dental Clinic Simulation -- Long Time Period Electrical Data Comparison	25
5	Dental Clinic Simulation -- Long Time Period Gas Data Comparison	26
6	Battalion Headquarters Simulation -- Short Time Period Electrical Data Comparison	30
7	Battalion Headquarters and Classroom Building Simulation -- Long Time Period Electrical Data Comparison	34
8	Battalion Headquarters and Classroom Building Simulation -- Long Time Period Hot Water Data Comparison	34

FIGURES

1	Dental Clinic Floor Plan	12
2	Dental Clinic Wall, Floor, and Ceiling Details	12
3	Battalion Headquarters and Classroom Building Floor Plan	13
4	Battalion Headquarters and Classroom Wall, Floor, and Ceiling Details	14
5	Dental Clinic Internal Electric Load Profile (Weekdays Only)	20
6	Dental Clinic Occupancy Profile (Weekdays Only)	20
7	Dental Clinic Chiller Package Part-Load Power Consumption	20
8	Dental Clinic Hourly Total Electrical Consumption	24
9	Dental Clinic Chiller Electrical Consumption	24
10	Battalion Headquarters and Classroom Building Internal Load Profile	29
11	Battalion Headquarters and Classroom Building Occupancy Profile	29

FIGURES (Cont'd)

<u>Number</u>		<u>Page</u>
12	Battalion Headquarters Measured Hot Water Mass Flow Rate	32
13	Battalion Headquarters Measured Hot Water Supply Temperatures	32

COMPARISON OF BUILDING LOADS ANALYSIS AND
SYSTEM THERMODYNAMICS (BLAST) COMPUTER PROGRAM
SIMULATIONS AND MEASURED ENERGY USE FOR ARMY BUILDINGS

1 INTRODUCTION

Background

The Building Loads Analysis and System Thermodynamics (BLAST) computer program predicts hourly space heating and cooling requirements, simulates hourly fan system performance, and simulates hourly performance of conventional heating and cooling, solar energy, or total energy systems for new and existing buildings.¹ The program has been field tested and was released for general use in December 1977. The BLAST program is considerably more powerful, accurate, and provides more information to the designer than hand calculation methods. Consequently, it is now widely used by the Army, Department of Defense, other Federal agencies, and private architect/engineers in the United States, Europe, and Canada to determine both expected energy use in new and existing buildings, and to help optimize building and energy system design.

Although extensive BLAST field tests have proved the program to be accurate and usable, a study comparing BLAST simulation results to measured field data was considered desirable. Such a study could identify weaknesses in the BLAST program and help define important building parameter inputs. Therefore, the U.S. Army Construction Engineering Research Laboratory (CERL) was asked to analyze and compare actual measured data against BLAST-predicted energy consumption for two Army buildings in an attempt to verify the prediction capabilities of the BLAST program.

Objective

The objective of this report is to compare the results of BLAST simulations with measured building energy consumption data.

Approach

The following approach was used to perform this comparative study:

1. Two Army buildings were selected from among some 100 Army buildings participating in an energy monitoring project designed to measure actual, onsite energy-use and climate data.

¹ D. C. Hittle, The Building Loads Analysis and System Thermodynamics (BLAST) Program, Version 2.0, Users Manual, Vols I and II, Technical Report (TR) E-153/ADA072272 and ADA0722730; and E. Sowell, The Building Loads Analysis and System Thermodynamics (BLAST) Program Input Booklet, TR E-154/ADA072435 (U.S. Army Construction Engineering Research Laboratory [CERL], June 1979).

2. Detailed data concerning the buildings' design and operation, including construction drawings, heating, ventilating, and air-conditioning (HVAC) system information, occupancy use profiles, lighting and equipment usage, etc., were obtained by onsite visits, surveys, and measurement.

3. A BLAST input deck was created for each building.

4. Hourly weather data and concurrent detailed building energy-use data were obtained from onsite instruments for a short time period (about 1 month).

5. BLAST simulations were performed using onsite weather data and comparisons were made between predicted energy use and actual energy use for the selected buildings.

6. Results were analyzed to determine the extent of agreement between the BLAST simulation and measured energy use and to determine the cause of any disagreements.

7. Building boundary energy-use data for the two buildings and weather data for the National Weather Service observation site closest to each building were obtained for a time period of several months.

8. BLAST simulations were performed for the longer time period. Comparisons were made between the predicted and actual energy use for each building.

Scope

The results of Steps 1 through 6 in the approach section above are described in CERL Interim Report E-161.² This report summarizes those results and describes the work performed in Steps 7 and 8.

Mode of Technology Transfer

The results of this work will be referenced in a future version of the Energy Conservative Design Guide.

² D. Herron, L. Windingland, and D. Hittle, Comparison of Building Loads Analysis and System Thermodynamics (BLAST) Computer Program Simulations and Measured Energy Use for Army Buildings, Interim Report (IR) E-161/ADA085573 (CERL, May 1980).

2 DISCUSSION

Energy Conservative Design Rationale

Energy efficiency is one of the major considerations in the design of new facilities. Prescriptive standards for new facility designs such as those given in the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Standard 90-75 and the Department of Defense Criteria Manual 4270.1-M specify the types of materials, minimum insulation levels, amount and types of glass, type of HVAC systems, system operation and control schedules, etc. which may help ensure that a facility will be energy conservative in a certain climate. While these standards ensure a relatively energy efficient design, they severely restrict the design options available to architects and engineers.³

To circumvent this problem, the Department of the Army uses the design energy budget procedure, which assigns a maximum yearly design energy consumption rate, on a square foot basis, to each facility type (e.g., office, store) according to climatic zones.⁴ The actual facility design must be shown to consume no more than the amount of energy specified in the design energy budget for that facility type and climatic region. This allows for much flexibility in the design, provided the target design energy budget can be met.

Design Energy Budgets

Design energy budgets are determined for various facility types from computer simulations using energy analysis programs such as BLAST and by analyzing actual energy-use data. Design energy budgets are determined by fixing the construction details of the buildings at the levels specified by the prescriptive standards as discussed above, and by fixing the building operating parameters (occupancy, thermostat settings, etc.) at typical levels. Compliance of an actual design is shown by computer simulation of the facility using the actual construction details and assuming the same set of typical building operating parameters.

While the design energy budget procedure ensures that the design of a facility is energy efficient, it cannot predict the actual energy consumption of a facility after it is built and in operation. This is because a facility's actual energy consumption is determined by many factors beyond the control of the designer. For example, the quality of the construction, the effects building occupants have on lighting levels, infiltration, thermostat settings, and the actual performance of the HVAC system and its controls can significantly impact energy consumption. Thus, the energy budget computed for a facility is only an indication of what a facility's energy consumption would be if it were constructed as designed, and operated according to the energy conservative operating rules used in the budget procedure. Generally, the

³ Energy Conservation in New Building Design, ASHRAE Standard 90-75 (American Society of Heating, Refrigeration, and Air Conditioning Engineers [ASHRAE], 1975); and DOD Construction Criteria Manual 4270.1-M (Department of Defense [DOD], Office of the Assistant Secretary of Defense, 1 October 1972).

⁴ Interim Energy Budgets for New Facilities, Engineer Technical Letter (ETL) 1110-3-309 (Department of the Army, 30 August 1979).

energy budget procedure indicates the best energy performance that the facility could have; it is the target energy performance that building operators should try to achieve.

Energy Analysis Computer Programs

Energy analysis computer programs, such as BLAST, were developed to help designers create energy efficient buildings. These programs let designers evaluate design options for new and retrofit facilities by giving designers a way to rank design alternatives according to their relative energy savings. For these kinds of analyses, energy consumption factors beyond the designer's control, such as construction quality and occupant behavior, are not critical, since they do not affect how alternatives are ranked. Therefore, the energy efficient building operating rules used in these analyses can provide energy-use data that are useful for budget comparisons.

Such energy performance analyses indicate the optimum energy performance a facility could have for the climate used in the simulation. The facility's actual energy performance will agree with this prediction only if the actual weather conditions match those used in the simulation, and if the building is operated in the manner assumed in the simulation.

If, for validation purposes, the predictions from an energy analysis program such as BLAST are to be compared to the long-term, actual energy consumption data of a facility, precise data about the building's actual operation and energy use must be obtained by intensive monitoring and energy-use surveys. To do this, accurate data describing the building's occupancy level, lights and equipment use, thermostat settings, and mechanical system operation, as well as actual weather data for the desired period, must be available. Actual energy-use data on each of the facility's major components must also be collected, so energy-use comparisons can be made at the individual component level. Enough information about a building must be collected to ensure that when predicted and actual data are compared, the cause of any disagreement can be identified as an error in either the BLAST input deck for the building or the BLAST simulation algorithms.

Building Selection

From 1976 to 1978, the Fixed Facilities Energy Consumption Investigation (FFECI), an Army-sponsored energy monitoring project, measured hourly building boundary energy consumption data for more than 100 Army buildings at different installations throughout the continental United States. Hourly climatic data, including ambient temperature, dew point temperature, wind speed, wind direction, barometric pressure, and solar radiation were also collected using appropriate sensors, electronic interface devices, and recorder systems.⁵

⁵ L. M. Windingland and B. J. Sliwinski, Fixed Facilities Energy Consumption Investigation -- Initial Energy Data, IR E-120/ADA051074 (CERL, January 1978); L. Windingland, B. Sliwinski, and A. Mech, Fixed Facilities Energy Consumption Investigation Data Users Manual, IR E-127/ADA052708 (CERL, February 1978); and B. Sliwinski, D. Leverenz, and L. Windingland, Fixed Facilities Energy Consumption Investigation -- Data Analysis, IR E-143/ADA066513 (CERL, February 1979).

However, only a few of these 100 buildings were monitored closely enough to allow their individual energy use, including heating and cooling requirements, to be identified. It was from among the buildings with measurable individual data that CERL selected two representative Army buildings for the BLAST prediction/comparison study.

The first building selected was a single-story, 18-chair dental clinic with laboratory at Fort Hood, TX. Figures 1 and 2 show the floor plan and typical wall, roof, and floor sections of the dental clinic, respectively. The clinic was built in 1968 and has a gross area of 9384 sq ft (872 m²). It is constructed of block and brick and uses a steel truss roof system and built-up roof. It has an exterior wall area of 4050 sq ft (376 m²), of which about 340 sq ft (32 m²) are windows or glass doors. The clinic is served by a multizone air-handling system with 10 zones. A reciprocating chiller and air-cooled condenser package (60-ton capacity) supply the chilled water to the multizone system, and a gas-fired hot water boiler is used for heating. The clinic's hourly total electrical consumption, which includes the electrical consumption of the building's lights, dental equipment, HVAC equipment, chiller package, and the hourly total natural gas usage is being metered under the FFECI project.

The second building chosen was a battalion headquarters and classroom building built in 1974 at Fort Carson, CO. This one-story structure has a ground floor area of 18,907 sq ft (1757 m²) and a basement area of 3330 sq ft (310 m²). The building is 259 ft (79 m) long, 73 ft (24 m) wide, and has an exterior wall area of 8235 sq ft (765 m²), of which 933 sq ft (87 m²) are windows and glass doors. Figure 3 shows the building's floor plan. Figure 4 shows typical wall, roof, and floor sections. The building core is served by a seven-zone multizone air-handling system which receives its hot and chilled water from a remote central boiler/chiller plant. The wings at each end and the basement are served by single zone heating systems which also receive their hot water from the remote central plant. FFECI data being measured for this building include hourly total hot and chilled water energy supplied from the central plant and the hourly total electrical consumption, including building lights, office equipment, and HVAC equipment.

Construction Drawings

The as-built construction drawings for each of the buildings selected for analysis were obtained from each installation's Facilities Engineer and verified in the field. These drawings included floor plans, architectural details (including wall, roof, and floor construction details), electrical plans, mechanical plans, equipment lists and schedules, and HVAC control diagrams.

Building and HVAC System Data

A field survey and onsite measurements of system parameters were necessary to prepare accurate input for the BLAST program. A contractor, Yandell and Hiller, Inc., Fort Worth, TX, collected these additional field data for CERL; the contractor's data collection activities were divided into three tasks:

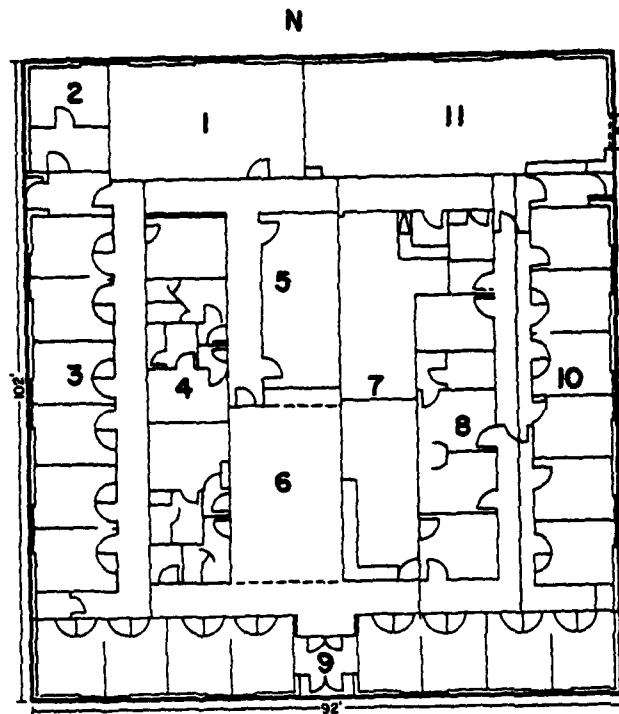


Figure 1. Dental clinic floor plan.

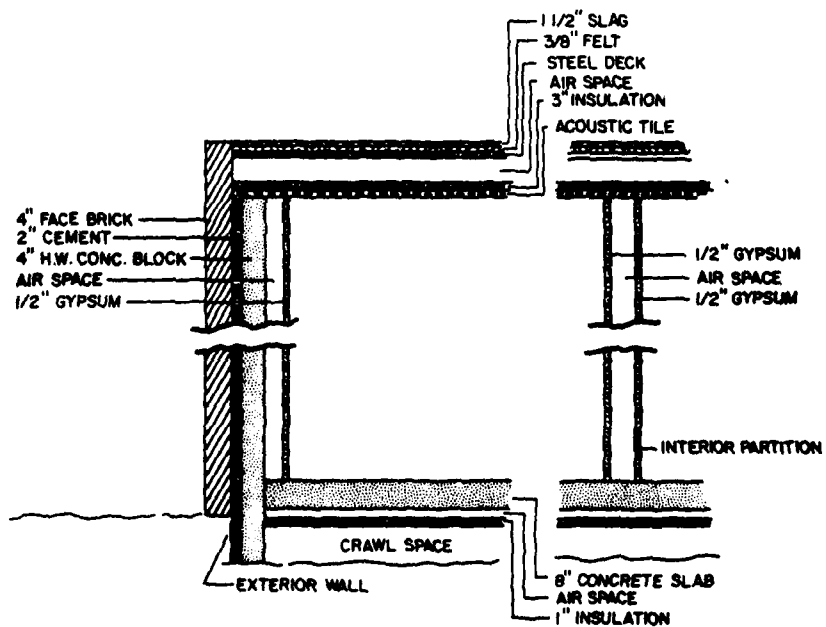


Figure 2. Dental clinic wall, floor, and ceiling details.

