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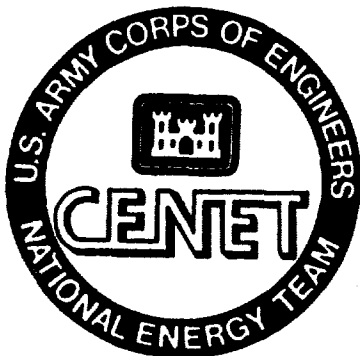
US Army Corps of Engineers
Construction Engineering
Research Laboratories

**TECHNOLOGY
TRANSFER
TEST BED
PROGRAM**

Evaluation of Five Additional Enhancements to the Building Loads Analysis and System Thermodynamics (BLAST) Program

by
Robert J. Nemeth

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The Building Loads Analysis and System Thermodynamics (BLAST) energy analysis computer program has undergone a multiyear enhancement program based on feedback and priorities of the BLAST users' group. This project was conducted to evaluate the convenience and applicability of the following BLAST enhancements:
• Air-to-Air Heat Pump
• Expanded Baseboard Heat Options
• Report Writer
• Thermal Comfort Model
• Ice Storage Model

Evaluation responses indicate that the enhancements satisfied users' needs for advanced building energy analysis tools. Although the evaluations revealed program bugs and the lack of documentation in some areas, the programs were easy to install and use. The bugs have been removed and the documentation expanded in the *BLAST Users Reference*. It is recommended that the enhancements be distributed with future updates and releases of the BLAST program.

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TECHNOLOGY TRANSFER TEST BED PROGRAM

FINDINGS AND RECOMMENDATIONS OF TEST/DEMONSTRATION

WORK UNIT NO./TITLE OF TEST: T^3B, Blast Enhancements Evaluation

PERFORMING LABORATORY: USACERL

PRODUCT/SYSTEM: Additions and improvements to the BLAST program

PERFORMING TEST SITES: The following U.S. Army Corps of Engineers (USACE) Districts: Omaha, NE; Fort Worth, TX; Tulsa, OK; and Mobile, AL.

DESCRIPTION/OBJECTIVE OF TEST/DEMONSTRATION:

The objective of this T^3B Program was to evaluate the convenience and applicability of BLAST program enhancements. The enhancements increase the modeling options, and consequently the breadth of BLAST, and are a direct result of user-requested program modifications. Four Districts evaluated five enhancements to the BLAST program. The objective of the T^3B Program was to verify that the enhancements were implemented in an acceptable and convenient fashion well-suited to Corps District designers' needs.

RESULTS OF TEST/DEMONSTRATION:

Overall, respondents found the enhancements very beneficial to their analytic needs. The enhancements will increase Corps District designers' analytic capabilities to create more comfortable and energy efficient buildings. Most respondents found the documentation supporting the enhancements insufficient, and some found minor bugs in the program.

RECOMMENDATION FOR PRODUCT/SYSTEM:

It is recommended that some of the enhancements be modified per the respondents' feedback and that some of the users' more complex concerns be studied. New documentation has been released since these tests were conducted.

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13. ABSTRACT (Maximum 200 words)

The Building Loads Analysis and System Thermodynamics (BLAST) energy analysis computer program has undergone a multiyear enhancement program based on feedback and priorities of the BLAST users' group. This project was conducted to evaluate the convenience and applicability of the following BLAST enhancements:

•Air-to-Air Heat Pump
•Expanded Baseboard Heat Options
•Report Writer
•Thermal Comfort Model
•Ice Storage Model

Evaluation responses indicate that the enhancements satisfied users' needs for advanced building energy analysis tools. Although the evaluations revealed program bugs and the lack of documentation in some areas, the programs were easy to install and use. The bugs have been removed and the documentation expanded in the *BLAST Users Reference*. It is recommended that the enhancements be distributed with future updates and releases of the BLAST program.

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FOREWORD

This work was performed for Headquarters, U.S. Army Corps of Engineers (HQUSACE) and the Corps of Engineers National Energy Team (CENET) under the Technology Transfer Test Bed (T³B) program, work unit EA-KA1, "Test New BLAST Enhancements," and project 4A162784AT45, "Energy and Energy Conservation," work unit XG2, "Energy Analysis Techniques for Design." The HQUSACE technical monitor was Mr. D. Gentil, CEMP-ET.

The field tests were administered by the Energy and Utility Systems Division (FE), of the Infrastructure Laboratory (FL), of the U.S. Army Construction Engineering Research Laboratories (USACERL). Dr. David M. Joncich is Chief, CECER-FE and Dr. Michael J. O'Connor is Chief, CECER-FL. Participation of the following USACE Districts is greatly appreciated: Omaha, NE; Fort Worth, TX; Tulsa, OK; and Mobile, AL. The USACERL technical editor was Gloria J. Wienke, Information Management Office.

COL Daniel Waldo, Jr., is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

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EVALUATION OF FIVE ADDITIONAL ENHANCEMENTS TO THE BUILDING LOADS ANALYSIS AND SYSTEM THERMODYNAMICS (BLAST) PROGRAM

1 INTRODUCTION

Background

The Building Loads Analysis and System Thermodynamics (BLAST) energy analysis computer program (Hittle 1979) has undergone a multiyear enhancement program based on feedback and priorities of the BLAST users' group. During the annual BLAST planning meeting, certain BLAST improvements supported by the users' group are incorporated into the ongoing BLAST development program. Several of these enhancements have been field-tested (Nemeth 1992) and incorporated into the BLAST program. It is important at this stage to demonstrate additional enhancements in the users' production environment to evaluate their ability to resolve deficiencies and other needs noted by the users' group.

When first introduced in 1977, BLAST required such a high level of manpower and computer power that the program gained the reputation of being difficult to operate. With the completion of several enhancements to improve "user friendliness" and with the availability of powerful personal computers, it is believed that BLAST has overcome these early deficiencies. Whether these improvements are sufficient to change users' earlier opinions about BLAST is an additional focus of this project. Additionally, for all U.S. Army Corps of Engineers design organizations expressing interest, the BLAST Support Office (BSO) is conducting "Jump-Start" training sessions to demonstrate the effectiveness and ease of operation that recent changes and enhancements have made to the BLAST family of programs.

Objective

This Technology Transfer Test Bed (T³B) project is being conducted to evaluate the convenience and applicability of selected BLAST enhancements. The objective of the demonstration is to help determine how well the BLAST enhancement project is serving the general needs of the BLAST users' group regarding ease of use, speed of execution, breadth of application, reliability, and accuracy.

Approach

Four U.S. Army Corps of Engineers Districts (Omaha, NE; Fort Worth, TX; Tulsa, OK; and Mobile, AL) participated in the T³B evaluation. Each District tested enhancements applicable to the types of projects administered by its organization.

Mode of Technology Transfer

It is anticipated that all of the enhancements be distributed with future updates and releases of the BLAST program. The User Reference Section of the *BLAST Manual* (BSO 1991) has been updated and includes documentation on how to use the enhancements. Release of future enhancements will also be announced in *BLASTnews* newsletters, which will contain articles describing their use. Information regarding the distribution of BLAST and *BLASTnews* can be obtained from the BSO, by telephone: (800) UI-BLAST or (217) 333-3977; or by mail at: BLAST Support Office, 30 Mechanical Engineering Bldg., 1206 W. Green Street, Urbana, IL 61801; or by electronic mail at: Support@blast.bso.uiuc.edu.

2 DESCRIPTION OF THE T³B TEST

Researchers asked the participating Districts to select the enhancements most likely ~e used for projects administered by their office. The enhancements were to be tested on current in house design projects; if no current project was applicable, a past or simulated project would suffice.

Following is a summary of the enhance ~nt options evaluated, and the District performing the evaluation.

Enhancement Option	District
Air-to-Air Heat Pump Model	Fort Worth, TX
Report Writer	Omaha, NE
Expanded Baseboard Heat Options	Omaha, NE
Ice Storage Model	Tulsa, OK
Comfort Reporting	Mobile, AL

Districts were given the flexibility to develop test programs but were provided a list of specific issues that were to be addressed in the report submitted to researchers at the U.S. Army Construction Engineering Research Laboratories (USACERL). Appendix A is an example of a test procedure supplied to one of the Districts. Allowing the Districts to develop their own test plans gave them the freedom to use the models as they would in their day-to-day work functions.

The following chapter contains the reports submitted by participating Districts. Responses to questions and concerns are interspersed throughout each report in italics, and were provided by personnel at the BSO and USACERL.

These tests were conducted before development of extensive documentation on how to use the enhancements. The computer program and documentation in outline form was supplied to each participating District. As a result of the sparse documentation, some of the participants criticism was that more documentation would have been helpful. This issue was resolved with more thorough documentation being included in the new User Reference Section of the *BLAST Manual* released at the beginning of FY92.

3   TEST RESULTS

Air-to-Air Heat Pump Model — Fort Worth District

The BLAST air-to-air packaged heat pump model features variable fan operation, backup heat using either hot water or electricity, and a set of input parameters that allows for complete flexibility of heat pump specifications.

A separate program (available from the BSO) allows users to quickly generate accurate BLAST heat pump parameters from manufacturers' catalog data. Two sets of parameters (for a residential and a large heat pump) are included with the model.

Objective

The objective of this study was to test and evaluate the air-to-air heat pump enhancement to the BLAST computer program. To this end, the study of an on-going design project was selected and that study, in part, was reanalyzed to include the heat pump model as an additional alternative design. The original study objective was to determine the most feasible heating, ventilation, and air conditioning (HVAC) system for the Mobility Storage/Training Facility to be constructed at Lackland Air Force Base (AFB), TX. A secondary objective was to evaluate the energy budget figure for each of the considered alternative designs. This analysis concentrated on reprocessing the BLAST analyses involved and thereby evaluating the air-to-air heat pump model.

Facility Description

The Mobility Storage/Training Facility, to be constructed at Lackland AFB, is a single-story 13,243.5 sq ft* facility consisting of the following areas: office rooms 110, 111, and 112 (zone 1), classrooms 106 and 107 (zone 2), classroom 103 and breakroom 104 (zone 3), restrooms 113 and 115 and storage room 114 (zone 4), mechanical room 118 (zone 5), corridor rooms 105, 108, 109, 116, and 117 (zone 6), mobility room 101 and pilferable room 102 (zone 7), and the area above the offices, classrooms, and corridors (zone 8). Figure 1 illustrates a simplified model of the structure. The envelope characteristics were designed to be in compliance with the latest edition of the American Society of Heating, Refrigeration, and Air Conditioning Engineers/Industrial Electronics Society (ASHRAE/IES) Standard 90.1. Table 1 summarizes the envelope characteristics as modeled.

Alternative Descriptions

In the BLAST analysis, the following alternatives were evaluated. Evaluators assigned titles based on local convention to differentiate the computer runs.

1. SZDT-ChW. Single zone draw-through fan systems with an air-cooled chiller for zones 1, 2, and 3. Zone 1 incorporated a return air economy cycle.

2. SZDT-DX. Single zone draw-through fan systems with a direct expansion condensing unit for zones 1, 2, and 3. Zone 1 incorporated a return air economy cycle.

3. TDM-ChW. Three deck multizone fan system with an air cooled chiller for zones 1, 2, and 3.

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*A metric conversion table is on page 30.

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PLAN VIEW OF BUILDING SURFACES.

                              +Y          N
MIN X =    0.00                1          1
MAX X =    163.50         -X--+--+X   W--+--E
MIN Y =    0.00                1          1
MAX Y =    81.00              -Y          S

* = BUILDING SURFACE, + = SHADOWING SURFACE      MOBILITY STORAGE

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Figure 1. Model floor plan.

4. TDM-DX. Three deck multizone fan system with a direct expansion condensing unit for zones 1, 2, and 3.

5. HP. Heat pump fan systems for zones 1, 2, and 3.

For all alternatives, unit heater fan systems for zones 4 and 6 and unit ventilator fan systems for zones 5 and 7 together with hot water heating were simulated. Zone 8 was not controlled nor assigned to a fan system.

Blast Analysis Synopsis

BLAST Input File. Library modifications were included in the BLAST input file to define walls, roofs, floors, windows, and doors in accordance with the latest edition of ASHRAE/IES Standard 90.1. Location and design day data were defined in accordance with Air Force manual (AFM) 88-29. Schedule data were defined in accordance with the energy budget figure facility operating schedule requirements of Air Force Engineer Technical Letter (AF ETL) 87-4. Controls were defined for single zone draw-through, three deck multizone, heat pump, unit ventilator, and unit heater fan systems to be compatible with the previously defined BLAST schedules.

Table 1

Surface U-Values

Construction without film coefficient (Btu/hr/sq ft/°F)	U-Value	
INSLWALL	0.170	
A2: 4 in. dense face brick		2.162
Ins - expanded ext polystyrene 1 in.		0.251
CBLK - 3 CO SGA 12 in.		0.780
E1: 3/4-in. plaster or gyp board		6.720
WINDOW	0.910	
Glass - bronze plate 1/2 in.		10.593
B1: airspace resistance		1.099
Glass - clear plate 1/2 in.		10.593
CONCRETE MASONRY UNIT	0.700	
E1: 3/4-in. plaster or gyp board		6.720
CBLK: 3 CO SGA 8 in.		0.885
E1: 3/4-in. plaster or gyp board		6.720
GYPSUM	0.828	
E1: 3/4-in. plaster or gyp board		6.720
B1: airspace resistance		1.099
E1: 3/4-in. plaster or gyp board		6.720
SLAB	0.095	
Dirt 12 in.		0.100
C13: 6-in. HW concrete		2.000
INSLCEIL	0.046	
B12: 3-in. dense insulation		0.100
B12: 3-in. dense insulation		0.100
E5: acoustic tile		0.560
UNINSLWALL	0.573	
A2: 4-in. dense face brick		2.162
CBLK: 3 CO SGA 12-in.		0.780
DOOR	0.157	
Metal - galvanized steel 1/6-in.		5038.462
Ins - expanded polyurethane R11, 1-in.		0.157
Metal - galvanized steel 1/16-in.		5038.462
UNINSLROOF	5038.462	
Metal - galvanized steel 1/16 in.		5038.462
INSLROOF	0.050	
Metal - galvanized steel 1/16-in.		5038.462
B12: 3-in. dense insulation		0.100
B12: 3-in. dense insulation		0.100
INSLFLOOR	0.046	
E5: acoustic tile		0.560
B12: 3-in. dense insulation		0.100
B12: 3-in. dense insulation		0.100

The eight zones depicted in Figure 1 were described as zones 1 through 8 of the BLAST input file. Controls were provided to effect a heat.ng thermostat setting of 70 °F and a cooling setting of 78 °F with a 10 °F heating only setback on nights and weekends for zones 1 through 3. Heating only controls effecting a thermostat setting of 60 °F with a 10 °F setback on nights and weekends were provided for zones 4, 6, and 7. Zone 5 was provided with heating only to 40 °F constantly while zone 8 was left uncontrolled.