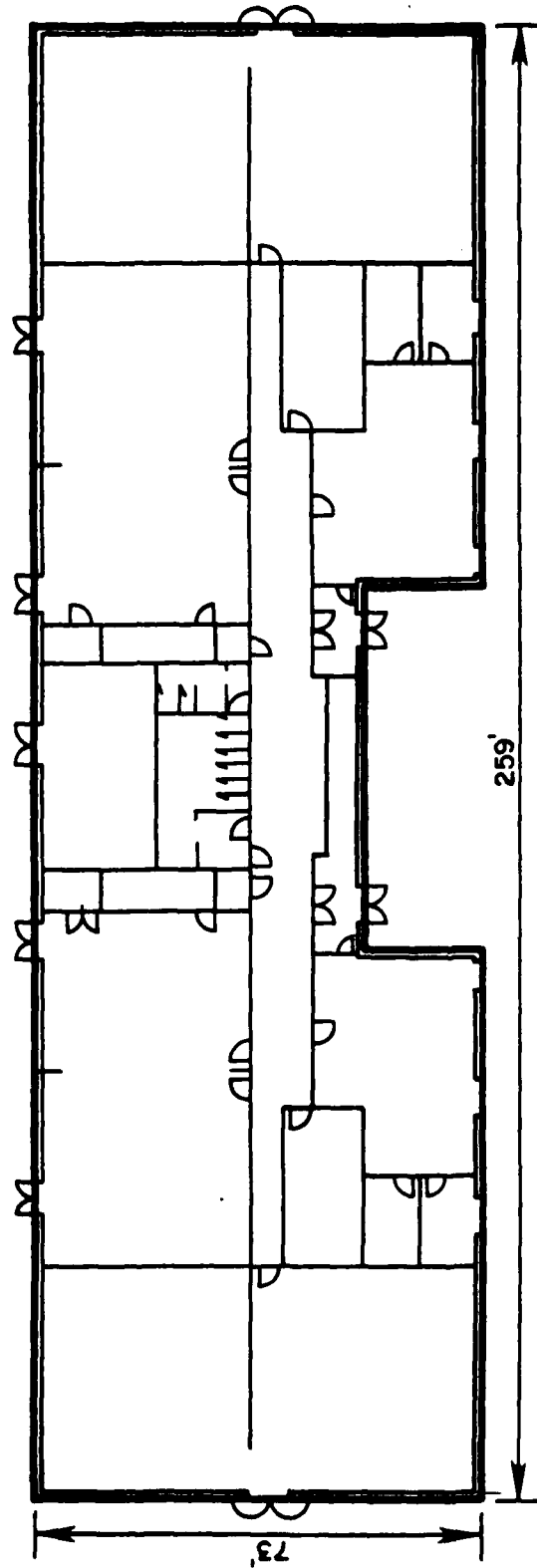


Figure 3. Battalion headquarters and classroom building floor plan.

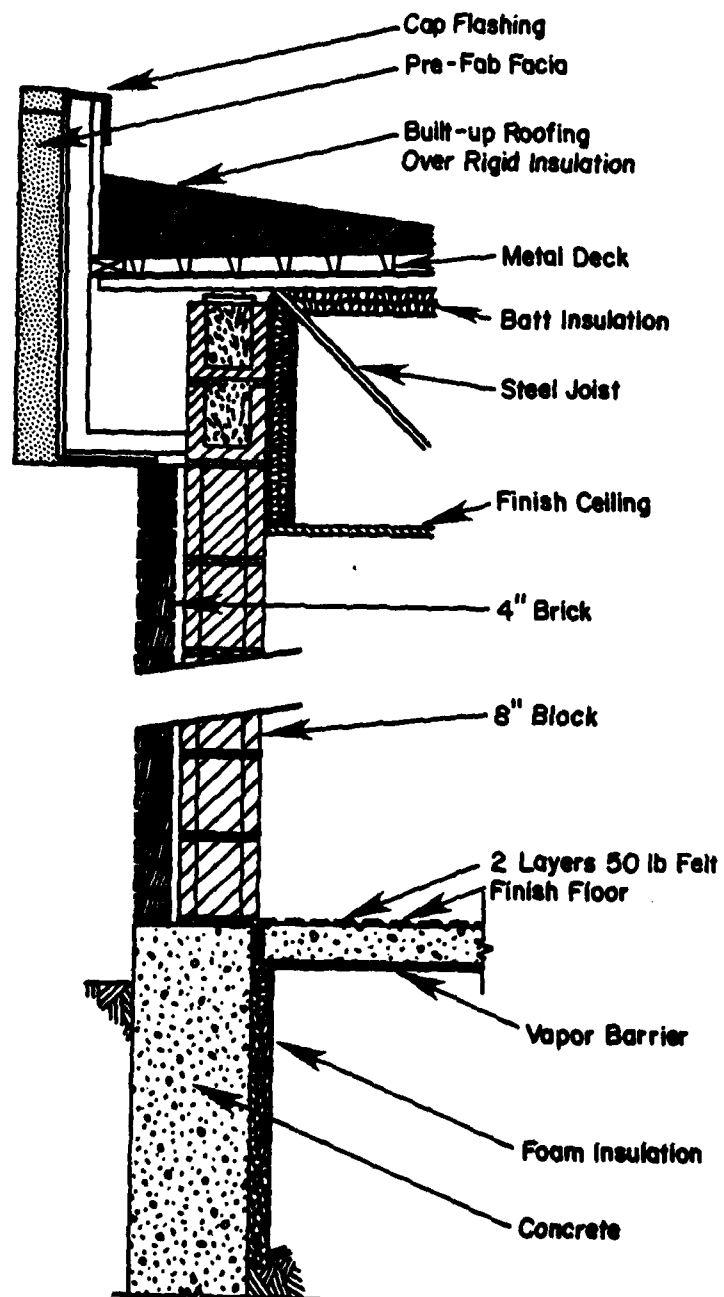


Figure 4. Battalion headquarters and classroom wall, floor, and ceiling details.

1. Task 1 -- Familiarization With Buildings. The contractor reviewed building drawings and made onsite visits to verify as-built drawings against the actual building. Particular emphasis was placed on building modifications; installed equipment capacities; verification of actual wall, roof, floor, and ceiling construction materials; equipment control strategies; and operating procedures.

2. Task 2 -- Building Survey. The contractor prepared and distributed an occupancy questionnaire which was analyzed to determine the building's occupancy profile (i.e., the number of occupants in the building, when they went to lunch, and when they left for the day). The contractor also observed the operation of the building, recording for short periods the number of times doors were opened, exhaust fan operation, and other parameters so an estimate could be made of the building's air infiltration. In addition, the contractor determined the capacities of installed mechanical equipment and obtained manufacturer's specifications or data sheets for each piece of equipment in the building, including air-handling unit fans, heating and cooling coils, boilers and chillers, unit heaters, water heaters, exhaust fans, and HVAC system controls.

3. Task 3 -- Data Monitoring. The contractor measured outside air quantities, return air quantities, total supply air flow, the supply air flow to each zone in the building, and air temperatures of both the hot and cold decks. In addition, each building's fan operating periods and full-load consumption were determined. Temporary electrical measuring devices were installed so the energy use of the heating and cooling systems' components could be separated from the remaining electrical energy used within the building. The contractor also installed temporary recording devices to monitor the detailed energy performance of one zone in each building. Building HVAC system controls were checked to determine the actual sequence of operation and, where possible, controller set point and throttling ranges. Table 1 lists the items surveyed, method of monitoring, and frequency and duration of monitoring.

The data listed in Table 1 were continuously recorded for the dental clinic at Fort Hood between 24 June and 26 July 1978. Data for the battalion headquarters and classroom building at Fort Carson were recorded between 4 August and 6 September 1978.

Computer Simulation for the Short Time Period

BLAST input decks were prepared to simulate both the dental clinic and the battalion headquarters and classroom building using data from field surveys, contractor measurements, and as-built drawings. Using actual onsite weather data, each building was simulated for the 1-month period when detailed energy use information was available. To ensure the independent integrity of the BLAST simulation, the FFECI energy-use data were not inspected before or during BLAST input preparation.

Table 1
BLAST Validation Data

<u>Item Surveyed or Monitored</u>	<u>Collection Method</u>	<u>Number and Frequency of Sample</u>	<u>Duration Sample</u>	<u>Measuring Accuracy</u>
Number of occupants	Questionnaire and survey	8 observations for both weekdays & weekend	2-4 days	+5% _
Door & window openings	Physical survey	48 observations	2-4 days	+10% _
Exhaust fan operation	Physical survey	24 observations	2-4 days	+10% _
Zone				
Indoor temperature	Sensor	Continuous monitoring	2 each 2-week period	+10% (+0.560C) _
Relative humidity	Sensor	Continuous monitoring	2 each 2-week period	+2% _
Lighting & appliances	Sensor	Continuous monitoring	2 each 2-week period	+2% _
Supply air temperature	Sensor	Continuous monitoring	2 each 2-week period	+2% _
Supply volume	Rotating vane anemometer	12 measure- ments	2 different days each period	+2% _
Building				
Mixed air dew- point temperature	Sensor	Continuous monitoring	2 each 2-week period	+10% (+0.560C) _
Total fan supply volume	Pitot rack	Continuous monitoring	2 each 2-week period	+5% _

Table 1 (Cont'd)

<u>Item Surveyed or Monitored</u>	<u>Collection Method</u>	<u>Number and Frequency of Sample</u>	<u>Duration Sample</u>	<u>Measuring Accuracy</u>
Return & outside air volume	Engineering calculations	Continuous monitoring	2 each 2-week period	+5% —
Volume to each zone*	Pitot tube traverse	12 measure- ments	2 different days each period	+5% —
Cold deck air temperature	Sensor	Continuous monitoring	2 each 2-week period	+10F (+0.560C) —
Hot deck air temperature	Sensor	Continuous monitoring	2 each 2-week period	+10F (+0.560C) —
Cold deck water temperature	Sensor	Continuous monitoring	2 each 2-week period	+0.50F (+0.280C) —
Hot deck water temperature	Sensor	Continuous monitoring	2 each 2-week period	+0.50F (+0.280C) —
Fan power	Sensor	Continuous monitoring	2 each 2-week period	+2% —
Fan speed	Tachometer	1 observation	N/A	+2% —
Mechanical equipment power	Sensor	Continuous monitoring	2 each 2-week period	+2% —
Boiler "on-time"	Sensor	Continuous monitoring	2 each 2-week period	+2% —
Water heater "on-time"	Sensor	Continuous monitoring	2 each 2-week period	+2% —

*Volume is the volumetric airflow rate in cubic feet per minute.

Comparison of Actual and Simulated Results for the Short Time Period

After the BLAST simulations were completed, the actual energy-use data were inspected for the 1-month period for which the simulations were performed. Simulated and measured total consumption data were then compared for the total period and on an hourly basis to determine the agreement between BLAST-predicted and measured energy-use data. The hourly energy data for each building component were examined to ensure that cancelling errors did not result in unusually close agreement in total energy use for the simulation period. A statistical analysis was performed on the variances between the BLAST simulation and the actual energy use.

Computer Simulation for the Long Time Period

The BLAST simulations were repeated for each building for a period of several months using weather data obtained from the National Weather Service for the location closest to each building. For these periods, actual energy data included only the hourly building boundary energy consumption information available from the Army's energy monitoring project.

Comparison of Actual and Simulated Results for the Long Time Period

After the BLAST simulations were complete, data comparisons were made between the simulated and measured data.

3 ANALYSES AND FINDINGS -- DENTAL CLINIC

BLAST Input Deck

The dental clinic was divided into 10 simulation zones. Each simulation zone corresponded to a zone served by the clinic's multizone air-handling unit (Figure 1). Zone geometries and construction details of the walls, roof, and floor were determined from the construction drawings. The crawlspace was also simulated to accurately model heat transfer through the floor.

The internal electrical peak load and daily internal electrical load profile (which included building lights and dental equipment) was determined by analyzing contractor-supplied measured data (Figure 5). Peak electrical demand for each zone was estimated from a disaggregation of the peak internal building electrical demand, based on the distribution of lights and equipment within the building as determined by a building survey. The building's occupancy profile (Figure 6), zone peak occupancy (based on building-use patterns), and zone thermostat settings and control profiles were determined from contractor-supplied data.

Specific information about the HVAC system was obtained from control diagrams, control specifications, and measured or observed data. Design cooling coil parameters were obtained from the construction drawings. Design data for the water chiller package were obtained from manufacturers' catalogs for the specific unit installed in the building; the chiller part-load curve was determined from measured data (Figure 7). The peak electrical demands of the chiller, condenser, and HVAC fans were determined by contractor-supplied measured data. HVAC system air volume flow rates were also supplied by the contractor.

The BLAST input deck for the dental clinic is in Appendix A. Table 2 summarizes the fan system input parameters.

Computer Simulation -- Short Time Period

Actual weather data from Fort Hood, TX were available from the Army's energy monitoring project for the period 1 June through 6 July, 1978. Actual weather data were not available for the period 6 to 26 July 1978 because of an instrumentation malfunction.

A BLAST simulation was performed for the dental clinic for the period 1 June through 6 July. The simulation predicted the hourly total, internal building, fan, and chiller electrical consumption. Because the clinic's hot water supply pump was disabled during the simulation period, BLAST simulated the hot water boiler as being turned off; thus, no gas consumption was predicted.

Comparison of Data -- Short Time Period

For the period 1 June to 6 July 1978, hourly data on the building's total electrical consumption were available from the Army's energy monitoring

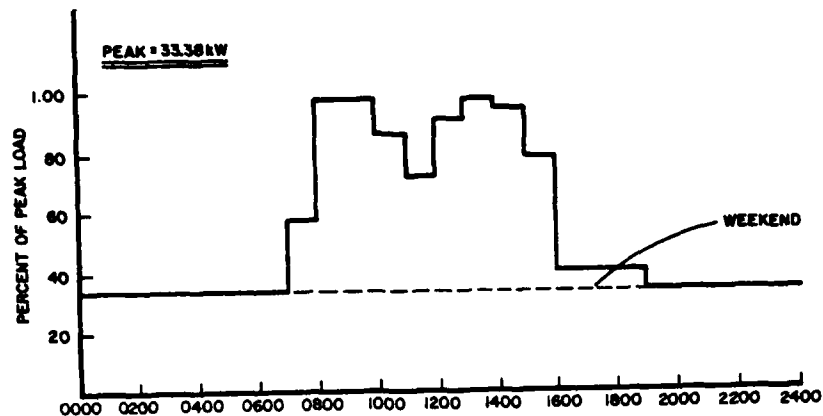


Figure 5. Dental clinic internal electric load profile (weekdays only).

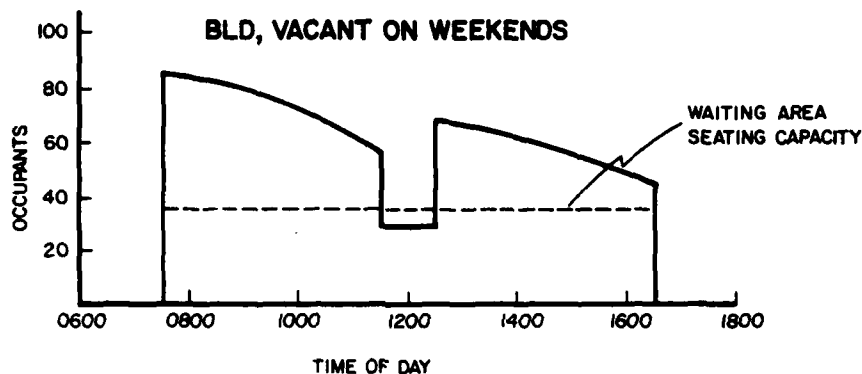


Figure 6. Dental clinic occupancy profile (weekdays only).