To simulate the restroom exhaust fan operating at 2 cubic feet per minute (cfm)/sq ft, mixing statements in the zone 6 and zone 4 descriptions accounted for the heat transfer from zones 1 through 3 to zone 6 and from there to zone 4. Similarly, to simulate the mobility and pilferable room exhaust fan, mixing statements were included to describe the heat transfer from zones 1 through 3 to zone 8 and from there to the zone 7. The restroom and mobility and pilferable room fan energy consumption was simulated by including zone exhaust for zones 1 through 3 in their fan system descriptions and zeroing the supply fan static pressure of the zone 4 and 6 unit heater fans. Ventilation cooling at 20 air changes per hour in the summer (1 May through 31 Oct) and 10 air changes per hour in the winter (1 Nov through 30 Apr) was provided in the mechanical room. Equipment radiant energy release in zone 5 was simulated by including a nonutility consuming heat gain.

The following fan system descriptions were used:
* System 1 assigns a single zone draw-through fan system with return air economy cycle and chilled water coil to zone 1,
* System 2 assigns a single zone draw-through fan system with return air economy cycle and direct expansion coil to zone 1,
* System 3 assigns a single zone draw-through fan system and chilled water coil to zone 2,
* System 4 assigns a single zone draw-through fan system and direct expansion coil to zone 2,
* System 5 assigns a single zone draw-through fan system and chilled water coil to zone 3,
* System 6 assigns a single zone draw-through fan system and direct expansion coil to zone 3,
* System 7 assigns a unit heater fan system to zone 4,
* System 8 assigns a unit ventilator fan system to zone 5,
* System 9 assigns a unit heater fan system to zone 6,
* System 10 assigns a unit ventilator fan system to zone 7,
* No fan system assignment is made to zone 8,
* System 11 assigns a three-deck multizone fan system with chilled water coil to zones 1, 2, and 3,
* System 12 assigns a three-deck multizone fan system with direct expansion coil to zones 1, 2, and 3,
* Systems 13, 14, and 15 assign air-to-air packaged heat pump fan systems to zones 1, 2, and 3, respectively.

The following central plant descriptions were used:
* Plant 1 assigns a boiler and an air-cooled chiller to fan systems 1, 3, 5, 7, 8, 9, and 10,
* Plant 2 assigns a boiler and an air-cooled chiller to fan systems 2, 4, 6, 7, 8, 9, and 10,
* Plant 3 assigns a boiler and an air-cooled chiller to fan systems 11, 7, 8, 9, and 10, and
* Plant 4 assigns a boiler and an air-cooled chiller to fan systems 12, 7, 8, 9, and 10, and
* Plant 5 assigns a boiler to fan systems 13, 14, 15, 7, 8, 9, and 10.

Including a chiller in plants 2 and 4 is required to provide the compressor and condenser simulations of the distributed direct expansion coil fan systems.

BLAST Design Day Analyses. The input file was processed through zone simulations for a typical winter and summer design day. The design peak zone sensible heating and cooling loads resulting from these analyses are summarized in Table 2. Based on these values, and considering the

loads resulting from these analyses are summarized in Table 3. Based on these values, the boiler, chiller, condensing unit, heat pump, heating coil, and reheat coil sizes, as appropriate for each fan system, were calculated and are included in the table.

BLAST Annual Analyses. The design values of Tables 2 and 3 were inserted into the BLAST input file and the results processed through zone, fan system, and central plant simulations with a year of weather data for San Antonio, TX. The results of these analyses are summarized in Table 4.

Incurred Problems

1. The BTEXT code and documentation were not received in time for this evaluation. The relevant heat pump code had to be inserted into the input file for a single zone draw-through fan system. Some difficulties occurred in trying to interpret the received documentation. Phone calls were required to resolve these difficulties.

Response: The Heat Pump Code has been installed in the main body of the program and is now selected as any other system would be.

2. The documentation was incomplete and contained errors. In HEAT PUMP HEATING PARAMETERS, the EDBDH parameter was indicated as EWBDH. The ending syntax was indicated as END HEAT PUMP COOLING PARAMETERS.

Response: The new User Reference Section of the BLAST Manual was issued at the beginning of fiscal year 1992. The documentation for the Heat Pump model was reviewed and revised before publication.

3. The documentation of the FOR ZONE, OTHER SYSTEM PARAMETERS, and EQUIPMENT SCHEDULES data blocks of the fan system description contained syntax not applicable to the heat pump. This was confusing and sometimes misleading.

Table 2

Zone Design Day Analysis Results

Zone #	Heating/Cooling (KBtu/hr)	OA (cfm)	EA (cfm)	CDSA (cfm)	CDT (°F)	HDSA (cfm)	HDT (°F)	OA/SA (%)	Vent (cfm)
1	4.237 / 12.288	120	120	569	58	569	77	21	
2	3.888 / 12.190	640	640	640	60	640	76	100	
3	3.989 / 9.956	480	480	480	58	480	78	100	
Data from zones 1,2, and 3		1240	1240	1689	58	1689	78	73	
4	1.000 / 0.000		578*			578*	72	0	
5	1.000 / 0.000	0	0			984**	71		1968S, 984W
6	1.000 / 0.000					576**	72		
7	49.460 / 0.000	0	622*			0662	140	0	
8	0.000 / 0.000								

Headings: OA=outside air requirements in accordance with ASHRAE 62; EA=exhaust air; CDSA=cold deck supply air; CDT=cold deck temperature; HDSA=hot deck supply air; HDT=hot deck temperature; OA/SA=outside air/supply air.
*Simulated in zones 1, 2, and 3.
**Zero supply fan static pressure.

Table 3

Zone and Fan System Design Day Analysis Results

System #	System Name	Zone #s	Heating (KBtu/hr)	Coil Size (KBtu/hr)	Cooling (KBtu/hr)
1	SZDT-ChW	1	9.030	10	20.271
2	SZDT-DX	1	9.030	10	18.978
3	SZDT-ChW	2	31.524	36	40.508
4	SZDT-DX	2	31.524	36	33.061
5	SZDT-ChW	3	24.715	28	32.227
6	SZDT-DX	3	24.715	28	28.087
7	UH	4	0.000	1	--
8	UV	5	0.000	1	--
9	UH	6	0.000	1	--
10	UV	7	49.217	57	--
11	TDM-ChW	1,2,3	64.786	75	92.411
12	TDM-DX	1,2,3	64.786	75	89.125
13	HP	1	15.205	--	18.451
14	HP	2	31.891	--	27.628
15	HP	3	24.990	--	21.592

Plant #	Plant Name	System (KBtu/hr)	Heating Equipment (KBtu/hr)	Cooling Equipment*
1	SZDT-ChW	1,3,5,7,8,9,10	135	24+42+36=102
2	SZDT-DX	2,4,6,7,8,9,10	135	24+36+30=90
3	TDM-ChW	11,7,8,9,10	135	96
4	TDM-DX	12,7,8,9,10	135	90
5	HP	13,14,15,7,8,9,10	57	--

* These values are the correct design values used in the original study. For this analysis, these values were changed to 100 KBtu/hr each because of several hours of extreme temperature in the annual weather data file.

Response: The nonapplicable syntax has been removed from the documentation.

4. It was not clear just what program code was received and how it was to be installed. Phone calls were required to resolve these difficulties.

Response: This has been resolved by installing the code in the main body of the program.

5. Most of BLAST code for zone and fan system simulations was based on physical laws and modeling of those laws. With the DX and HEAT PUMP PACKAGED UNITs, the black box methodology is being introduced (the central plant simulations have always been black box). This approach, unfortunately, almost always limits simulations to repetitions of already known facts, and inhibits experimentation and research into unknown and untried areas. Its adoption is, therefore, an undesirable feature of these enhancements and a severe restriction on their possible use.

Response: The black box methodology referred to is nothing more than a curve fit. Curve fit methodologies are well documented in the BLAST technical references. Central plants have always been modeled by using curve fits and both the DX and HEAT PUMP PACKAGED UNIT are modeled similarly. In essence, the DX and HEAT PUMP PACKAGED UNIT are small central plants modeled as fan systems, thus the similar analytic methodologies.

Table 4

BLAST Annual Energy Analysis Summary*

Plant #	Plant Name	Electric (MBtu/yr)	Natural Gas (MBtu/yr)	Energy Budget (KBtu/sq ft-yr)
1	SZDT-ChW	150.0	49.5	15.0
2	SZDT-DX	148.0	49.5	14.9
3	TDN-ChW	152.0	45.9	14.9
4	TDM-DX	152.0	45.9	14.9
5	HP	197.0	5.71	15.3

*Does not include domestic water energy consumption.

6. The Air Force energy budget evaluations, and most other energy analysis processes, require that each utility consumption estimate be categorized by load component: heating, cooling, ventilation, lighting, domestic water, and process. With BLAST, this has not always been easy. With the distributed DX and heat pump coil enhancements, the present fan system and central plant reports have been, and possibly will continue to be revised. The new reports make utility consumption estimating even more difficult. BLAST reports should be revised so each utility can be traced to its end use. The reports should present the following information:

Zone Simulation:
Heating Peak and Total
Heating Electric Peak and Total
Heating Gas Peak and Total
Cooling Peak and Total
Lighting Peak and Total
Ventilation Electric Peak and Total (Ventilation Cooling)
Process Electric (Zone Electric) Peak and Total
Process Gas (Zone Gas) Peak and Total

Fan System Simulation:
Heating Hot Water and Steam Peak and Total
Heating Electric Peak and Total (Including Packged Heat Pump)
Heating Gas Peak and Total
Cooling Chilled Water Peak and Total
Cooling Electric Peak and Total (Packged DX and Heat Pump)
Lighting Peak and Total
Ventilation Electric Peak and Total (Including Supply, Return, and Exhaust Fans)
Process Elec Peak and Total
Process Gas Peak and Total

Central Plant Simulation:
Heating Purchased Hot Water and Steam Peak and Total
Heating Electric Peak and Total (Including Distribution Heat Pump Compressor and Condenser,
    Electric Boiler, Hot Water Pump, and Boiler Fan and Controls)
Heating Gas Peak and Total
Boiler Fuel Peak and Total Cooling Purchased Chilled Water Peak and Total

Cooling Electric Peak and Total (Including Dist Heat Pump and DX Compressor and
    Condenser, Chiller, Condenser Pump and Fan, and Chilled Water Pump)
Lighting Peak and Total
Ventilation Electric Peak and Total
Domestic Water Electric Peak and Total
Domestic Water Gas Peak and Total
Process Electric Peak and Total
Process Gas Peak and Total

Thus, with almost an identical format, the above 12 parameters (peak and total) could be displayed for each zone, fan system, and central plant. The values would be displayed as hourly values for design day analyses and as monthly values for annual analyses in a one-page report. This would reduce the present BLAST output to a simple, highly useful form.

Response: Enhanced reports incorporating some of these suggestions will be in the next release.

7. The humidity report header always prints out at the bottom of the fan system summary report creating an additional unnumbered page with the title "FRACTION OF OUTSIDE AIR VALUES ARE BASED ON SYSTEM OPERATING HOURS ONLY!" even when this report is not requested or required.

8. The REHEAT COIL LOADS title of the fan system coil loads report prints out at the bottom of the first page while the values are always located on the second page.

Response: Telephone conversations with the BSO resolved both of these printing problems.

9. A significant amount of psychrometric error conditions occur before each of the heat pump fan system simulation outputs. In previous studies, this has also occurred with the distributed DX coils.

Response: Psychrometric errors (and ways to avoid them) are discussed in detail on pages 1124 and 1125 of the User Reference Section of the BLAST Manual, volume 2. The errors encountered in this particular study related primarily to calculation of the humidity ratio. These errors either indicate that condensation has occurred in the system ductwork or that the air is completely dry (depending on the warning message that accompanies the error). In either case, BLAST resets the humidity ratio within a valid range and continues the simulation.

10. Corrections have been made to the distributed DX coil fan system simulation such that a chiller is now required in central plants to effect the compressor and condenser portions of the system. The BLAST input file had to be corrected and reprocessed to include chiller specifications to rid the analysis of unmet plant loads. To the typical designer, this is completely illogical. No designer would pair distributed DX coils with a centrally located chiller. Rather, a centrally located condensing unit (compressor and air- or water-cooled condenser) would be used. Thus BLAST must be provided with an AIR COOLED COMPRESSOR/CONDENSER and a COMPRESSOR WITH condenser type (COOLING TOWER, WELL WATER CONDENSER, or EVAPORATIVE CONDENSER) models.

Response: These suggestions will be considered for future modifications.

BLAST Heat Pump Model Evaluation

1. Once the source code was correctly installed and the appropriate input syntax was determined, the packaged heat pump model worked well except for a significant number of psychrometric problems.

Since source code documentation was incomplete, additional review comments concerning the code installation, BTEXT installation and usage, and heat pump input syntax are not offered. However, it is recommended that the psychrometric problems associated with the heat pump model simulations be given greater study to determine their impact and possible resolution and elimination.

Response: Psychrometric errors (and ways to avoid them) are discussed in detail on pages 1124 and 1125 of the User Reference Section of the BLAST Manual, volume 2. The errors encountered in this particular study related primarily to the calculation of the humidity ratio. These errors either indicate that condensation has occurred in the system ductwork or that the air is completely dry (depending on the warning message that accompanies the error). In either case, BLAST resets the humidity ratio within a valid range and continues the simulation.

2. Because the black box methodology used for both the packaged heat pump and DX fan systems almost always limits experimentation and research into unknown and untried areas, it is further recommended that future developments return to the modeling of physical laws for all fan systems, and that the heat pump and DX fan systems be updated as soon as practical.

Response: The curve fit methodologies reflect standard industry design procedures. These methodologies do allow experimentation. The computation time required to execute analytical models is inordinate.

3. The BLAST output is both massive and unsuitable for the typical designer. This problem is not restricted to the heat pump model, but is emphasized by it. Recommendations for a completely new, reduced size output format are detailed in the section entitled Incurred Problems (page 11). It is strongly recommended that this output format be given immediate attention and plans to incorporate this format be initiated. The massive amount of hand calculation and estimation that must be performed with each BLAST analysis to extract the required information needs to be reduced.

Response: As recommended, a new condensed report is being developed for the new release.

4. The need to include a chiller for the distributed DX and future heat pump fan systems is illogical to most designers. These fan systems would naturally call for an air- or water-cooled condensing unit (compressor/condenser combination equipment). New modeling must be added to the central plant code to support these capabilities. It is therefore recommended that, before issuing the BLAST heat pump model code, an AIR COOLED COMPRESSOR/CONDENSER and a COMPRESSOR WITH condenser type (COOLING TOWER, WELL WATER CONDENSER, or EVAPORATIVE CONDENSER) model be added to the central plant.

Response: These suggestions will be considered for future modifications.

Expanded Baseboard Heat Options and Report Writer — Omaha District

The thermostatic baseboard heat option has been changed to increase the flexibility and usefulness of the model. The baseboard heat option in the fan specifications data block can now be used with any of the BLAST fan systems. Additionally, the new model allows the baseboard heater to provide heat to a zone without turning on the system fans.

Where available, the baseboard heater will supply heat to reduce or eliminate any unmet load or overcooling load generated by the system. When used in conjunction with a heating or reheat coil, baseboard heat acts as a supplementary heat source that is independent of air flow, hot deck temperature,

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or reheat tempera.ure limit. It can also be used as the sole source of heat for a zone. If baseboard heat is available and the system is off, a heating load will not turn the system on. The baseboard heater will attempt to meet the load without operating the system. If the baseboard heater capacity is insufficient to meet the load, an unmet heating load will be recorded.