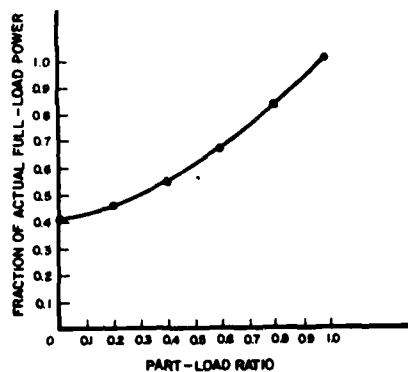


Figure 7. Dental clinic chiller package part-load power consumption.

Table 2

Fan System Parameters -- Dental Clinic

Type system = multizone
System operation = continuous

Seasonal Component Schedules

Heating coil on: 1 January; off: 31 December
Cooling coil on: 1 January; off: 31 December

Mixed air control = fixed amount
Fixed outside air volume = 1.942 m³/s

Hot deck control = outside air control
Hot deck throttling range = 4.00°C
Hot deck control schedule = (48.89 at -12.11, 26.67 at 21.11)°C

Heating coil capacity = 1000 kW
Heating coil energy supply = hot water

Cold deck control = fixed set point
Cold deck throttling range = 2.77°C
Cold deck fixed temperature = 15.55°C

<u>Zone Number</u>	<u>Zone Supply Air Volume (m³/s)</u>	<u>Zone Exhaust Air Volume (m³/s)</u>
1	0.842	0.4719
2	0.1916	0.0
3	0.9486	0.0
4	0.3592	0.2832
5	0.2369	0.0
6	0.3931	0.0
7	0.4172	0.0
8	0.3912	0.0
9	1.060	0.0
10	0.9934	0.0

Total design supply air volume = 5.883 m³/s

project; hourly (Table 3 and Figure 8) and total (Table 3) consumption comparisons between measured and predicted total electrical consumption were made. For the period 25 June to 1 July 1978, hourly electrical data for the building's internal and chiller electrical consumption were also available; hourly (Table 3 and Figure 9) and total (Table 3) comparisons were made between these measured and predicted data.

The comparison results in Table 3 show that BLAST-predicted total building electrical consumption is 12.1 percent higher than the measured total building electrical consumption. The correlation coefficient for the measured vs predicted data is 0.87. Figure 8 shows a plot of predicted and measured total electrical consumption for the week of 25 June to 1 July 1978.

To determine why measured and predicted total electrical consumption data disagreed, individual electrical load components were analyzed. Results for internal building and chiller package electrical consumption are shown in Table 3. A plot of predicted vs actual chiller electrical consumption data for the week of 25 June to 1 July 1978 is shown in Figure 9.

The results of the detailed analyses of the internal building electrical consumption prediction indicate that the profile predicts a consumption within 10 percent of the measured data and has a correlation coefficient of 0.90. The results also indicate that the internal building electrical consumption profile consistently overpredicts the electrical consumption.

The results of the detailed analyses of the chiller package electrical consumption prediction indicate agreement within 10 percent of the measured data; the correlation coefficient is 0.79. The chiller input predicts the low part-load operation almost exactly, but consistently overpredicts during the high part-load operating conditions of the chiller package (Figure 9).

Computer Simulation-- Long Time Period

While the short-term simulation was indicative of the accuracy of the dental clinic simulation model, comparison for a longer time period, including both the heating and cooling season, was desirable. Because the typical BLAST user does not have access to actual onsite weather for his or her simulation, it was decided to use weather data from the closest National Weather Service recording station -- Waco, TX. Continuous energy data were available from the Army's energy monitoring project for the period 15 March to 31 July 1980. Weather data were obtained for Waco, TX for that period, and using the dental clinic input deck (as described above) a BLAST simulation was performed. The simulation predicted the hourly total electrical consumption. It included the electrical consumption from building lights, dental equipment, HVAC equipment, the packaged chiller, and the hourly total gas consumption.

Table 3

Dental Clinic Comparison -- Short Time Period
Electrical Data Comparison

<u>Total Building Electrical</u>	<u>Measured (kWh)</u>	<u>Predicted (kWh)</u>	<u>% Difference</u>
1 June 0000 to 6 July 0900	44,687	50,091	-12.1
<u>Internal Building Electrical</u>			
25 June 0000 to 1800 and 26 June 0700 to 1 July 0900	2345	2581	-10.1
<u>Chiller Electrical</u>			
25 June 0000 to 1800 and 26 June 0200 to 1 July 0900	4597	5308	-9.6

<u>Statistics (hourly)*</u>	<u>Total Bldg</u>	<u>Internal Bldg</u>	<u>Chiller</u>
R**	0.87	0.90	0.79
DIFFAV (kW)	-5.87	-1.12	-1.25
DIFFVAR	55.90	39.20	6.26
DIFFSTD	7.43	4.36	6.26
PERAVE	-15.76	-46.03	-2.79
PERVAR	620.75	17,135.00	327.14
PERSTD	24.91	130.90	18.09
DABSAVE (kW)	7.30	3.44	4.97
DABSVAR	36.29	8.37	15.91
DABSSTD	6.02	2.89	3.99

* See Appendix C for definition of statistics

**Correlation coefficient

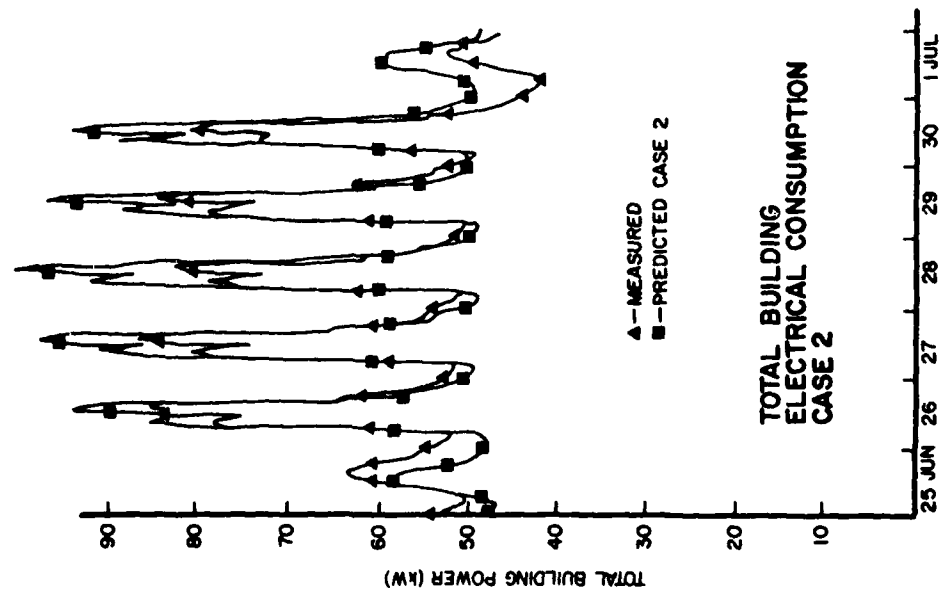


Figure 8. Dental clinic hourly total electrical consumption.

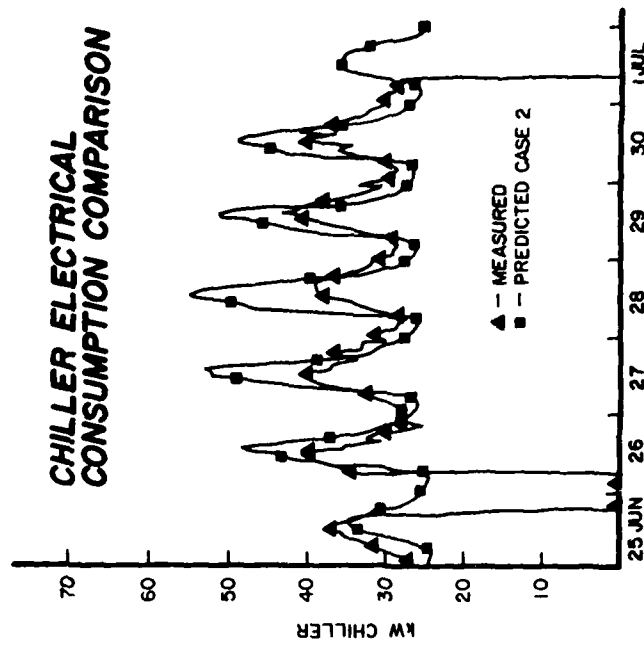


Figure 9. Dental clinic chiller electrical consumption.

Comparison of Data -- Long Time Period

After the simulation was completed, energy data from the Army's energy monitoring project were examined for the same time period. This analysis revealed a skewness of up to several hours in portions of the data. These hourly data were recorded by the energy monitoring project in about 2-week intervals, but the skewness could not be evaluated in each 2-week data period because of the data collection procedure. Thus, comparisons of predicted vs measured data were deemed valid only for intervals of 2 weeks or longer. Hourly or daily comparisons could not be made. Predicted vs measured total electrical consumption data for the period 15 March to 31 July 1980 is in Table 4. Comparison results show that BLAST-predicted total building electrical consumption for the entire simulation period: the predicted electrical consumption is consistently too high throughout the simulation period. These results agree with the results of the short-term simulation of the dental clinic.

Predicted vs measured total gas consumption for the period 15 March to 31 July 1980 is in Table 5. BLAST-predicted total building gas consumption is 11.7 percent lower than measured total building gas consumption for the entire simulation period. As the results for the comparisons by 2-week intervals show, the predicted gas consumption is too low during the spring months and too high during the summer months. This indicates that the part-load operation of the boiler is not as simulated by BLAST. The default part-load curve, which was used to model the clinic's boiler, appears to underpredict the boiler's gas consumption at high part-load operation, and overpredict the boiler's gas consumption at low part-load operation.

Table 4

Dental Clinic Simulation -- Long Time Period Electrical Data Comparison

<u>Total Building Electrical</u>	<u>Measured (kWh)</u>	<u>Predicted (kWh)</u>	<u>% Difference</u>
15 March to 31 July	175,738	194,390	10.61
15 March to 31 March	10,661	20,620	-93.42
01 April to 15 April	15,944	18,270	-14.59
16 April to 30 April	17,818	18,580	-4.28
01 May to 15 May	22,000	19,389	+11.87
15 May to 31 May	21,170	21,871	-3.31
01 June to 15 June	20,911	21,429	-2.48
16 June to 30 June	20,638	24,520	-18.81
01 July to 15 July	22,094	24,316	-10.06
16 July to 31 July	24,502	25,393	-3.64

Table 5
Dental Clinic Simulation -- Long Time Period
Gas Data Comparison

<u>Total Building Gas</u>	<u>Measured (kWh)</u>	<u>Predicted (kWh)</u>	<u>% Difference</u>
15 March to 31 July	82,515	72,851	+11.71%
15 March to 31 March	11,501	14,650	-27.38%
01 April to 15 April	18,593	12,085	+35.00%
16 April to 30 April	13,420	11,322	+15.63%
01 May to 15 May	13,450	10,067	+25.15%
16 May to 31 May	11,316	7,823	+30.87%
01 June to 15 June	5,129	5,451	-6.28%
16 June to 30 June	3,071	3,760	-22.44%
01 July to 15 July	2,658	3,467	-30.44%
16 July to 31 July	3,376	3,956	-17.18%

Summary

BLAST predicted the energy performance of the dental clinic to within 10 to 12 percent. Because the energy consumption of the dental clinic is dominated by the energy consumption of the HVAC equipment, these results indicate that BLAST is accurately modeling the performance of the multizone fan system and the chiller package. Even in the complicated case where the multizone system is supplied with both heating and cooling, BLAST predicts the total energy consumption to within 12 percent.

The load profile used to predict internal building electrical loads could be revised to improve the accuracy of the BLAST prediction. Analysis of the measured internal electrical consumption data, however, indicates that the baseline internal building electrical consumption for nights and weekends fluctuates irregularly. Thus, it would be very difficult to accurately predict a single profile for the clinic's internal electrical consumption. Because of the size of the facility, even small fluctuations in this demand can cause relatively large errors in predicted vs measured data.

Improvements could be made in the input used to describe the dental clinic's chiller package performance. The default full-load power ratio adjustment curve as input to the BLAST program could be revised to more accurately reflect actual chiller operation; also, the part-load ratio curve could

be modified at the higher load conditions to more accurately reflect actual consumption. (It would be difficult to accurately determine these parameters, since the system did not operate at full load during the simulation/monitoring period.)

The actual part-load ratio curve for the boiler could be included in the input to more accurately reflect the boiler's operation. Determination of this curve would require detailed measurements of the boiler operation. (These measurements could not be made during the detailed monitoring period, since the hot water supply pump was out of service.)

Other revisions could be made to the simulation input deck to achieve more accurate predictions; if exact input information is available, BLAST should be able to accurately predict the building's energy consumption.

4 ANALYSES AND FINDINGS -- BATTALION HEADQUARTERS AND CLASSROOM BUILDING

BLAST Input Deck

The first floor of the battalion headquarters and classroom building was divided into nine simulation zones. These simulation zones corresponded to the seven zones served by the building's multizone air handler and the two zones served by the building's unit heaters (Figure 3). The basement floor of the facility was modeled as a single zone served by a single zone draw-through system (as shown in the as-built drawings). Zone geometries and construction details of the walls, roof, floors, and ceiling were determined from the construction drawings. The electrical load profiles for the building and the peak building internal electrical demand were determined by analyzing data supplied by the contractor (Figure 10). Peak electrical demand for each zone was estimated from a disaggregation of the peak internal building electrical demand. Building occupancy was determined from occupant questionnaires. The occupancy profile for the building was estimated by the contractor (Figure 11). Zone peak occupancy (estimated from building use patterns), zone thermostat settings, and control profiles were determined from the contractor-supplied data.

Information about the fan system was obtained from construction drawings, the HVAC control diagrams, control specifications, and contractor-measured data. Because this facility is supplied by a large central boiler/chiller plant which serves many buildings, a mechanical plant was not simulated.

The basement HVAC system operation could not be simulated exactly. In the actual system, the fan runs only when the outside air dry-bulb temperature is below 25.56°C. In the BLAST simulation, the fan runs whenever there is a demand for heating. Thus, the BLAST model probably simulates the system for more hours than the actual system operates.

The BLAST input deck for the battalion headquarters and classroom building is in Appendix B.

Computer Simulation -- Short Time Period

Actual weather data were obtained from the Army's energy monitoring project for the period 1 August to 6 September 1978 and a BLAST simulation of the battalion headquarters and classroom building was performed for this period. The hourly data available from the simulation included total building boundary, and internal building and fan system electrical consumption. BLAST also predicted the building's hourly hot and chilled water consumption.

Comparison of Data -- Short Time Period

The results of the BLAST simulation are in Table 6. The prediction for total building electrical consumption for the entire simulation period is 5.2 percent lower than the measured total building electrical consumption. The correlation coefficient for the week of 6 to 12 August 1978 is 0.93.