Objective

The purpose of this test was to evaluate ,ertain aspects of the BLAST Report Writer and the Enhanced Thermostatic Baseboard Heat enhancements. The first and most important issue was to determine if the enhancements were easy to use and if any problems were encountered trying to execute the programs. The output from these enhancements was evaluated to determine if it contained appropriate information in an easy-to-read format. Lastly, a selected commercial program was to be compared with the BLAST model; the comparison was not performed because no commercial program has the same capabilities.

Procedure

All computer simulations were run with an IBM personal computer (PC) 20386 using BLAST Version 3.0. All BLAST input decks were generated using BTEXT. The model buildings used for the tests were kept relatively simple so the enhancements could be examined more easily. The following test runs were conducted for the analysis. Each test was conducted for an annual run using the Ellsworth, SD, weather file. The file names are given in parentheses after each test number.

Test 1 (TTTB1). A small three-zone building maintained between 70 and 76 °F during the day with a night setback temperature of 55 °F. The system and the heating and cooling coils were scheduled to be off during the night setback. The thermostatic baseboard heat was scheduled to be on continuously.

Test 1a (TTTB1A). This test was the same as test 1 except the system and the heating and cooling coils and the thermostatic baseboard heat were scheduled to be on continuously. The heating coil capacity was set below the peak heating demand.

Test 2 (TTTB2). This test was the same as test 1 except the thermostatic baseboard heat was scheduled off. The central plant was resized compared to test 1.

Test 2a (TTTB2A). This test was the same as test 2 except that the thermostatic baseboard heat was scheduled on. This test was for comparsion with test 2.

Test 3 (TTTB3). This test involved a new building where the core zone does not require heat. The system is scheduled on during the day and provides cooling only to the core zone. All heating required by the perimeter zone is supplied by thermostatic baseboard heat. At night the system is scheduled to be off.

Thermostatic Baseboard Heat Results

Test 1 was used to see how the Thermostatic Baseboard Heat (TSTAT) worked when used as the source of heat during the night when the system is turned off. The TSTAT was scheduled on continuously but only operated during the hours the system was scheduled off. It was never on while the system was running. It was shown that the TSTAT would run only when there was a heating load that was not met by the fan system.

Test 1a was used to check if the TSTAT would compliment the fan system heating coils if the coils could not meet the entire load. The heating coil capacity had been set at 25,000 British thermal units (Btu) and the peak load on the heating coil was 79,070 Btu. The result was that the peak capacity of the heating coils had been exceeded. This was shown in the coil loads report in the BLAST output. However, the TSTAT never ran to make up the heating load unmet by the heating coils. The unmet load by the heating coils was not reported in the Fan System Underheating report. It appeared that the TSTAT would not operate if the system was scheduled on, even if there was a need for supplemental heat.

Response: Coils cannot be capacity limited and TSTAT cannot be used in this manner. Coils are of infinite capacity and will accept all of the load and pass it on to the central plant. TSTAT only responds to underheating in loads if one of three conditions is met: (1) underheating occurs when there is insufficient airflow to the zone, (2) when the deck temperature is too low, and (3) when the heating coil is scheduled off.

Test 2 was conducted for comparison to test 2a. Test 2 created the following problems in the output due to the system being turned off at night:

Fan System Underheating,
Fan System Overheating,
Heating Without Demand, and
Cooling Without Demand.

A heating load was created by having the controls set at 55 °F during the night, but no heat source was specified to meet this load. The TSTAT was then used to evaluate how it compensated for the problems listed above that frequently occur in the output of BLAST runs.

Response: The listed problems are frequently the result of a loads and systems mismatch as specified by the modeler.

Test 2a added TSTAT to eliminate all the undesired conditions experienced in test 2. Examining the TSTAT loads in the coil reports and comparing them to the loads associated with the conditions in test 2 pr· ·ced an interesting correlation. The TSTAT load for each zone in test 2a was equal to the combination of the heating demand for the zone during the times of fan system underheating and fan system overheating in test 2. The hours of underheating and overheating equaled the hours of TSTAT consumption as well. The TSTAT must have run only for the times that these two conditions had occurred.

Test 3 used TSTAT to heat perimeter zones appeared to have performed adequately using the BLAST simulation. The TSTAT operated at times when the system was scheduled on, but the heating coils were always scheduled off. Instead of being able to run only when the system was off, TSTAT was dependant on whether the heating coils were scheduled off.

TSTAT Summary

Use of the thermostatic baseboard heat model needs to be defined more precisely. Confusion exists regarding the distinction between the thermostatic baseboard heat model and the baseboard heat option in the zone scheduled loads of BTEXT. It was obvious after experimenting with each one that they are not related in their effects on the system. The TSTAT works through the fan system and operates according to the control profile specified for the zone. The baseboard heating option is controlled by outside temperature and is treated entirely as a zone load instead of a system load. The

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BLAST output lists the outside temperature controlled baseboard heat in the zone loads and in the coil loads, but does not include its consumption in "heating provided by the system." The TSTAT is shown only in the coil loads and its consumption is included in "heating provided by the system." It is necessary to make this distinction clear to the user.

Response: The new BLAST documentation clarifies the difference between thermostatic baseboard heat and the baseboard heat option in the zone scheduled loads.

The User Reference Section in the *BLAST Manual* should outline how each form of baseboard heat contributes to the energy budget; as a zone load or a system load. The TSTAT should be an available input in BTEXT under the FAN DESCRIPTION section. This would be more convenient and remind the user of the differences between the two types of baseboard heat since each one would be encountered in BTEXT under different sections. As it is now, a fan system has to be declared in BTEXT to get the TSTAT option in the input deck.

This raises the question of what to do for a zone that is heated only and that heat is to be thermostatic baseboard heat. The current method mandates that a fan system has to be chosen along with an air supply in cubic feet per minute so TSTAT can be used. There should be a method of installing TSTAT without having to enter a complete fan system to accommodate cases such as this. The option to install TSTAT without a fan system should be made available in BTEXT.

Response: A fan system must be specified for BLAST to account for the energy used by TSTAT during the system simulation. This is due to how BLAST internally keeps records. However, the fan system can be configured for heating such that it will never run if heating by Thermostatic Baseboard Heat only is desired.

Report Writer

The new BLAST Report Writer allows BLAST users to custom design hourly reports in either tabular or spreadsheet readable format. Using the Report Writer, BLAST simulation results are saved either in a standard table format or as an ASCII file that can be easily read by spreadsheet and graphing programs (such as Lotus or Excel). Report Writer facilitates the analysis and presentation of simulation results in engineering reports.

1. The User Reference Section in the *BLAST Manual* does not fully explain how to implement every function within the command file. It does not explain to the first time user where or in what sequence the variable function descriptions are to be placed in the command file. Only one example file is shown and it demonstrates the use of only two function descriptions. This example is clear in the placement of the period string (e.g., DAILY) but there is no mention of the exact location where the CUT and SLICE functions are to be placed.

Response: Syntax examples have been added to the new BLAST Manual.

2. It was assumed the CUT and SLICE functions are used in the same manner as the period string functions; inserted after the line declaring the variable. This was the proper position. In cases when the CUT command was used with a period string, placement before or after the period string produced different results. For example, when CUT was placed one line before DAILY AVERAGE, the output created was truncated by one less day than what was specified. When CUT was placed the line after DAILY AVERAGE, the full set of days was listed in the output file. This subtle difference occurred for every case. The CUT command was used with date strings that included the day and hour, and others that included only the day.

These conflicts in the output according to the positioning of the function commands created some doubt as to whether or not the rest of the file was formatted properly whenever a discrepancy occurred between the output and input files. Because the User Reference Section of the *BLAST Manual* does not detail the proper format, it was difficult to tell whether the discrepancy occurred because of the format or because of an error in the program itself.

The User Reference Section of the *BLAST Manual* also gives an example of a series of commands that does not function properly. The following was given as an example of a command file:

```
VARIABLE
  TEMP%SURFACE(2) T2 5
  DAILY MINIMUM
  DAILY MAXIMUM
END
```

This example shows that more than one output can be specified for one variable listing. This command block was run within the command file. The Report Writer program only recognized the first function, DAILY MINIMUM, specified after the variable. The daily minimums were listed but the daily maximums did not appear in the output. Report Writer would not give two different outputs for the same variable if it was listed only once in the command file. To print different outputs of the same variable, the variable has to be listed separately for each output. An example of the correct way to format the request is shown below:

```
VARIABLE
  TEMP%SURFACE(2) T2 5
  DAILY MINIMUM
VARIABLE
  TEMP%SURFACE(2) T2 5
  DAILY MAXIMUM
END
```

Response: Documentation describing how to use Report Writer was expanded for the new BLAST manual. Furthermore, a program named "Report Writer File Generator (RWFGEN)" was created to produce the command file with the proper syntax.

3. All the function commands except for the SLICE command worked accordingly when used properly. SLICE and the HOURLY/dd-dd functions were the only ones that did not perform properly no matter how they were used. After many attempts to use these two commands in varying ways without success, the BSO was consulted and confirmed that the SLICE and HOURLY/dd-dd functions were not working properly within Report Writer. They tested the functions and were going to update Report Writer once they had fixed the problems.

One other error was uncovered during the evaluation of the Report Writer. It occurs within the column explanation heading in the output file. The description of the variables is frequently inter-changed with the other variables in the output. Thus, the description does not match the variable declared for that column, but the variable name and the data associated with it are matched up correctly within the table.

Response: All of the errors found by Omaha were fixed in Report Writer.

4. A few additions to the Report Writer that would make it easier to use and understand. The most noticeable aspect of the output files created using the Report Writer is the absence of any units for the data. The values are listed in the tables for all the variables, but the output lacks units describing the values. The user must determine if the units for the variables are the same as those in the BLAST output file. Including units, at least in the description of the variables in the heading of the Report Writer output, would make the entire file much easier to read and understand.

Response: All of the variable units have been added to the Report Writer documentation; adding units to program output could be added in the future.

5. One other change in the output file would make it more useful and easier to understand. Report Writer prints the value -9999 for SYSTEM and ZONE IN SYSTEM variables when the system is off. There are instances when it is important to look at these variables when the system is off; thermostatic baseboard heat is a good example. TSTAT is used sometimes for nighttime heating when the system is turned off. If the nighttime operation of the TSTAT was examined using Report Writer, the output would show nothing but -9999 for every hour. In other cases where the variable being looked at is in operation when the system is both on and off, the reporting of the averages or maximums and minimums is unrealistic. The value of -9999 for every hour the system is off is incorporated into the calculation of the daily averages and the maximums and minimums. It would be very helpful and more beneficial if the actual values for variables were printed out for the times the system is off.

Response: The -9999 field is printed not just because the system is OFF, but to discern that variables are undefined and their values cannot be used. In an operating system, these variables could be determined; however, during a computer simulation, values for systems that are OFF are not calculated, thus they are impossible to report. The error of including the -9999 values into the daily averages and max/min values has been fixed.

Conclusions

1. The Thermostatic Baseboard Heat Model for BLAST seems to respond and work properly as a heat source when the heating coils are scheduled off. TSTAT would resemble actual use better if it could be used in conjunction with the heating coils.

Response: This can and will be done when improved coil models are put into BLAST systems.

2. Another realistic application would be the use of TSTAT in a small building without a fan system if only heating was required. The controls of the TSTAT should be independent of the fan system status. Baseboard heat should be controlled by the thermostat. Baseboard heat controlled by outside air is not commonly used. Therefore, it is suggested to eliminate the outside air controlled baseboard heat and modify the thermostatic baseboard heat.

Response: It is possible to control TSTAT by a thermostat in Integrated BLAST (IBLAST)*, but BLAST has no thermostat.

3. Report Writer can be very helpful in understanding the output generated from BLAST. The ability to use Lotus and potentially Excel, appears to be extremely advantageous for those who want to view the output in graphic form or to tailor it to their individual needs. The Report Writer output was used with the Lotus program; Excel was not available. The experimentation with Lotus worked very

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* IBLAST is a new version of BLAST in which the Loads and Systems simulating routines are integrated, rather than separate as in BLAST.

well in being able to manipulate the output. The capabilities of the Report Writer program are desirable, but the bugs must be worked out before the user will be totally confident in its use. It will also help the user if the User Reference Section of the *BLAST Manual* is updated and provides more detailed descriptions of how each function is used.

Response: The documentation sent out with the new release should resolve most questions.

Thermal Comfort Model — Mobile District

The BLAST program was recently enhanced to include three popular thermal comfort models developed by P.O. Fanger, the J.B. Pierce Foundation, and researchers at Kansas State University. All three apply an energy balance to a fictitious person in the space being modeled. The energy exchanged between the zone and its occupant is used, along with empirically derived physiological parameters, to predict the thermal sensation and the physiological response (or satisfaction) of a person due to environmental conditions. This is a powerful tool in that it appraises numerous parameters that affect occupant satisfaction with the surroundings rather than focusing only on air temperature. It also allows the designer to model various design options and mechanical operational strategies to assess how these would affect occupant comfort without ever having to dedicate anything more than computer time and effort.

The test model consisted of an aircraft hanger being designed for Eglin Air Force Base, Florida. However, Birminghan, Alabama weather data was used. The test consisted of multiple runs of the program modifying only the summer ventilation rate, which changed the relative air velocity in the facility, which changed thermal comfort levels.

Thermal Comfort Model Results

The overall content and format of the Thermal Comfort output reports were good. The data in the reports would be very beneficial in helping to make judgements and decisions regarding thermal comfort. The "partial pressure of water vapor" column would be more relevant if these values were converted to percent relative humidity.

Response: The model is not defined for relative variables. Moisture calculations are passed on as a definite quantity like partial pressure, not a relative variable such as relative humidity.

No comments are provided on the contents and format of the BTEXT input and default parameters related to the model because BTEXT is not frequently used.

It would be beneficial to including a carbon-dioxide concentration calculation in the output report per equation D-1 in appendix D of ASHRAE 62-89. If the thermal comfort inputs are entered, all the data required for this calculation is available.

Response: This suggestion will be considered for future modifications.

The required input parameters/values are readily available either from the ASHRAE Handbook of Fundamentals or the User Reference Section of the *BLAST Manual* for the BLAST Thermal Comfort Model. This model is one of the easiest to use inside the BLAST program. Output from the model is easy to read and very useful for judging thermal comfort levels. No other program from any source addresses the issue of thermal comfort. This is another BLAST original; a one-of-a-kind diagnostic tool for the HVAC engineer. While some may question the need for such a report, it enhances the status and

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uniqueness of the BLAST program while providing a model for situations where thermal comfort could become a prominent design issue.

Conclusions

The executable "comfort" version of BLAST performed flawlessly while producing the "tcrpt.dat" data file. Visual inspection of the file contents revealed no unusual items. After invoking the "comanl.exe" comfort analysis program, the appropriate output report was rapidly produced. No bugs or problems were encountered during any of the procedures. The output report provides an excellent summation of thermal comfort levels to the user, categorizing the two most important features of thermal comfort, temperature and humidity, in a way that is better understood.