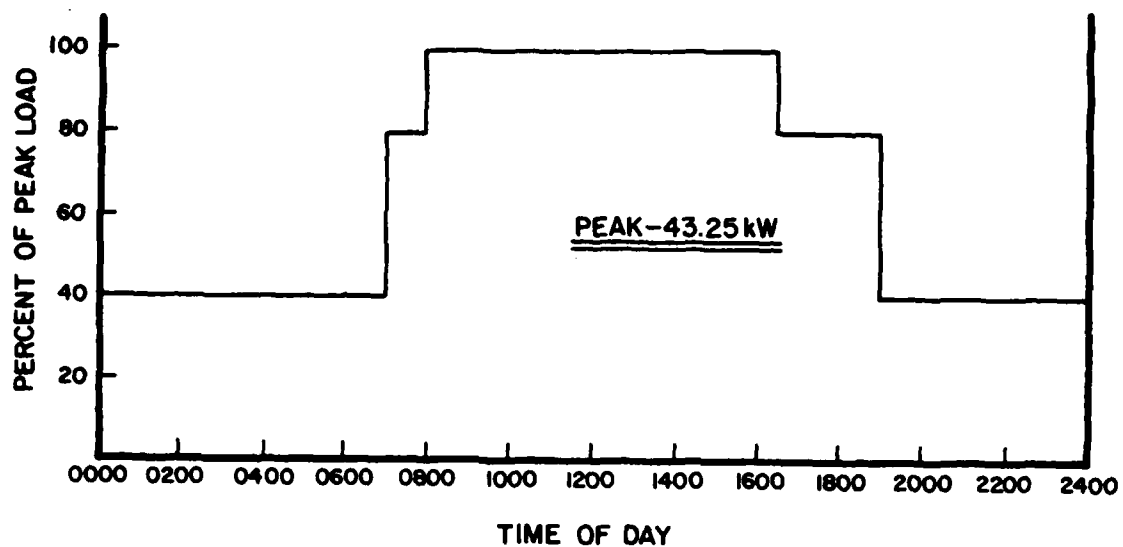


Figure 10. Battalion headquarters and classroom building internal load profile.

WEEKDAYS AND WEEKENDS

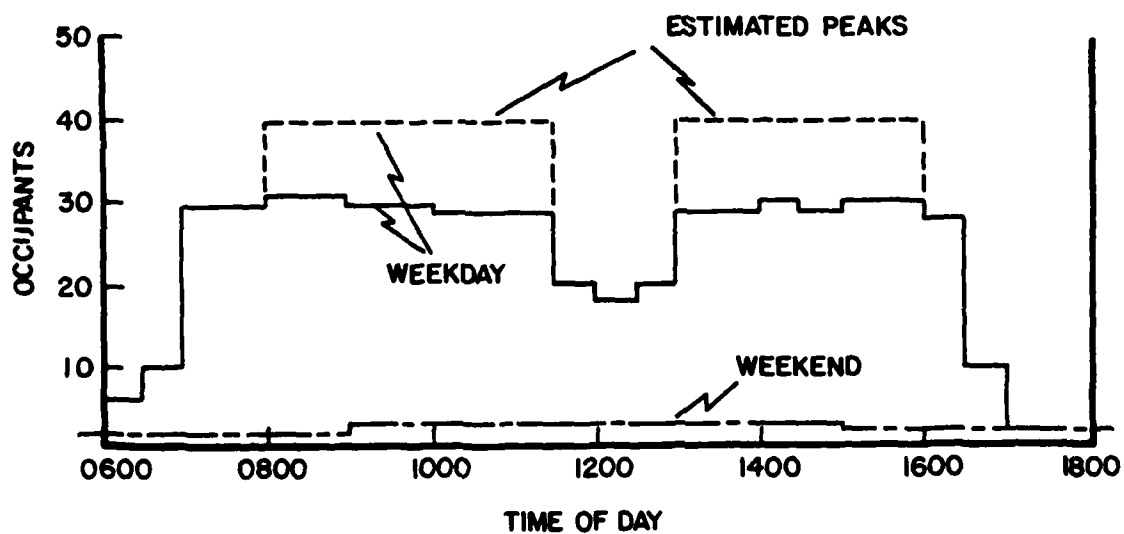


Figure 11. Battalion headquarters and classroom building occupancy profile.

Table 6
Battalion Headquarters Simulation -- Short Time Period
Electrical Data Comparison

<u>Total Building Electrical</u>	<u>Measured (kWh)</u>	<u>Predicted (kWh)</u>	<u>% Difference</u>
1 August to 6 September 1978	20,952.9	19,910	+5.24
<u>Statistics (hourly)* for 6 to 12 August 1978</u>	<u>Total Building Electrical</u>		
R**	0.93		
DIFFFAVE (kWh)	-0.89		
DIFFVAR	5.06		
DIFFSTD	2.25		
PERAVE	-1.16		
PERVAR	78.71		
PERSTD	8.87		
DABSAVE	1.561		
DABSVAR	2.619		
DABSTD	1.618		

* See Appendix C for definition of statistics

**Correlation coefficient

Computer Simulation -- Long Time Period

While the short-term simulation was indicative of the accuracy of the battalion headquarters and classroom building simulation model, comparison for a longer time period, including both the heating and cooling season, was desirable. Because the typical BLAST user does not have access to actual onsite weather data for his/her simulation, it was decided to use weather data from the closest National Weather Service recording station -- Colorado Springs, CO. Energy data were available from the Army's energy monitoring project for the periods 6 December 79 to 8 April 1980 and 23 Apr to 15 June 1980. (No data were available for the period 9 to 22 April 1980 because of an instrumentation failure.) Weather data were obtained for Colorado Springs, CO for the period 6 December 1979 to 15 June 1980, and using the battalion headquarters input deck, a BLAST simulation was performed for this period. The simulation predicted the hourly total electrical consumption, which included the building's internal and fan system electrical consumption, and the hourly hot and chilled water consumption for the building.

Comparison of Data -- Long Time Period

After the simulation was completed and the energy data from the Army's energy monitoring project were examined for the same time period, several problems were identified. The measured data were to have included hourly building boundary electrical, hot water, and chilled water consumption data. (The hot and chilled water consumption was determined by measuring the supply and return temperatures and the mass flow rate of the water.) But because the temperature instrumentation for the chilled water consumption measurement failed, no data were available for chilled water consumption for the entire period. However, as determined by a building survey, the chilled water supply pump for the building was shut off during the entire simulation period; thus, no chilled water was used by the battalion headquarters during the simulation period.

Analysis of the measured hot water data revealed that the building's hot water energy consumption was measured inaccurately. During the heating season, the hot water mass flow rate to the building should be more or less constant. But as Figure 12 shows, the measured hot water mass flow rate varied sporadically during the heating season. Figure 13 shows that the hot water supply temperature varied during the same period. These variations caused the measured hot water energy consumption to be less than the actual consumption. Because the hot water supply temperature is reset according to the outside air dry-bulb temperature, it is difficult to determine the magnitude of the error in the measured data. However, analysis of the data for the 6th, 7th, and 8th of January 1980 shows that the measured data underaccounts for the hot water energy consumption by 20 to 30 percent.

Analysis of the measured electrical consumption data revealed a skewness in the hourly data. Hourly data were collected by the monitoring project in about 2-week intervals; several hours skewness was identified in some of these intervals. The skewness could not be evaluated in other 2-week periods because of the data collection procedure. Because of this skewness, only comparisons of predicted vs measured data for the total 2-week periods were deemed valid. Hourly or daily comparisons could not be made.

Predicted vs measured building boundary electrical consumption is in Table 7. Comparison results show that for the total simulation period, the predicted electrical consumption is 10.4 percent higher than the measured electrical consumption. As the comparison for the 2-week intervals shows, the predicted electrical consumption is consistently too high. Since detailed measurements of electrical consumption data were not available, it was difficult to analyze the potential errors in the simulation. Two possible sources of error were (1) a change in the building's use pattern, which would make the internal electrical profile incorrect, and (2) the incorrect simulation of the basement fan system. Either of these errors could have caused BLAST to over-predict the building's electrical consumption.

Predicted vs measured building boundary hot water consumption is in Table 8. The comparison shows that for the total simulation period, the predicted hot water consumption is 48.7 higher than the measured hot water consumption. Because detailed measurements of hot water consumption for each individual fan system were not available, it was difficult to determine the cause of this error. A large percentage of this error (20 to 30 percent) could be the

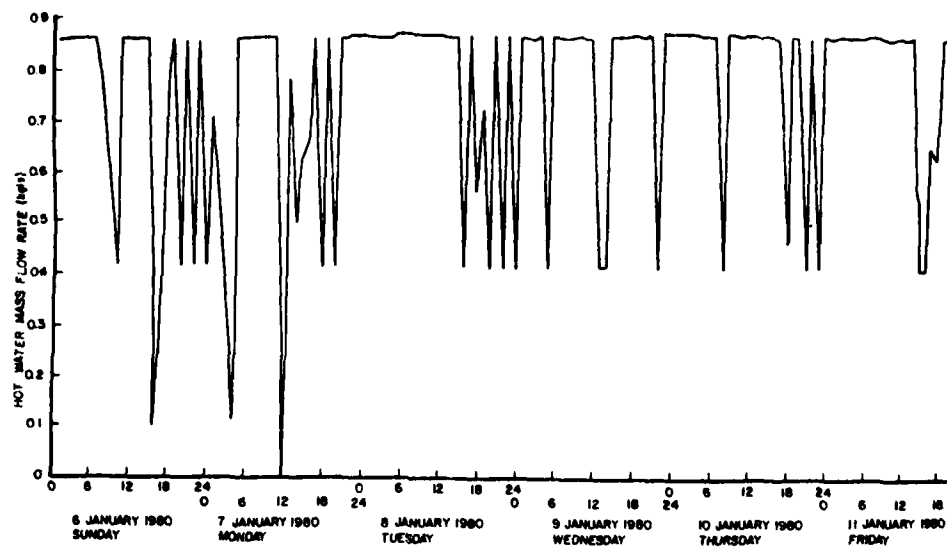


Figure 12. Battalion headquarters measured hot water mass flow rate.

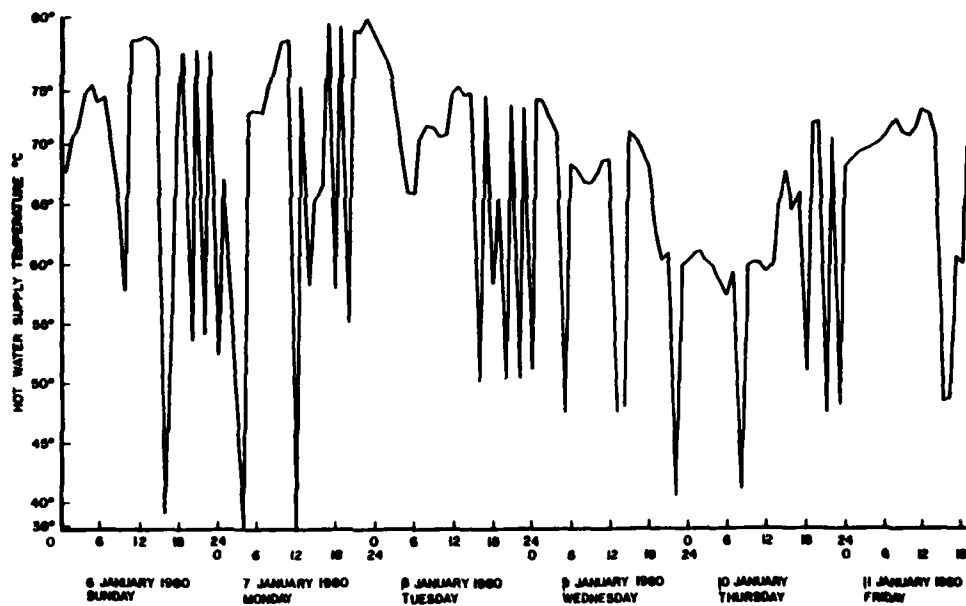


Figure 13. Battalion headquarters measured hot water supply temperatures.

result of inaccurate measured data. As the 2-week data in Table 8 show, agreement is much worse in the May to June period. This is probably caused by the inaccurate simulation of the basement fan system. Thermostat settings in the building that differed from those simulated and a multizone HVAC system that operated differently from the one simulated could have also caused disagreement.

Summary

BLAST predicted the electrical energy consumption of the battalion headquarters and classroom building to within 10 percent, but the BLAST input deck could be revised to make its predictions more reliable. Because the building's electrical consumption is dominated by its internal consumption, a more accurate internal electrical consumption profile could be developed. Since the building is a battalion headquarters, however, it is occupied by a small staff at night and on weekends. Analysis of the measured data has shown that night and weekend electrical consumption is a direct function of the efforts the night and weekend staff make toward energy conservation. Because of the facility's size, this effect has a significant impact on the total electrical consumption and makes the determination of a single internal electrical profile for a long time period very difficult.

Revisions could be made to the fan system input deck to more accurately reflect the fan system's electrical consumption, but it is probably impossible to significantly improve the accuracy of the BLAST fan system electrical prediction without revising BLAST's simulation capabilities to allow for an exact simulation of the basement fan system.

The agreement between BLAST-predicted and measured hot water consumption for this building was very poor (49 percent). Analysis of the measured data reveals that a significant fraction of that error could be the result of inaccurate measurement. Thus, it is impossible to determine exactly what revisions (if any) are needed in the BLAST input deck.

Table 7

Battalion Headquarters and Classroom Building Simulation -- Long Time
Period Electrical Data Comparison

<u>Total Electrical Consumption</u>	<u>Measured (kWh)</u>	<u>Predicted (kWh)</u>	<u>% Difference</u>
6 December 1979 to 8 April 1980 and 23 April to 22 July 1980	104,651	115,485	10.4
16 to 31 December 1979	8,041	10,190	26.7
1 to 15 January 1980	8,797	9,648	9.7
16 to 31 January 1980	9,689	10,483	8.2
1 to 15 February 1980	9,163	9,789	6.8
16 to 29 February 1980	8,379	8,961	7.0
1 to 15 March 1980	8,192	9,648	17.8
16 to 31 March 1980	9,713	10,342	6.5
1 March to 15 May 1980	9,683	10,135	4.7
16 March to 31 May 1980	9,195	9,791	6.5
1 to 15 June 1980	8,443	9,544	13.0

Table 8

Battalion Headquarters and Classroom Building Simulation --
Long Time Period Hot Water Data Comparison

<u>Total Hot Water Consumption</u>	<u>Measured (kWh)</u>	<u>Predicted (kWh)</u>	<u>% Difference</u>
6 December 1979 to 8 April 1980 and 23 April to 22 July 1980	737,997	1,097,859	48.7
16 to 31 December 79	83,517	115,118	37.8
1 to 15 January 1980	71,292	108,411	52.1
16 to 31 January 1980	84,375	138,574	64.2
1 to 15 February 1980	67,522	110,286	63.3
16 to 29 February 1980	66,827	88,233	32.0
1 to 15 March 1980	70,979	96,297	35.7
16 to 31 March 1980	81,059	107,995	33.2
1 to 15 May 1980	43,993	75,900	72.5
16 to 31 May 1980	28,730	62,170	116.4
1 to 15 June 1980	21,586	39,856	84.6

5 GENERAL RESULTS

The analyses described in Chapters 3 and 4 indicate that it is very difficult to compare predicted energy-use data obtained from an energy analysis computer program with measured energy-use data. As discussed in Chapter 2, a building's actual energy use is partially determined by factors which cannot be accurately described to a computer analysis program. For example, the occupant effects on lighting use, window and door openings, and thermostat settings are highly variable over a long time period and cannot be defined for a building without extensive monitoring. The actual operation of the HVAC control system over a long time period is also very difficult to determine.

As the analyses in this report illustrate, obtaining consistent and reliable building boundary energy-use data is also difficult, especially if it is necessary to measure hot and chilled water energy use. Building boundary energy data are sufficient only for determining if the computer program's total energy predictions are correct. To determine the accuracy of each portion of the simulation, detailed measurements of each building component's operation and energy use, including occupant effects, must be made. Outside of a controlled laboratory environment, these measurements are extremely difficult.

Within these constraints, the agreement between the BLAST-predicted and measured energy use for the two buildings analyzed during this study is very good. BLAST predicted the total energy consumption of the dental clinic (including electricity and gas consumption) to within 10 to 12 percent and the electrical energy consumption of the battalion headquarters and classroom building to within 10 percent when accurate simulation models were used. However, this agreement can be improved only if an extensive monitoring effort was undertaken for each building.