Ice Storage Model — Tulsa District

The BLAST ice storage model was developed to simulate two types of ice storage configurations; the ice-on-coil storage unit, and the ice shucker (also referred to as the ice harvester). Both use a vapor compression refrigeration cycle but different methods for ice production. The evaporator for the ice-on-coils unit is composed of tubes that are submerged in a tank of water. As the refrigerant is cycled through these tubes, ice forms on the coils. The evaporator for the ice shucker is composed of thin flat plates. Ice forms on these plates and is periodically removed by allowing hot gases to flow around them.

This model allows the designer to investigate the effect of implementing an ice storage system. Rather than operate a chiller during on-peak electric rate time periods, the facility can now be modeled with an ice storage system that can take advantage of off-peak electric rates.

Purpose

This study was done to determine the ease of using the BLAST ice storage module and to compare it to at least one commercially available model. Procedures, input, and output that are not necessarily unique to the BLAST ice storage simulation model are discussed to provide an overall comparison.

Background

The commercial software used is part of the Trane Company's popular Trace energy simulation program. The original plan was to use BLAST and Trace simultaneously to study buildings at the McAlester Army Ammunition Plant (AAP), OK. The BLAST models were completed after the Trane models were running. The BLAST model was late in completion both because the ice storage program arrived later than expected and because data needed for the ice storage models was difficult to obtain. True ice-on-coil data was not available and equipment distributors and manufacturers are slow in providing information that may not lead to a direct sale.

McAlester AAP Building 4 was arbitrarily selected as the basis for this study. To the degree possible, the Trace and BLAST models were the same. The degree of similarity is limited because each program handles surface loads, temperature drift, infiltration, and some scheduling differently. Trace loads were closest to the loads calculated by BLAST when Trace used the cooling load temperature difference (CLTD) method.

In an attempt to keep the evaluation simple, separate runs were done for each case rather than using the program's ability to simulate several equipment options. This allowed one chiller plant to be tested at a time. It also prevented excessive time lost while waiting for data.

Because the original study was to investigate the benefit of full storage, the full storage option was used. This option also was also used because it made it easier to determine how well the simulation of the ice storage equipment worked.

Loads from people and lighting were based on actual data. Items such as outside air and exhaust were based on the original design criteria. Infiltration was estimated.

Input Ease

Both the Trace and BLAST programs guide the user through the necessary input. Trace input is in a page format that allows the user to see the related data all at once. It checks input data as it is entered. Sometimes the program decided the correct input was not acceptable. Usually, however, provision is made to allow the user to override the input checker. A somewhat less aggressive checker would be appreciated. The BLAST input is easier to edit if one has the patience to wait to edit it until after BTEXT produces the .BIN file. The file allows the user to use a search command to go directly to the item to be modified without paging through input or having to look up a location code.

A minor disadvantage to BLAST is that after the input file (.BIN) is edited, BTEXT cannot be used to edit the file or to make additions to it. This problem can be solved by using BTEXT to generate the desired input and using an editor to place the new data in position in the .BIN file. This technique is quicker and simpler than it sounds and could be used routinely for equipment and plant data. It may be worth the effort to set up equipment files that can be pasted into an input file.

Input Common to Both BLAST and Trace

Surfaces and Schedules. The surface and zone input are similar. Both programs have extensive libraries of standard surfaces and schedules. A major source of error among users of both programs is the proper assignment of schedules. The BTEXT schedule generation and modification seemed easier to use than the Trace schedule generation and modification utility.

The BLAST level 5 user must be careful to avoid negative volumes, which result in long run times, unreadable results, and run-time errors, usually a memory failure. Although there is no significant difference in the complexity of the input, BLAST input allows more flexibility in simulation.

Plant Equipment. Trace's input for equipment is much simpler than BLAST's input; two methods are available. The equipment may be selected from a standard library or a utility may be used to modify a standard library entry to approximate a different piece of equipment. The level of confidence in Trace's ability to simulate an ice harvester by using a Calmac* model with a modified kilowatt per ton (kW/ton) input alone is limited.

Although it is easier to use Trace standard library equipment, it is also very easy to make an error in selecting the correct item (e.g., inadvertently using a heat reclaim chiller rather than a regular air-cooled chiller). BLAST users are less likely to make equipment selection errors since equipment is selected by providing the appropriate coefficients from catalog data.

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*Calmac is a manufacturer of thermal storage systems.

BLAST users should use reasonable values for the design option to avoid a memory failure type of run-time error. Initial values for the equipment sizes must not be too much greater than the required size. It is easy to specify a size that was too small for the initial guess.

Controls. Controls in Trace are not as sophisticated as they are in BLAST. Exhaust fans, for example, cannot be controlled independently. Although neither program can provide for every conceivable possibility, the Trace user can decide which error is most acceptable more often than the BLAST user.

BLAST Input Variables

CONDCP. This input is not as straightforward as it seems. CONDCP and QBASE appear to be the same except for units. The use of this variable in the calculations is not apparent and it is not apparent if the rating temperature makes any difference.

Response: Yes, CONDCP is the same as QBASE. It is used to calculate the heat rejection factor as shown in the technical reference. QBASE is the rated condenser capacity. The model does not appear to account for temperature differences.

CONTYP. This input is straightforward.

COMPCP. This appears to be essentially the same as RCAP; that is what was used.

Response: Yes, both are the nominal rated capacity of the compressor.

REFTYP. Input for REFTYP is fairly straightforward. It appears that one would have to do a new curve fit for a piece of equipment that was to be modeled with another refrigerant even if the new refrigerant is on the list.

Response: Anytime you use a different refrigerant, performance changes.

BGNPEAK, ENDPEAK. Although this input is straightforward, it is not adequate for scheduling ice generation. Because rate schedules may be a function of time of day during the peak cooling season, provisions should be made to include this effect. For example, at Tulsa, OK, the time-of-day rate for peak hours is three times that of the night/evening rate, and one and one-half times as great as the off-peak rate. It is recommended that the present on/off control scheme be retained as a default and that a more sophisticated on/off schedule be incorporated later. The more sophisticated schedule would affect the balance among storage size, chiller size, and power cost for all models in which the chiller is to run only when the least expensive power is available.

Response: This is a good idea for a possible future enhancement and should be evaluated to minimize difficulties arising from the number of possible strategies.

COMPEF. The COMPEF input should be equal to 1.0 in almost all cases. The efficiency should normally be accounted for in the curve fitting process. There may be rare occasions in which a designer may wish to use a number other than 1.0. It is recommended that the library default be 1.0.

ITGAIN. A rough heat gain can be calculated easily using this input, although it will be close to the library default. The library default is different from the value in the manual. The value in the manual appears to be excessively generous.

Response: Values in BLAST, BTEXT, and the User Reference Section of the BLAST Manual are all the same. That shown in the technical reference is an example but will be changed to reflect the default.

IHARLS. The value of IHARLS should be set to 0.0 as a default. IHARLS would be a nonzero value only if the user specifically selected another value. A value other than zero may be useful in some diagnostic cases.

Response: The default setting is 0.0 for the ice-on-coil model and nonzero for the ice harvester.

ICEPAR1, ICEPAR2. These inputs would be more useful if the user knew what energy was assumed to be consumed by specific parasitic loads.

Response: This is described on pp 979 and 980 in the technical reference.

CONDEL. This input is well defined.

OPFAC. OPFAC is not an input, but it appears to be a fixed error source. It appears to assume a three-step unloading process for the condenser. It would be more reasonable to give the user control over this item. If evaporative condensers with variable speed fans are used, the curve will be cubic or "saw tooth cubic." Sometimes two-speed fans are used. If this is the case, several unequal steps of cooling power consumption are used. Sometimes only one fan and one speed are available. It is suggested that the present system be retained as a default and that more useful options be provided. It should be noted that fan control systems can have a very good payback if properly selected.