6 CONCLUSIONS

1. To compare actual building energy use with energy use predicted by an energy analysis computer program such as BLAST, accurate, concurrent hourly measurements of weather data, energy-use data, occupancy-dependent parameters, and equipment operating parameters must be obtained. These data are typically very difficult to collect outside a laboratory environment.

2. Within the constraints of available, accurate measured data for the typical Army buildings analyzed in this study, the BLAST energy analysis computer program can successfully predict building boundary energy consumption, including both electrical and gas consumption, to within 10 to 12 percent when accurate input is made to the program.

3. BLAST can accurately predict electrical consumption of a chiller package for the typical Army buildings analyzed in this study. The chiller's predicted vs actual curve (Figure 13) confirms the validity of modeling cooling components on an hourly time step. The chiller simulation actually models the average performance of the component over the hour, while the real chiller cycles during a much smaller time step. The predicted and actual curves show BLAST's modeling validity and its sensitivity to changes in the part-load ratios and full-load power of a chiller package.

4. When an energy analysis program such as BLAST is used to evaluate design alternatives, most of the hard-to-define effects of building occupants on building energy use are constant and therefore relatively unimportant. When the program is used to predict the actual energy performance of a building, values for building geometry, materials, schedules, controls, and HVAC systems must be precise and consistent and the effects of occupants on the building's energy use must be carefully described to the program.

APPENDIX A:

DENTAL CLINIC SIMULATION MODEL

Dental Clinic Simulation Model

```

1 BEGIN INPUT;
2 RUN CONTROL: NEW ZONES,
3               NEW AIR SYSTEMS,
4               CENTRAL PLANT,
5   UNITS(OUT=METRIC);
6 TEMPORARY LOCATION: FT HOOD = (LAT=31, LONG=97.8, TZ=6); END;
7 TEMPORARY DESIGN DAYS:
8   FT HOOD WINTER = (HIGH=32, LOW=20, WEEKEND, W8=20, DATE=21JAN),
9   FT HOOD SUMMER = (HIGH=106, LOW=84, W8=85, DATE=21JUL, PRES=405,
10                  CLEARNESS=.95, WEEKDAY); END;
11 TEMPORARY SCHEDULE (ALL ZONES PEOPLE):
12   MONDAY THRU FRIDAY = (17 TO 07 = 0., .5, .94, .92, .79, .52, .56, .75,
13                      .68, .61, .29),
14   SATURDAY THRU SUNDAY = (00 TO 24 = 0),
15   HOLIDAY = SUNDAY;
16 END;
17 TEMPORARY SCHEDULE (CLINIC LIGHTS AND EQUIPMENT):
18   MONDAY THRU FRIDAY = (19 TO 07 = .34, .58, .98, .98, .98, .86,
19                      .72, .91, .98, .95, .79, .40, .40),
20   SATURDAY THRU SUNDAY = (00 TO 24 = .34),
21   HOLIDAY = SUNDAY;
22 END;
23 TEMPORARY CONTROLS (CLINIC CONTROLS):
24   PROFILES:
25     CONSTANT = (1 AT 66, 0 AT 68, -.125 AT 70, -1 AT 140);
26   SCHEDULES:
27     MONDAY THRU SUNDAY = (00 TO 24 = CONSTANT),
28     HOLIDAY = SUNDAY;
29 END;
30 TEMPORARY WALLS:
31   EWALL1 = (BRICK - FACE 4 IN,
32             CONCRETE - CEMENT MORTAR 1/2 IN,
33             CONCRETE - CEMENT MORTAR 1/2 IN,
34             CONCRETE - CEMENT MORTAR 1/2 IN,
35             CONCRETE - CEMENT MORTAR 1/2 IN,
36             C3 - 4 IN HW CONCRETE BLOCK,
37             B1 - AIRSPACE RESISTANCE,
38             BUILDING BOARD - GYPSUM PLASTER 1 / 2 IN),
39   PWALL1 = (BUILDING BOARD - GYPSUM PLASTER 1 / 2 IN,
40             B1 - AIRSPACE RESISTANCE,
41             BUILDING BOARD - GYPSUM PLASTER 1 / 2 IN),
42   PWALL2 = (C8 - 8 IN HW CONCRETE BLOCK,
43             B1 - AIRSPACE RESISTANCE,
44             BUILDING BOARD - GYPSUM PLASTER 1 / 2 IN),
45   CPWALL = (A1 - 1 IN STUCCO,
46             C10 - 8 IN HW CONCRETE,
47             E1 - 3 / 4 IN PLASTER OR GYP BOARD);
48 END;
49 TEMPORARY ROOFS:
50   ROOF1 = (E2 - 1 / 2 IN SLAG OR STONE,
51            E3 - 3/8 IN FELT AND MEMBRANE,
52            A3 - STEEL SIDING,
53            E4 - CEILING AIRSPACE,
54            B4 - 3 IN INSULATION,
55            E5 - ACOUSTIC TILE),
56   CPCEIL = (FINISH FLOORING - TILE 1/16 IN,
57             C10 - 8 IN HW CONCRETE,
58             B1 - AIRSPACE RESISTANCE,
59             B2 - 1 IN INSULATION);
60 END;

```

Note: The line numbers are NOT a part of the BLAST input requirements. They have been added for convenience.

```

61 TEMPORARY FLOORS:
62     FLOOR1 = (R2 - 1 IN INSULATION,
63              R1 - AIRSPACE RESISTANCE,
64              C10 - 8 IN HW CONCRETE,
65              FINISH FLOORING - TILE 1/16 IN),
66     CPFLOOR = (DIRT 12 IN);
67 END;
68 TEMPORARY DOORS:
69     WINDOW PANEL = (GLASS - HEAT ABSORBING PLATE 1/2 IN,
70                    INSULATION - CELLULAP GLASS 2 IN,
71                    C3 - 4 IN HW CONCRETE BLOCK,
72                    BUILDING BOARD - GYPSUM PLASTER 1/2 IN);
73 END;
74 PROJECT = "FT HOOD DENTAL CLINIC";
75 LOCATION= FT HOOD;
76 WEATHER TAPE FROM 01 JUN 78 THRU 06 JUL 78;
77 GROUND TEMPERATURES = (62,61,62,65,68,71,75,75,71,68,65,62);
78 BEGIN BUILDING DESCRIPTION;
79     NORTH AXIS = 0;
80     DIMENSIONS: HEIGHT1 = 9;
81     CRAWL SPACE 1000 "CRAWL SPACE";
82     ORIGIN:(0,0,-2.5);
83     NORTH AXIS = 0;
84     CRAWL SPACE CEILING:
85         STARTING AT (0,0,2.5) FACING (180) CPCEIL (92 BY 102);
86     SLAB ON GRADE FLOOR:
87         STARTING AT (0,102,0) FACING (180) CPFLOOR (92 BY 102);
88     BASEMENT WALLS:
89         STARTING AT (0,0,0) FACING (180) CPWALL (92 BY 2.5),
90         STARTING AT (92,0,0) FACING (90) CPWALL (102 BY 2.5),
91         STARTING AT (92,102,0) FACING (0) CPWALL (92 BY 2.5),
92         STARTING AT (0,102,0) FACING (270) CPWALL (102 BY 2.5);
93 END ZONE;
94 ZONE 1 "NORTH LAB":
95     ORIGIN:(14,83,0);
96     NORTH AXIS = 0;
97     EXTERIOR WALLS:
98         STARTING AT (31,19,,0) FACING (0) EWALL1 (31 BY HEIGHT1)
99         WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
100             (6.66 BY 4.25) AT (10,4)
101         WITH DOORS OF TYPE WINDOW PANEL
102             (6.66 BY 4.0) AT (10,0)
103         WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
104             (3.33 BY 4.25) AT (27.5,4)
105         WITH DOORS OF TYPE WINDOW PANEL
106             (3.33 BY 4.0) AT (27.5,0)
107         WITH OVERHANGS (50 BY 3) AT (-10,HEIGHT1);
108     PARTITIONS:
109         STARTING AT (31,0,0) FACING (90) PWALL2 (19. BY HEIGHT1),
110         STARTING AT (0,0,0) FACING (180) PWALL1 (31 BY HEIGHT1),
111         STARTING AT (0,19,,0) FACING (270) PWALL1 (19 BY HEIGHT1);
112     ROOFS:
113         STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (31 BY 19.);
114     FLOOR OVER CRAWL SPACE:
115         STARTING AT (0,19,,0) FACING (180) FLOOR1 (31 BY 19.);
116     PEOPLE = 4, ALL ZONE'S PEOPLE;
117     ELECTRIC EQUIPMENT = 10.24, CLINIC LIGHTS AND EQUIPMENT;
118     LIGHTS = 5.73, CLINIC LIGHTS AND EQUIPMENT;
119     CONTROLS = CLINIC CONTROLS, 104 HEATING, 154.1 COOLING;
120 END ZONE;

```

121 ZONE 2 "NORTH WEST LAH":
122 ORIGIN:(0,83,0);
123 NORTH AXIS = 0;
124 EXTERIOR WALLS:
125 STARTING AT (0,0,0) FACING (180) EWALL1 (4 BY HEIGHT1)
126 WITH OVERHANGS (7 BY 83) AT (-3,HEIGHT1)
127 WITH WINGS (HEIGHT1 BY 83) AT (4,0),
128 STARTING AT (0,19,0) FACING (270) FWALL1 (19 BY HEIGHT1)
129 WITH OVERHANGS (108 BY 3) AT (-3,HEIGHT1),
130 STARTING AT (14,19,0) FACING (0) EWALL1 (14 BY HEIGHT1)
131 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
132 (3.33 BY 4.25) AT (1.5,4)
133 WITH DOOR OF TYPE WINDOW PANEL
134 (3.33 BY 4.0) AT (1.5,0)
135 WITH OVERHANGS (60 BY 3) AT (-42,HEIGHT1);
136 PARTITIONS:
137 STARTING AT (14,6.5,0) FACING (90) PWALL1 (11.5 BY HEIGHT1),
138 STARTING AT (4,0,0) FACING (180) PWALL1 (10 BY HEIGHT1);
139 ROOFS:
140 STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (14 BY 19);
141 FLOOR OVER CRAWL SPACE:
142 STARTING AT (0,19,0) FACING (180) FLOOR1 (14 BY 19);
143 PEOPLE = 2, ALL ZONES PEOPLE;
144 LIGHTS = 2.18, CLINIC LIGHTS AND EQUIPMENT;
145 ELECTRIC EQUIPMENT = 6.82, CLINIC LIGHTS AND EQUIPMENT;
146 GAS EQUIPMENT = 5, CLINIC LIGHTS AND EQUIPMENT;
147 CONTROLS = CLINIC CONTROLS, 23.68 HEATING, 35.1 COOLING;
148 END ZONE;
149 ZONE 3 "WEST OPER RMS":
150 ORIGIN:(0,13,0);
151 NORTH AXIS = 0;
152 EXTERIOR WALLS:
153 STARTING AT (0,70,0) FACING (270) EWALL1 (70 BY HEIGHT1)
154 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
155 (5 BY 8.9) REVEAL (3.67) AT (1.5,0.05)
156 WITH OVERHANGS (87 BY 3) AT (-16,HEIGHT1)
157 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
158 (6.66 BY 4.25) AT (13,4)
159 WITH DOORS OF TYPE WINDOW PANEL
160 (6.66 BY 4.0) AT (13,0)
161 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
162 (6.66 BY 4.25) AT (33,4)
163 WITH DOORS OF TYPE WINDOW PANEL
164 (6.66 BY 4.0) AT (33,0)
165 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
166 (6.66 BY 4.25) AT (53,4)
167 WITH DOORS OF TYPE WINDOW PANEL
168 (6.66 BY 4.0) AT (53,0);
169 PARTITIONS:
170 STARTING AT (0,0,0) FACING (180) PWALL1 (19 BY HEIGHT1),
171 STARTING AT (19,5,0) FACING (90) PWALL1 (59 BY HEIGHT1),
172 STARTING AT (19,70,0) FACING (0) PWALL1 (19 BY HEIGHT1);
173 ROOFS:
174 STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (19 BY 70);
175 FLOOR OVER CRAWL SPACE:
176 STARTING AT (0,70,0) FACING (180) FLOOR1 (19 BY 70);
177 PEOPLE = 11, ALL ZONES PEOPLE;
178 LIGHTS = 7.14, CLINIC LIGHTS AND EQUIPMENT;
179 ELECTRIC EQUIPMENT = 3.41, CLINIC LIGHTS AND EQUIPMENT;
180 CONTROLS = CLINIC CONTROLS, 117 HEATING, 173.7 COOLING;

```

181 END ZONE;
182 ZONE 4 "LOCKER RMS";
183   ORIGIN:(18,19,0);
184   NORTH AXIS = 0.;
185   PARTITIONS:
186     STARTING AT (0,0,0) FACING (180) PWALL1 (13 BY HEIGHT1),
187     STARTING AT (13,0,0) FACING (90) PWALL1 (59 BY HEIGHT1),
188     STARTING AT (13,59,0) FACING (0) PWALL1 (13 BY HEIGHT1),
189     STARTING AT (0,59,0) FACING (270) PWALL1 (59 BY HEIGHT1);
190   ROOFS:
191     STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (13 BY 59);
192   FLOOR OVER CRAWL SPACE:
193     STARTING AT (0,59,0) FACING (180) FLOOR1 (13 BY 59);
194   PEOPLE = 2, ALL ZONES PEOPLE;
195   LIGHTS = 3.96, CLINIC LIGHTS AND EQUIPMENT;
196   ELECTRIC EQUIPMENT = 0, CLINIC LIGHTS AND EQUIPMENT;
197   CONTROLS = CLINIC CONTROLS, 44.4 HEATING, 65.8 COOLING;
198 END ZONE;
199 ZONE 5 "LIBRARY CONF RMS";
200   ORIGIN:(31,47,0);
201   NORTH AXIS = 0;
202   PARTITIONS:
203     STARTING AT (0,0,0) FACING (180) PWALL1 (6 BY HEIGHT1),
204     STARTING AT (6,0,0) FACING (90) PWALL1 (3 BY HEIGHT1),
205     STARTING AT (6,3,0) FACING (180) PWALL1 (12 BY HEIGHT1),
206     STARTING AT (18,3,0) FACING (90) PWALL1 (29 BY HEIGHT1),
207     STARTING AT (18,36,0) FACING (0) PWALL1 (30 BY HEIGHT1),
208     STARTING AT (-12,36,0) FACING (270) PWALL1 (6 BY HEIGHT1),
209     STARTING AT (-12,30,0) FACING (180) PWALL1 (12 BY HEIGHT1),
210     STARTING AT (0,30,0) FACING (270) PWALL1 (30 BY HEIGHT1);
211   ROOFS:
212     STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (6 BY 3),
213     STARTING AT (0,3,HEIGHT1) FACING (180) ROOF1 (18 BY 33),
214     STARTING AT (-12,30,HEIGHT1) FACING (180) ROOF1 (12 BY 6);
215   FLOORS OVER CRAWL SPACE:
216     STARTING AT (0,3,0) FACING (180) FLOOR1 (6 BY 3),
217     STARTING AT (0,36,0) FACING (180) FLOOR1 (18 BY 33),
218     STARTING AT (-12,36,0) FACING (180) FLOOR1 (12 BY 6);
219   PEOPLE = 4, ALL ZONES PEOPLE;
220   LIGHTS = 3.28, CLINIC LIGHTS AND EQUIPMENT;
221   ELECTRIC EQUIPMENT = 3.41, CLINIC LIGHTS AND EQUIPMENT;
222   CONTROLS = CLINIC CONTROLS, 29.3 HEATING, 43.4 COOLING;
223 END ZONE;
224 ZONE 6 "WAITING ROOM";
225   ORIGIN:(19,13,0);
226   NORTH AXIS = 0.;
227   PARTITIONS:
228     STARTING AT (0,0,0) FACING (180) PWALL1 (42 BY HEIGHT1),
229     STARTING AT (42,5.5,0) FACING (0) PWALL1 (12 BY HEIGHT1),
230     STARTING AT (30,5.5,0) FACING (90) PWALL1 (31 BY HEIGHT1),
231     STARTING AT (30,36.5,0) FACING (0) PWALL1 (12 BY HEIGHT1),
232     STARTING AT (18,36.5,0) FACING (270) PWALL1 (3 BY HEIGHT1),
233     STARTING AT (18,33.5,0) FACING (0) PWALL1 (6 BY HEIGHT1),
234     STARTING AT (12,33.5,0) FACING (270) PWALL1 (28 BY HEIGHT1),
235     STARTING AT (12,5.5,0) FACING (0) PWALL1 (12 BY HEIGHT1);
236   ROOFS:
237     STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (42 BY 5.5),
238     STARTING AT (12,5.5,HEIGHT1) FACING (180) ROOF1 (18 BY 28),
239     STARTING AT (18,33.5,HEIGHT1) FACING (180) ROOF1 (12 BY 3);
240   FLOORS OVER CRAWL SPACE:

```

241 STARTING AT (0,5.5,0) FACING (180) FLOOR1 (42 BY 5.5),
 242 STARTING AT (12,33.5,0) FACING (180) FLOOR1 (18 BY 28),
 243 STARTING AT (18,36.5,0) FACING (180) FLOOR1 (12 BY 3))
 244 PEOPLE = 31, ALL ZONES PEOPLE;
 245 LIGHTS = 2.73, CLINIC LIGHTS AND EQUIPMENT;
 246 ELECTRIC EQUIPMENT = 1.82, CLINIC LIGHTS AND EQUIPMENT;
 247 CONTROLS = CLINIC CONTROLS, 48.6 HEATING, 72.0 COOLING;
 248 END ZONE;
 249 ZONE 7 "RECORDS AND SUPPLY":
 250 ORIGIN:(49,18.5,0))
 251 NORTH AXIS = 0.0
 252 PARTITIONS:
 253 STARTING AT (0,0,0) FACING (180) PWALL1 (12 BY HEIGHT1),
 254 STARTING AT (12,0,0) FACING (90) PWALL1 (45 BY HEIGHT1),
 255 STARTING AT (12,45,0) FACING (180) PWALL1 (6 BY HEIGHT1),
 256 STARTING AT (18,45,0) FACING (90) PWALL1 (13 BY HEIGHT1),
 257 STARTING AT (18,58,0) FACING (180) PWALL1 (7 BY HEIGHT1),
 258 STARTING AT (25,64.5,0) FACING (0) PWALL2 (25 BY HEIGHT1),
 259 STARTING AT (0,64.5,0) FACING (270) PWALL1 (64.5 BY HEIGHT1));
 260 ROOFS:
 261 STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (12 BY 64.5),
 262 STARTING AT (12,45,HEIGHT1) FACING (180) ROOF1 (6 BY 18.5),
 263 STARTING AT (18,58,HEIGHT1) FACING (180) ROOF1 (7 BY 5.5))
 264 FLOORS OVER CRAWL SPACE:
 265 STARTING AT (0,64.5,0) FACING (180) FLOOR1 (12 BY 64.5),
 266 STARTING AT (12,64.5,0) FACING (180) FLOOR1 (6 BY 18.5),
 267 STARTING AT (18,64.5,0) FACING (180) FLOOR1 (7 BY 5.5))
 268 PEOPLE = 7, ALL ZONES PEOPLE;
 269 LIGHTS = 4.37, CLINIC LIGHTS AND EQUIPMENT;
 270 ELECTRIC EQUIPMENT = 3.41, CLINIC LIGHTS AND EQUIPMENT;
 271 CONTROLS = CLINIC CONTROLS, 51.6 HEATING, 76.4 COOLING;
 272 END ZONE;
 273 ZONE 8 "XRAY":
 274 ORIGIN:(61,13,0))
 275 NORTH AXIS = 0.0
 276 PARTITIONS:
 277 STARTING AT (0,0,0) FACING (180) PWALL1 (16 BY HEIGHT1),
 278 STARTING AT (16,0,0) FACING (90) PWALL1 (69 BY HEIGHT1),
 279 STARTING AT (16,69,0) FACING (0) PWALL2 (4 BY HEIGHT1),
 280 STARTING AT (12,64,0) FACING (0) PWALL1 (7 BY HEIGHT1),
 281 STARTING AT (5,64,0) FACING (270) PWALL1 (14 BY HEIGHT1),
 282 STARTING AT (5,50,0) FACING (0) PWALL1 (5 BY HEIGHT1),
 283 STARTING AT (0,50,0) FACING (270) PWALL1 (45 BY HEIGHT1));
 284 ROOFS:
 285 STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (16 BY 50),
 286 STARTING AT (5,50,HEIGHT1) FACING (180) ROOF1 (11 BY 14),
 287 STARTING AT (12,64,HEIGHT1) FACING (180) ROOF1 (4 BY 5))
 288 FLOORS OVER CRAWL SPACE:
 289 STARTING AT (0,50,0) FACING (180) FLOOR1 (16 BY 50),
 290 STARTING AT (5,64,0) FACING (180) FLOOR1 (11 BY 14),
 291 STARTING AT (12,69,0) FACING (180) FLOOR1 (4 BY 5))
 292 PEOPLE = 5, ALL ZONES PEOPLE;
 293 LIGHTS = 3.96, CLINIC LIGHTS AND EQUIPMENT;
 294 ELECTRIC EQUIPMENT = 28.87, CLINIC LIGHTS AND EQUIPMENT;
 295 CONTROLS = CLINIC CONTROLS, 48.3 HEATING, 71.6 COOLING;
 296 END ZONE;
 297 ZONE 9 "SOUTH OPER RMS":
 298 ORIGIN:(0,0,0))
 299 NORTH AXIS = 0.0
 300 EXTERIOR WALLS:

301 STARTING AT (0,0,0) FACING (180) EWALL1 (92 BY HEIGHT1)
 302 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
 303 (6.66 BY 4.25) AT (9,4)
 304 WITH DOORS OF TYPE WINDOW PANEL
 305 (6.66 BY 4.0) AT (9,0)
 306 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
 307 (6.66 BY 4.25) AT (28,4)
 308 WITH DOORS OF TYPE WINDOW PANEL
 309 (6.66 BY 4.0) AT (28,0)
 310 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
 311 (8 BY 8.9) REVEAL (4) AT (42,.05)
 312 WITH OVERHANGS (98 BY 3) AT (-3,HEIGHT1)
 313 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
 314 (6.66 BY 4.25) AT (58,4)
 315 WITH DOORS OF TYPE WINDOW PANEL
 316 (6.66 BY 4.0) AT (58,0)
 317 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
 318 (6.66 BY 4.25) AT (78,4)
 319 WITH DOORS OF TYPE WINDOW PANEL
 320 (6.66 BY 4.0) AT (78,0),
 321 STARTING AT (92,0,0) FACING (90) FWALL1 (13.5 BY HEIGHT1)
 322 WITH OVERHANGS (100 BY 3) AT (-3,HEIGHT1),
 323 STARTING AT (0,13.5,0) FACING (270) EWALL1 (13.5 BY HEIGHT1)
 324 WITH OVERHANGS (100 BY 3) AT (-93.5,HEIGHT1);
 325 PARTITIONS:
 326 STARTING AT (92,13.5,0) FACING (0) PWALL1 (92 BY HEIGHT1);
 327 ROOFS:
 328 STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (92 BY 13.5);
 329 FLOOR OVER CRAWL SPACE:
 330 STARTING AT (0,13.5,0) FACING (180) FLOOR1 (92 BY 13.5);
 331 PEOPLE = 11, ALL ZONES PEOPLE;
 332 LIGHTS = 9.28, CLINIC LIGHTS AND EQUIPMENT;
 333 ELECTRIC EQUIPMENT = 3.41, CLINIC LIGHTS AND EQUIPMENT;
 334 CONTROLS = CLINIC CONTROLS, 130.9 HEATING, 194.0 COOLING;
 335 END ZONE;
 336 ZONE 10 "EAST OPER RMS":
 337 ORIGIN:(77,13,0);
 338 NORTH AXIS = 0.1
 339 PARTITIONS:
 340 STARTING AT (0,0,0) FACING (180) PWALL1 (15 BY HEIGHT1),
 341 STARTING AT (0,70,0) FACING (270) PWALL1 (70 BY HEIGHT1),
 342 STARTING AT (15,70,0) FACING (0) PWALL2 (15 BY HEIGHT1);
 343 EXTERIOR WALLS:
 344 STARTING AT (15,0,0) FACING (90) EWALL1 (70 BY HEIGHT1)
 345 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
 346 (6.66 BY 4.25) AT (12,4)
 347 WITH DOORS OF TYPE WINDOW PANEL
 348 (6.66 BY 4.0) AT (12,0)
 349 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
 350 (6.66 BY 4.25) AT (32,4)
 351 WITH DOORS OF TYPE WINDOW PANEL
 352 (6.66 BY 4.0) AT (32,0)
 353 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
 354 (6.66 BY 4.25) AT (51,4)
 355 WITH DOORS OF TYPE WINDOW PANEL
 356 (6.66 BY 4.0) AT (51,0)
 357 WITH WINDOWS OF TYPE SINGLE PANE TINTED WINDOW
 358 (5 BY 8.9) REVEAL (3.67) AT (65,0)
 359 WITH OVERHANGS (76 BY 3) AT (-3,HEIGHT1);
 360 ROOFS:

```

361     STARTING AT (0,0,HEIGHT1) FACING (180) ROOF1 (15 BY 70)
362     FLOOR OVER CRAWL SPACE;
363     STARTING AT (0,70,0) FACING (180) FLOOR1 (15 BY 70);
364     PEOPLE = 8,ALL ZONES PEOPLE;
365     LIGHTS = 6.41,CLINIC LIGHTS AND EQUIPMENT;
366     ELECTRIC EQUIPMENT = 3.41,CLINIC LIGHTS AND EQUIPMENT;
367     CONTROLS = CLINIC CONTRLS, 122.7 HEATING, 181.9 COOLING;
368     END ZONE;
369     END BUILDING DESCRIPTION;
370     BEGIN FAN SYSTEM DESCRIPTION;
371     MULTIZONE SYSTEM 1 "MAIN FAN SYSTEM" SERVING ZONES 1,2,3,4,5,6,7,8,9,10;
372     FOR ZONE 1:
373         EXHAUST AIR VOLUME = 1000;
374         SUPPLY AIR VOLUME = 1784;
375     END;
376     FOR ZONE 2:
377         SUPPLY AIR VOLUME = 406;
378     END;
379     FOR ZONE 3:
380         SUPPLY AIR VOLUME = 2010;
381     END;
382     FOR ZONE 4:
383         EXHAUST AIR VOLUME = 600;
384         SUPPLY AIR VOLUME = 761;
385     END;
386     FOR ZONE 5:
387         SUPPLY AIR VOLUME = 502;
388     END;
389     FOR ZONE 6:
390         SUPPLY AIR VOLUME = 833;
391     END;
392     FOR ZONE 7:
393         SUPPLY AIR VOLUME = 884;
394     END;
395     FOR ZONE 8:
396         SUPPLY AIR VOLUME = 829;
397     END;
398     FOR ZONE 9:
399         SUPPLY AIR VOLUME = 2245;
400     END;
401     FOR ZONE 10:
402         SUPPLY AIR VOLUME = 2105;
403     END;
404     OTHER SYSTEM PARAMETERS;
405         SUPPLY FAN EFFICIENCY = .38;
406         HOT DECK CONTROL = OUTSIDE AIR CONTROLLED;
407         HOT DECK CONTROL SCHEDULE = (120 AT 10, 80 AT 70);
408         COLD DECK CONTROL = FIXED SET POINT;
409         COLD DECK TEMPERATURE = 60.;
410         COLD DECK THROTTLING RANGE = 5;
411         MIXED AIR CONTROL = FIXED AMOUNT;
412         OUTSIDE AIR VOLUME = 4114.;
413     END;
414     COOLING COIL DESIGN PARAMETERS;
415         COIL TYPE = DX;
416         ENTERING AIR DRY BULB TEMPERATURE = 87.6;
417         ENTERING AIR WET BULB TEMPERATURE = 70.3;
418         LEAVING AIR DRY BULB TEMPERATURE = 61.;
419         LEAVING AIR WET BULB TEMPERATURE = 59.;
420         AIR FACE VELOCITY = 514.6;

```

```

421     AIR VOLUME FLOW RATE = 15760;
422     BAROMETRIC PRESSURE = 405;
423     LEAVING REFRIGERANT TEMPERATURE=45;
424     ENTERING REFRIGERANT TEMPERATURE = 45;
425     TOTAL COOLING LOAD = 600;
426     NUMBER OF TUBE CIRCUITS=20;
427 END;
428 DX CONDENSING UNIT PARAMETERS;
429     RPRCD(.40349281,.21287191,.39339793);
430     DESIGN SATURATED SUCTION TEMPERATURE=40;
431     DESIGN SATURATED CONDENSING TEMPERATURE=130;
432     DESIGN FULL LOAD POWER RATIO=.351;
433     DX CONDENSING UNIT CAPACITY=600;
434 END DX CONDENSING UNIT PARAMETERS;
435 END SYSTEM;
436 END FAN SYSTEM DESCRIPTION;
437 BEGIN CENTRAL PLANT DESCRIPTION;
438     PLANT 1 "BOILER ONLY" SERVING ALL SYSTEMS;
439     EQUIPMENT SELECTION;
440         1 BOILER OF SIZE 100;
441     END EQUIPMENT SELECTION;
442     END PLANT;
443 END CENTRAL PLANT DESCRIPTION;
444 END INPUT;

```

APPENDIX B:

BATTALION HEADQUARTERS AND CLASSROOM BUILDING SIMULATION MODEL

Battalion Headquarters and Classroom Building Simulation Model

```

1  BEGIN INPUT;
2  RUN CONTROL : NEW ZONES, NEW SYSTEMS, PLANT,
3  UNITS(IN=ENGLISH,OUT=ENGLISH),
4  REPORTS (ZONE LOADS,SYSTEM LOADS,COIL LOADS,SYSTEM,PLANT LOADS,
5  38);
6  DEFINE LOCATION:
7  FT CARSON = (LAT=38.75, LONG=104.5, TZ=7);
8  END;
9  DEFINE DESIGN DAYS:
10 FT CARSON SUMMER = (HIGH=92, LOW=61, WB=59, DATE=21JUL, WEEKDAY, PRES=390),
11 FT CARSON WINTER = (HIGH=10, LOW=-2, WB=-2, DATE=21JAN, WEEKEND, PRES=390);
12 END;
13 TEMPORARY WALLS:
14 WALL = (BRICK - FACE 4 IN,
15 AIRSPACE - VERTICAL,
16 CB - 8 IN HW CONCRETE BLOCK);
17 WALL1 = (E1 - 3/4 IN PLASTER OR GYP BOARD,
18 AIRSPACE - VERTICAL,
19 E1 - 3/4 IN PLASTER OR GYP BOARD),
20 WALL2 = (CB - 8 IN HW CONCRETE BLOCK);
21 END;
22 TEMPORARY ROOFS:
23 ROOF = (E2 - 1 / 2 IN SLAG OR STONE,
24 E3 - 3 / 8 IN FELT AND MEMBRANE,
25 R6 - 2 IN DENSE INSULATION,
26 A3 - STEEL SIDING,
27 R6 - 2 IN DENSE INSULATION,
28 E4 - CEILING AIRSPACE,
29 E5 - ACOUSTIC TILE);
30 END;
31 TEMPORARY CONTROLS (ADMIN COOL AND HEAT):
32 PROFILES:
33 CANDH = (1 AT 74, 0 AT 76., -0 AT 78);
34 SCHEDULES:
35 MONDAY THRU SUNDAY = (00 TO 24 - CANDH),
36 HOLIDAY = SUNDAY);
37 END;
38 TEMPORARY CONTROLS (ADMIN H ONLY):
39 PROFILES:
40 HONLY = (1 AT 74, 0 AT 76);
41 SCHEDULES:
42 MONDAY THRU SUNDAY = (00 TO 24 - HONLY),
43 HOLIDAY = SUNDAY);
44 END;
45 TEMPORARY SCHEDULE (ADMIN OFFICE OCCUPANCY):
46 SATURDAY THRU SUNDAY = (00 TO 24 - .2),
47 MONDAY THRU FRIDAY = (.17 TO 06 - .2, 06 TO 08 - .5, 08 TO 12 - 1.0,
48 12 TO 13 - .67, 13 TO 17 - 1.);
49 END;
50 TEMPORARY SCHEDULE (ADMIN CLASSROOM OCCUPANCY):
51 SATURDAY THRU SUNDAY = (00 TO 24 - 0.),
52 MONDAY THRU FRIDAY = (11 TO 09 - 0., 09 TO 11 - 1.);
53 END;
54 TEMPORARY SCHEDULE (OA VENT):
55 SUNDAY THRU SATURDAY = (00 TO 24 - .5);
56 END;
57 TEMPORARY SCHEDULE (OFF):
58 SUNDAY THRU SATURDAY = (00 TO 24 - 0.);
59 END;
60 TEMPORARY SCHEDULE (ADMIN LIGHTS):

```

61 MONDAY THRU FRIDAY = (20 TO 07 = .49,.63,04 TO 18 = 1...82,.63),
 62 SATURDAY THRU SUNDAY = (00 TO 24 = .49),
 63 HOLIDAY = SUNDAY;
 64 END;
 65 PROJECT = "ADMIN BUILDING";
 66 GROUND TEMPERATURES = (50,52,54,56,60,66,72,69,66,62,58,54);
 67 WEATHER TAPE FROM 06 DEC THRU 23 JUL;
 68 LOCATION = FT CARSON;
 69 BEGIN BUILDING DESCRIPTION;
 70 NORTH AXIS=0;
 71 DIMENSIONS: H1=10.75;
 72 ZONE 101 "STORAGE A";
 73 ORIGIN:(0,0,0);
 74 NORTH AXIS = 0;
 75 ROOF;
 76 STARTING AT (0,0,H1) FACING (180) ROOF (41 BY 77);
 77 SLAB ON GRADE FLOOR;
 78 STARTING AT (0,77,0) FACING (180) FLOOR SLAB 4 IN (41 BY 77);
 79 EXTERIOR WALLS;
 80 STARTING AT (0,0,0) FACING (180) WALL (41 BY H1),
 81 STARTING AT (41,77,0) FACING (0) WALL (41 BY H1),
 82 STARTING AT (0,77,0) FACING (270) WALL (77 BY H1);
 83 PARTITIONS;
 84 STARTING AT (41,0,0) FACING (90) WALL1 (77 BY H1);
 85 LIGHTS = 16.59, ADMIN LIGHTS;
 86 PEOPLE = 7, ADMIN OFFICE OCCUPANCY;
 87 CONTROLS = ADMIN H ONLY;
 88 END ZONE;
 89 ZONE 4 "OFFICE A";
 90 ORIGIN:(41,0,0);
 91 NORTH AXIS = 0;
 92 ROOF;
 93 STARTING AT (0,0,H1) FACING (180) ROOF(17 BY 10),
 94 STARTING AT (17,0,H1) FACING (180) ROOF (13 BY 19),
 95 STARTING AT (30,0,H1) FACING (180) ROOF (28 BY 28);
 96 SLAB ON GRADE FLOOR;
 97 STARTING AT (0,10,0) FACING (180) FLOOR SLAB 4 IN (17 BY 10),
 98 STARTING AT (17,19,0) FACING (180) FLOOR SLAB 4 IN (13 BY 19),
 99 STARTING AT (30,28,0) FACING (180) FLOOR SLAB 4 IN (28 BY 28);
 100 EXTERIOR WALLS;
 101 STARTING AT (0,0,0) FACING (180) WALL (58 BY H1)
 102 WITH WINDOWS (IF TYPE SINGLE PANE WITH BLINDS
 103 (5.33 BY H1) AT (5,0) AND (26,0) AND (51,0),
 104 STARTING AT (58,0,0) FACING (90) WALL (20 BY H1);
 105 PARTITIONS;
 106 STARTING AT (58,20,0) FACING (90) WALL (8 BY H1),
 107 STARTING AT (58,28,0) FACING (0) WALL1 (28 BY H1),
 108 STARTING AT (30,28,0) FACING (270) WALL1 (9 BY H1),
 109 STARTING AT (30,19,0) FACING (0) WALL1 (13 BY H1),
 110 STARTING AT (17,19,0) FACING (270) WALL1 (9 BY H1),
 111 STARTING AT (17,10,0) FACING (0) WALL1 (17 BY H1),
 112 STARTING AT (0,10,0) FACING (270) WALL1 (10 BY H1);
 113 LIGHTS = 6.26, ADMIN LIGHTS;
 114 CONTROLS = ADMIN COOL AND HEAT;
 115 PEOPLE = .4, ADMIN OFFICE OCCUPANCY;
 116 END ZONE;
 117 ZONE 3 "CONFERENCE A";
 118 ORIGIN:(41,10,0);
 119 NORTH AXIS=0;
 120 ROOF;

121 STARTING AT (0,0,H1) FACING (180) ROOF (17 BY 9),
122 STARTING AT (0,9,H1) FACING (180) ROOF (30 BY 14),
123 SLAB ON GRADE FLOOR:
124 STARTING AT (0,9,0) FACING (180) FLOOR SLAB 4 IN (17 BY 9),
125 STARTING AT (0,23,0) FACING (180) FLOOR SLAB 4 IN (30 BY 14),
126 PARTITIONS:
127 STARTING AT (0,0,0) FACING (180) WALL1 (17 BY H1),
128 STARTING AT (17,0,0) FACING (90) WALL1 (9 BY H1),
129 STARTING AT (17,9,0) FACING (180) WALL1 (13 BY H1),
130 STARTING AT (30,9,0) FACING (90) WALL1 (14 BY H1),
131 STARTING AT (30,23,0) FACING (0) WALL1 (30 BY H1),
132 STARTING AT (0,23,0) FACING (270) WALL1 (23 BY H1),
133 LIGHTS = 2.79, ADMIN LIGHTS;
134 CONTROLS = ADMIN COOL AND HEAT;
135 PEOPLE = 2, ADMIN OFFICE OCCUPANCY;
136 END ZONE;
137 ZONE 1 "CLASSROOM A":
138 ORIGIN: (41,40,0);
139 NORTH AXIS = 0;
140 ROOF:
141 STARTING AT (0,0,H1) FACING (180) ROOF (70 BY 37),
142 SLAB ON GRADE FLOOR:
143 STARTING AT (0,37,0) FACING (180) FLOOR SLAB 4 IN (70 BY 37),
144 PARTITIONS:
145 STARTING AT (0,0,0) FACING (180) WALL2 (70 BY H1),
146 STARTING AT (70,0,0) FACING (90) WALL2 (16 BY H1),
147 STARTING AT (0,37,0) FACING (270) WALL1 (37 BY H1),
148 EXTERIOR WALLS:
149 STARTING AT (70,37,0) FACING (0) WALL (70 BY H1),
150 WALLS TO UNCOOLED SPACES:
151 STARTING AT (70,16,0) FACING (90) WALL2 (21 BY H1),
152 LIGHTS = 13.54, ADMIN LIGHTS;
153 CONTROLS = ADMIN COOL AND HEAT;
154 PEOPLE = 25, ADMIN CLASSROOM OCCUPANCY;
155 END ZONE;
156 ZONE 2 "HALLWAY":
157 ORIGIN: (41,33,0);
158 NORTH AXIS = 0;
159 ROOF:
160 STARTING AT (70,7,H1) FACING (180) ROOF (38 BY 18),
161 STARTING AT (0,0,H1) FACING (180) ROOF (30 BY 7),
162 STARTING AT (30,-5,H1) FACING (180) ROOF (28 BY 12),
163 STARTING AT (58,-13,H1) FACING (180) ROOF (62 BY 20),
164 STARTING AT (120,-5,H1) FACING (180) ROOF (28 BY 12),
165 STARTING AT (148,0,H1) FACING (180) ROOF (30 BY 7),
166 SLAB ON GRADE FLOOR:
167 STARTING AT (70,25,0) FACING (180) FLOOR SLAB 4 IN (38 BY 18),
168 STARTING AT (0,7,0) FACING (180) FLOOR SLAB 4 IN (30 BY 7),
169 STARTING AT (30,7,0) FACING (180) FLOOR SLAB 4 IN (28 BY 12),
170 STARTING AT (58,7,0) FACING (180) FLOOR SLAB 4 IN (62 BY 20),
171 STARTING AT (120,7,0) FACING (180) FLOOR SLAB 4 IN (28 BY 12),
172 STARTING AT (148,7,0) FACING (180) FLOOR SLAB 4 IN (30 BY 7),
173 EXTERIOR WALLS:
174 STARTING AT (58,-13,0) FACING (180) WALL (62 BY H1),
175 WALLS TO UNCOOLED SPACE:
176 STARTING AT (108,25,0) FACING (0) WALL2 (38 BY H1),
177 CONTROLS = ADMIN COOL AND HEAT;
178 PEOPLE = 1, ADMIN OFFICE OCCUPANCY;
179 END ZONE;
180 ZONE 5 "OFFICE B":

```

181 ORIGIN:(161,0,0);
182 NORTH AXIS=0;
183 ROOF:
184   STARTING AT (0,0,H1) FACING (180) ROOF (28 BY 28),
185   STARTING AT (28,0,H1) FACING (180) ROOF (13 BY 19),
186   STARTING AT (41,0,H1) FACING (180) ROOF (17 BY 10);
187 FLOOR:
188   STARTING AT (0,28,0) FACING (180) FLOOR39 (28 BY 28),
189   STARTING AT (28,19,0) FACING (180) FLOOR39 (13 BY 19),
190   STARTING AT (41,10,0) FACING (180) FLOOR39 (17 BY 10);
191 EXTERIOR WALLS:
192   STARTING AT (0,0,0) FACING (180) WALL (58 BY H1)
193   WITH WINDOWS OF TYPE SINGLE PANE WITH BLINDS
194   (5.33 BY H1) AT (1,67,0) AND (17,0) AND (48,0),
195   STARTING AT (0,20,0) FACING (270) WALL (20 BY H1);
196 PARTITIONS:
197   STARTING AT (58,0,0) FACING (90) WALL1 (10 BY H1),
198   STARTING AT (58,10,0) FACING (0) WALL1 (17 BY H1),
199   STARTING AT (41,10,0) FACING (90) WALL1 (9 BY H1),
200   STARTING AT (41,19,0) FACING (0) WALL1 (13 BY H1),
201   STARTING AT (28,19,0) FACING (90) WALL1 (9 BY H1),
202   STARTING AT (28,28,0) FACING (0) WALL1 (28 BY H1),
203   STARTING AT (0,28,0) FACING (270) WALL (8 BY H1);
204 LIGHTS = 6.26,ADMIN LIGHTS;
205 CONTROLS = ADMIN COOL AND HEAT;
206 PEOPLE = 4,ADMIN OFFICE OCCUPANCY;
207 END ZONE;
208 ZONE 6 "CONFERENCE B":
209 ORIGIN:(202,10,0);
210 NORTH AXIS = 0;
211 ROOF:
212   STARTING AT (0,0,H1) FACING (180) ROOF (17 BY 9),
213   STARTING AT (-13,9,H1) FACING (180) ROOF (30 BY 14);
214 FLOOR:
215   STARTING AT (0,9,0) FACING (180) FLOOR39 (17 BY 9),
216   STARTING AT (-13,23,0) FACING (180) FLOOR39 (30 BY 14);
217 PARTITIONS:
218   STARTING AT (0,0,0) FACING (180) WALL1 (17 BY H1),
219   STARTING AT (17,0,0) FACING (90) WALL1 (23 BY H1),
220   STARTING AT (17,23,0) FACING (0) WALL1 (30 BY H1),
221   STARTING AT (-13,23,0) FACING (270) WALL1 (14 BY H1),
222   STARTING AT (-13,9,0) FACING (180) WALL1 (13 BY H1),
223   STARTING AT (0,9,0) FACING (270) WALL1 (9 BY H1);
224 LIGHTS = 2.79,ADMIN LIGHTS;
225 CONTROLS = ADMIN COOL AND HEAT;
226 PEOPLE = 2,ADMIN OFFICE OCCUPANCY;
227 END ZONE;
228 ZONE 7 "CLASSROOM B":
229 ORIGIN:(149,40,0);
230 NORTH AXIS = 0;
231 ROOF:
232   STARTING AT (0,0,0) FACING (180) ROOF (70 BY 37);
233 SLAB ON GRADE FLOOR:
234   STARTING AT (0,37,0) FACING (180) FLOOR SLAB 4 IN (70 BY 37);
235 PARTITIONS:
236   STARTING AT (0,0,0) FACING (180) WALL2 (70 BY H1),
237   STARTING AT (70,0,0) FACING (90) WALL1 (37 BY H1),
238   STARTING AT (0,16,0) FACING (270) WALL2 (16 BY H1);
239 EXTERIOR WALLS:
240   STARTING AT (70,37,0) FACING (0) WALL (70 BY H1);

```

```

241 WALLS TO UNCOOLED SPACES;
242   STARTING AT (0,37,0) FACING (270) WALL2 (21 BY H1);
243 LIGHTS = 13.54, ADMIN LIGHTS;
244 CONTROLS = ADMIN COOL AND HEAT;
245 PEOPLE = 25, ADMIN CLASSROOM OCCUPANCY;
246 END ZONE;
247 ZONE 102 "STORAGE B";
248   ORIGIN(219,0,0);
249   NORTH AXIS=0;
250   POOF;
251   STARTING AT (0,0,H1) FACING (180) ROOF (41 BY 77);
252 SLAB ON GRADE FLOOR;
253   STARTING AT (0,77,0) FACING (180) FLOOR SLAB 4 IN (41 BY 47);
254 FLOOR;
255   STARTING AT (0,30,0) FACING (180) FLOOR39 (41 BY 30);
256 EXTERIOR WALLS;
257   STARTING AT (0,0,0) FACING (180) WALL (41 BY H1);
258   STARTING AT (41,0,0) FACING (90) WALL (77 BY H1);
259   STARTING AT (41,77,0) FACING (0) WALL (41 BY H1);
260 PARTITIONS;
261   STARTING AT (0,77,0) FACING (270) WALL1 (77 BY H1);
262 LIGHTS = 16.59, ADMIN LIGHTS;
263 CONTROLS = ADMIN H ONLY;
264 PEOPLE = 7, ADMIN OFFICE OCCUPANCY;
265 END ZONE;
266 ZONE 1000 "BASEMENT";
267   ORIGIN(77,0,0);
268   NORTH AXIS = 0;
269   BASEMENT WALLS
270     STARTING AT (0,20,0) FACING (180) WALL2 (64 BY 8);
271     STARTING AT (64,20,0) FACING (270) WALL2 (20 BY 8);
272     STARTING AT (64,0,0) FACING (180) WALL2 (98 BY 8);
273     STARTING AT (162,0,0) FACING (90) WALL2 (30 BY 8);
274     STARTING AT (162,30,0) FACING (0) WALL2 (162 BY 8);
275     STARTING AT (0,30,0) FACING (270) WALL2 (10 BY 8);
276   CEILING
277     STARTING AT (0,20,8) FACING (180) CEILING39 (64 BY 10);
278     STARTING AT (64,0,8) FACING (180) CEILING39 (98 BY 30);
279   SLAB ON GRADE FLOOR
280     STARTING AT (0,30,0) FACING (180) FLOOR SLAB 4 IN (64 BY 10);
281     STARTING AT (64,30,0) FACING (180) FLOOR SLAB 4 IN (98 BY 30);
282 CONTROLS = ADMIN H ONLY;
283 PEOPLE = 3, ADMIN OFFICE OCCUPANCY;
284 LIGHTS = 6.26, ADMIN LIGHTS;
285 END ZONE;
286 END BUILDING DESCRIPTION;
287 BEGIN FAN SYSTEM DESCRIPTION;
288 MULTIZONE SYSTEM 1 "MAIN" SERVING ZONE 1,2,3,4,5,6,7;
289   FOR ZONE 1:
290     SUPPLY AIR VOLUME = 3000;
291   END;
292   FOR ZONE 2:
293     SUPPLY AIR VOLUME = 1975;
294   END;
295   FOR ZONE 3:
296     SUPPLY AIR VOLUME = 535;
297   END;
298   FOR ZONE 4:
299     SUPPLY AIR VOLUME = 2405;
300   END;

```

```

301 FOR ZONE 5:
302     SUPPLY AIR VOLUME = 2735;
303 END;
304 FOR ZONE 6:
305     SUPPLY AIR VOLUME = 615;
306 END;
307 FOR ZONE 7:
308     SUPPLY AIR VOLUME = 3000;
309 END;
310 OTHER SYSTEM PARAMETERS:
311     SUPPLY FAN EFFICIENCY = .6630;
312     HOT DECK CONTROL = OUTSIDE AIR CONTROLLED;
313     HOT DECK CONTROL SCHEDULE = (200 AT 5,80 AT 70);
314     COLD DECK TEMPERATURE = 58;
315     COLD DECK THROTTLING RANGE = 16;
316     MIXED AIR CONTROL = ENTHALPY ECONOMY CYCLE;
317     DESIRED MIXED AIR TEMPERATURE = 55;
318 END;
319 EQUIPMENT SCHEDULES:
320     HEATING COIL OPERATION = CONTINUOUS,78 MAXIMUM TEMPERATURE,
321         ~400 MINIMUM TEMPERATURE;
322     COOLING COIL OPERATION = OFF,58 MINIMUM TEMPERATURE;
323     MINIMUM VENTILATION SCHEDULE = OA VENT;
324 END;
325 END SYSTEM;
326 UNIT VENTILATOR SYSTEM 101 "UNIT HEATER" SERVING ZONE 101;
327     FOR ZONE 101
328         SUPPLY AIR VOLUME = 500;
329         REHEAT CAPACITY = 50000;
330     END;
331     EQUIPMENT SCHEDULES
332     SYSTEM OPERATION = INTERMITTENT;
333     HEATING COIL OPERATION = CONTINUOUS,78 MAXIMUM TEMPERATURE;
334     END;
335     OTHER SYSTEM PARAMETERS
336     MIXED AIR CONTROL = FIXED AMOUNT;
337     OUTSIDE AIR VOLUME = 0.;
338     HOT DECK CONTROL = OUTSIDE AIR CONTROLLED;
339     HOT DECK CONTROL SCHEDULE = (200 AT 5,80 AT 70);
340     END;
341 END SYSTEM;
342 UNIT VENTILATOR SYSTEM 102 "UNIT HEATER" SERVING ZONE 102;
343     FOR ZONE 102
344         SUPPLY AIR VOLUME = 500;
345         REHEAT CAPACITY = 50000;
346     END;
347     EQUIPMENT SCHEDULES
348     SYSTEM OPERATION = INTERMITTENT;
349     HEATING COIL OPERATION = CONTINUOUS,78 MAXIMUM TEMPERATURE;
350     END;
351     OTHER SYSTEM PARAMETERS
352     MIXED AIR CONTROL = FIXED AMOUNT;
353     OUTSIDE AIR VOLUME = 0.;
354     HOT DECK CONTROL = OUTSIDE AIR CONTROLLED;
355     HOT DECK CONTROL SCHEDULE = (200 AT 5,80 AT 70);
356     END;
357 END SYSTEM;
358 SINGLE ZONE DRAW THRU SYSTEM 1000 "BASEMENT" SERVING ZONE 1000;
359     FOR ZONE 1000
360         SUPPLY AIR VOLUME = 11200;

```

```

361      END;
362      EQUIPMENT SCHEDULES
363      SYSTEM OPERATION = INTERMITTENT, 78 MAXIMUM TEMPERATURE,
364      -300 MINIMUM TEMPERATURE;
365      HEATING COIL OPERATION = CONTINUOUS, 78 MAXIMUM TEMPERATURE;
366      COOLING COIL OPERATION = OFF;
367      MINIMUM VENTILATION SCHEDULE = CONTINUOUS;
368      END;
369      OTHER SYSTEM PARAMETERS
370      MIXED AIR CONTROL = FIXED AMOUNT;
371      OUTSIDE AIR VOLUME = 11200;
372      SUPPLY FAN EFFICIENCY = .819;
373      END;
374      END SYSTEM;
375      END FAN SYSTEM DESCRIPTION;
376      BEGIN CENTRAL PLANT DESCRIPTION;
377      END INPUT;

```

APPENDIX C:

STATISTICAL FORMULAS

$$\% \text{ Difference} = \frac{X-Y}{X}$$

$$\text{DIFFAVE} = \frac{\sum D}{N} \quad \text{PERAVE} = \frac{\sum P}{N} \quad \text{DABSAVE} = \frac{\sum D}{N}$$

$$\text{DIFFVAR} = \frac{N \sum D^2 - (\sum D)^2}{N(N-1)} \quad \text{PERVAR} = \frac{N \sum P^2 - (\sum P)^2}{N(N-1)} \quad \text{DABSVAR} = \frac{N \sum D^2 - (\sum D)^2}{N(N-1)}$$

$$\text{DIFFSTD} = \text{DIFFVAR}$$

$$\text{PERSTD} = \text{PERVAR}$$

$$\text{DABBSTD} = \text{DABSVAR}$$

where: X = measured
Y = predicted
D = X-Y
N = number of observations
P = D divided by X times 100

CERL DISTRIBUTION

Chief of Engineers
ATTN: Tech Monitor
ATTN: DAEN-ASI-L (2)
ATTN: DAEN-CCP
ATTN: DAEN-CW
ATTN: DAEN-CWE
ATTN: DAEN-CWM-R
ATTN: DAEN-CWO
ATTN: DAEN-CWP
ATTN: DAEN-MP
ATTN: DAEN-MPC
ATTN: DAEN-MPE
ATTN: DAEN-MPO
ATTN: DAEN-MPR-A
ATTN: DAEN-RD
ATTN: DAEN-RDC
ATTN: DAEN-RDM
ATTN: DAEN-RM
ATTN: DAEN-ZC
ATTN: DAEN-ZCE
ATTN: DAEN-ZCI
ATTN: DAEN-ZCM

US Army Engineer Districts

ATTN: Library
Alaska
Al Batn
Albuquerque
Baltimore
Buffalo
Charleston
Chicago
Detroit
Far East
Fort Worth
Galveston
Huntington
Jacksonville
Japan
Kansas City
Little Rock
Los Angeles
Louisville
Memphis
Mobile
Nashville
New Orleans
New York
Norfolk
Omaha
Philadelphia
Pittsburgh
Portland
Riyadh
Rock Island
Sacramento
San Francisco
Savannah
Seattle
St. Louis
St. Paul
Tulsa
Vicksburg
Walla Walla
Wilmington

US Army Engineer Divisions

ATTN: Library
Europe
Huntsville
Lower Mississippi Valley
Middle East
Middle East (Rear)
Missouri River
New England
North Atlantic
North Central
North Pacific
Ohio River
Pacific Ocean
South Atlantic
South Pacific
Southwestern

Waterways Experiment Station

ATTN: Library

Cold Regions Research Engineering Lab

ATTN: Library

US Government Printing Office

Receiving Section/Depository Copies (?)

Defense Technical Information Center

ATTN: DDA (12)

Engineering Societies Library

New York, NY

FESA, ATTN: Library

ETL, ATTN: Library

Engr. Studies Center, ATTN: Library

Inst. for Water Res., ATTN: Library

SHAPE

ATTN: Survivability Section, CCB-OPS
Infrastructure Branch, LANDA

HQ USEUCOM

ATTN: ECJ 4/7-LOE

Army Instl. and Major Activities (CONUS)

DARCOM - Dir., Inst., & Svcs.

ATTN: Facilities Engineer

ARRADCOM

Aberdeen Proving Ground
Army Matls. and Mechanics Res. Ctr.
Corpus Christi Army Depot
Harry Diamond Laboratories
Dugway Proving Ground
Jefferson Proving Ground
Fort Monmouth
Letterkenny Army Depot
Natick Research and Dev. Ctr.
New Cumberland Army Depot
Pueblo Army Depot
Red River Army Depot
Redstone Arsenal
Rock Island Arsenal
Savanna Army Depot
Sharpe Army Depot
Seneca Army Depot
Tobyhanna Army Depot
Tooele Army Depot
Watervliet Arsenal
Yuma Proving Ground
White Sands Missile Range

FORSCOM

FORSCOM Engineer, ATTN: AFEN-FE

ATTN: Facilities Engineers

Fort Buchanan
Fort Bragg
Fort Campbell
Fort Carson
Fort Devens
Fort Drum
Fort Hood
Fort Indiantown Gap
Fort Irwin
Fort Sam Houston
Fort Lewis
Fort McCoy
Fort McPherson
Fort George G. Meade
Fort Ord
Fort Polk
Fort Richardson
Fort Riley
Presidio of San Francisco
Fort Sheridan
Fort Stewart
Fort Wainwright
Vancouver Bks.

TRADOC

HQ, TRADOC, ATTN: ATEN-FE

ATTN: Facilities Engineer

Fort Belvoir
Fort Benning
Fort Bliss
Carlisle Barracks
Fort Chaffee
Fort Dix
Fort Eustis
Fort Gordon
Fort Hamilton
Fort Benjamin Harrison
Fort Jackson
Fort Knox
Fort Leavenworth
Fort Lee
Fort McClellan
Fort Monroe
Fort Rucker
Fort Sill
Fort Leonard Wood

INSCOM - Ch. Instl. Div.

ATTN: Facilities Engineer

Vint Hill Farms Station
Arlington Hall Station

WESTCOM

ATTN: Facilities Engineer

Fort Shafter

MDW

ATTN: Facilities Engineer

Cameron Station
Fort Lesley J. McNair
Fort Myer

HSC

HQ USAHSC, ATTN: HSLO-F
ATTN: Facilities Engineer
Fitzsimons Army Medical Center
Walter Reed Army Medical Center

USACC

ATTN: Facilities Engineer
Fort Huachuca
Fort Ritchie

MTMC

HQ, ATTN: MTMC-SA
ATTN: Facilities Engineer
Oakland Army Base
Bayonne MOT
Sunny Point MOT

US Military Academy

ATTN: Facilities Engineer
ATTN: Dept of Geography &
Computer Science
ATTN: DSCPER/MAEN-A

USAES, Fort Belvoir, VA

ATTN: ATZA-DIE-JM
ATTN: AT/A-DIE-SW
ATTN: ATZA-FE
ATTN: Engr. Library

Chief Inst. Div., IASA, Rock Island, IL

USA ARRCOM, ATTN: Dir., Instl & Svc

TARCOM, Fac. Div.

TECOM, ATTN: DRITE-LG-F

TSARCOM, ATTN: ATSA-F

NARAD COM, ATTN: DRUNA-F

AMMRC, ATTN: DRXMR-WI

HQ, XVIII Airborne Corps and

Ft. Bragg

ATTN: AFZA-FE-LI

HQ, 7th Army Training Command

ATTN: AETFG-DEH (5)

HQ USAREUR and 7th Army

ODCS/Engineer

ATTN: AEAEN-Eh (4)

V Corps

ATTN: AETVDEH (5)

VII Corps

ATTN: AETSDEH (4)

21st Support Command

ATTN: AEREH (5)

US Army Berlin

ATTN: AEBA-EN (2)

US Army Southern European Task Force

ATTN: AESE-ENG (5)

US Army Installation Support Activity, Europe

ATTN: AEUES-RP

8th USA, Korea

ATTN: EAFE

Cdr, Fac Engr Act (R)

AFE, Yongsan Area

AFE, 2D Inf Div

AFE, Area II Spt Det

AFE, Cp Humphreys

AFE, Pusan

AFE, Taegu

DLA ATTN: DLA-WI

USA Japan (USARJ)

Ch, FE Div, AJEN-FE

Fac Engr (Honshu)

Fac Engr (Okinawa)

ROK/US Combined Forces Command

ATTN: EUSA-HMC-CFC/Engr

416th Engineer Command

ATTN: Facilities Engineering

Norton AFB

ATTN: AFRCE-MX/DEE

Port Hueneme, CA 93043

ATTN: Library (Code LDPA)

AFESC/Engineering & Service Lab

Tyndall AFB, FL 32403

Chanute AFB, IL 61868

3345 CES/DE, Stop 27

National Guard Bureau

Installation Division

WASH DC 20310

EHE Team Distribution

Fort Belvoir, VA 22060
ATTN: DRDME-G
ATTN: FESA-TSD
ATTN: Canadian Liaison Officer (2)

Fort Leavenworth, KS 66027
ATTN: ATZLCA-SA

USA ARRADCOM
ATTN: DRDAR-LCM-SP

US Army Engineer Districts
ATTN: Chief, Engineer Division

US Army Engineer Divisions
ATTN: Chief, Engineer Division

Naval Facilities Engineering Command
ATTN: Code 032E
ATTN: Code 1023
ATTN: Code 11130
ATTN: Code 044

Naval Civil Engineering Laboratory
ATTN: Code L03AE
ATTN: Code L08A
ATTN: Code L60

Alexandria, VA 22314
ATTN: DLA-W
ATTN: DRCIS

Army-Air Force Exchange Service
ATTN: Chief, Engineering Div

Andrews AFB, WASH DC 20331
ATTN: AFSC-DEE

McClellan AFB, CA 95652
2852 APG/DE

Patrick AFB, FL 32925
ATTN: XRQ

Tyndall AFB, FL 32403
ATTN: RD

Wright-Patterson AFB, OH 45433
ATTN: POE

Washington, DC
DCNO (Logistics)
ODAS (EE&S)
ODAS (I&H)
HQDA (DALO-TSE-F) (3)
Office of Planning & Dev, OFEPM
Director, Bldg Technology & Safety Div
Public Building Service
Assistant Sec for Conservation & Solar Energy
Assistant Sec for Resource Applications
National Institute of Building Sciences
Director, Center for Building Technology
Energy Research and Development Foundation

Department of Energy
Oak Ridge, TN 37830

Herron, Dale

Comparison of Building Loads Analysis and System Thermodynamics (BLAST) computer program simulations and measured energy use for Army buildings (BLAST validation). -- Champaign, IL : Construction Engineering Research Laboratory ; Springfield, VA : available from NTIS, 1981.

52 p. (Technical report ; E-174)

1. Buildings-energy consumption. 2. BLAST (computer program).
I. Title. II. Series: U. S. Army. Construction Engineering Research Laboratory. Technical report ; E-174.