Response: This should be a fairly straightforward enhancement at a later date.

ICECTL, PSHAVE. These inputs were simple, however, each option should be illustrated with a schematic showing the general equipment locations and the locations of the load service and return.

Response: This could be included in the next documentation release.

STORE1. The evaporator temperature should be a function of the water temperature going through or over the heat exchanger surface. For the ice harvester operated in full storage mode or for modes in which ice building occurs when no coil load is present, C2 and C3 will normally be zero. For cases in which the ice storage chiller is operating simultaneously with a coil load, the evaporator temperature will probably be:

TEVAP = f(coil load) + reference temp.

The ice on coil evaporator temperature would probably be most accurately represented by equation 2.1 of the BLAST ice storage manual in all instances as long as there is ice in the system.

It appears that for two reasons, the ice-on-coil system can be used to model the Calmac system with the same limitations that apply to the ice harvester. First, in examining the Calmac output, it can be seen that charging temperature, and therefore the evaporator temperature, is a function of the amount of ice stored. Second, ice is built up on the outside of a tube. The heat transfer is not as direct as the true ice-on-coil, however, the process of curve fitting should, by its nature, include the heat transfer idiosyncrasies adequately. Unfortunately the problem of inaccurate evaporator temperature for any case in which chiller operation and coil loads occur simultaneously adversely affects this model too.

Response: This issue needs to be investigated further. The equation for the TEVAP works well for the ice-on-coil system and the ice harvester, except as noted, when the ice harvester is not actually producing ice solely. However, the suggested correction (TEVAP = f(coil load) + reference temp), while a better representation for that one case, is not valid either. The problem requires a review of manufacturer's data. A Project Modification Request form (PMRF) will be submitted. Note: the current ice storage models should not be used to simulate the Calmac ice tank system. The charging temperature is not simply a function of the amount of ice stored. While physically similar to an ice-on-coil system, there are several key differences. Work is currently being completed under separate funding (non-Corps) to allow the modeling of "indirect ice storage" systems such as the Calmac tank.

STORE2. The set of constants that comprise this equation are not easily obtained for an air-cooled system. A reasonable approximation may be obtained by assuming a 10 degree temperature difference between the condensing temperature and the ambient temperature for air-cooled systems.

When water-cooled chillers are modeled, care must be exercised to assure that they are modeled correctly. Many catalogs do not use constant flow rates as the condenser water temperature is varied. It may be necessary to do a considerable amount of interpolation to get a reasonably accurate curve.

STORE3 THROUGH STORE9. This input is difficult. Most spread sheets have matrix solving functions that should work.

CPUMP. Too little is known about the inputs for this pump. If the same pump is used for the water circulated to the load, this may result in excessive pump power consumption. If this pump circulates water over plates or through an ice tank or heat exchanger and chiller, the power consumption should be constant. It is not apparent under what circumstances the power consumption would vary.

Response: This is for water circulation to the load. Water circulation over the plates should be specified in ICEPAR1, ICEPAR2, as described in the documentation.

Output

The method BLAST uses to tabulate the ice storage output is much more useful than in the Trace report. Nevertheless, the following energy use categories would be useful:

1. Ice storage pump energy consumption,
2. Compressor energy consumption,
3. Condenser energy consumption (air cooled),
4. Cooling tower or evaporative cooler fan energy consumption, and
5. Condenser pump energy consumption.

All of these are affected by decisions made during the design phase. This information would allow optimizing the design more easily. This information also would alert the designer to possible input errors.

Response: The design report, which can be used during the design phase, displays these values. Ice storage pump energy consumption is described as the parasitic electric. Compressor energy consumption is the compressor electric. The remaining items are described as the condenser electric.

Deficiencies

General. The few deficiencies make it difficult to use the program in the way it would normally be used by a designer. For a program such as BLAST to be the number one choice of engineers, it must be easily used by designers and analysts. Both users have differing approaches to their work and need different features. BLAST is geared primarily to analysts. However, it does have the power to provide the features needed by designers and meets at least 80 percent of the designers' overall needs. It could probably meet 99 percent of the needs by providing a few more reports or expanding existing reports.

Storage Temperatures. Neither BLAST nor Trace appear to provide for ice storage temperatures to exceed 32 °F. This feature would make storage optimization easier in some cases.

Obtaining Equipment Data. Obtaining data to use to prepare the input for ice storage equipment is so difficult that in most cases users will be tempted to use default data. Adequate catalog data may not exist. Fortunately Calmac, Turbo, and Mueller provide software that either contains the necessary data or data that can be used to estimate the necessary input. Users should be told that they will need this software before attempting any simulation. It will take several weeks to obtain this software and about 4 hours to load it and learn how to use it effectively.

It is difficult to sufficiently emphasize the need to obtain useful data well in advance of attempting an ice storage study. This item is so critical that if adequate time and effort is not expended in obtaining the necessary data long before a study is required, there will be no time to do the study before the job is completed. The time required to gather useful information for this study was so great that it would have precluded the consideration of ice storage for a typical project. This is a critical bottle neck that may prevent the effective use of the ice storage module if not addressed.

One possible solution to the problem of obtaining data would be for the BSO to contact the manufactures of ice storage equipment and ask for permission to include preprinted requests for software that users could fill out and send in. Some may refuse, however, they should be informed that the nature of the technology is such that systems that cannot be considered during design will not be considered during construction.

Response: The BSO has requested and obtained all information the manufacturers will provide. Additional in-depth manufacturer's data has been obtained through Corps districts who have an easier time obtaining the information since they actually purchase equipment.

BLAST Chiller Performance Report. The system should output a conventional chiller performance report. It is not possible to determine exactly what energy is used by the chiller, condenser, cooling tower, etc. An hour-by-hour profile should be available to make it possible to compare performance with other conventional chillers and ice storage systems. This inability to compare puts the designer or analyst in an undesirable position since there is no good way to evaluate anything other than the gross cooling supplied. A design day chiller report similar to the ice storage report is very desirable. The ability to get a season's hour-by-hour chiller performance report would be useful also. Districts that use BLAST for diagnostics may find this helpful.

Response: Report Writer could be used to gather hour-by-hour information to make this comparison.

Ice Storage Manual Completeness. A major item missing from the manual is the rational basis for the module features and variables. It is impossible to determine what assumptions were used, how they affect the required input, and the effect on the output. The user often must guess how a variable is used to arrive at a value for it. The assumptions for all curves should be included; for example, several

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curves are a function of storage capacity. In practice, storage capacity may affect performance. The user must be given enough information to intelligently determine the proper coefficients. Despite the effort of diagraming inputs and based on Coleman's thesis, questions remain unanswered. The reason why a parameter is best described by a curve should be included each time a user is expected to input coefficients to save some input time in cases where the user knows that certain coefficients will be zero.

Response: Coleman's thesis (available from the BSO) and the references cited therein are the best sources of information for these questions.

All items included in all the variables should be itemized to avoid counting some items more than once. More diagrams are necessary. They would serve the dual purpose of showing both the system configuration and the sources of various losses and loads. It is possible that a diagram could answer many questions that a designer or analyst may have about the variables.

Response: These diagrams are currently being crreated.

Inadequate BLAST Zone Reports and Engineering Checks. Perhaps the major impediment to the use of BLAST for any purpose, including ice storage, is its inability to provide adequate zone load reports. BLAST needs a zone-by-zone summary report of each zone's loads at the time of the zone peak load. This is best done by Carrier's HAP program. This report is necessary for both heating and cooling. For heating, the user should have the option of selecting peak loads during occupied or unoccupied hours, or both. Information required for an engineering check report for both heating and cooling are:

1. Supply air (cfm/sq ft),
2. Outside air (cfm/sq ft),
3. Heating and cooling load (Btu/sq ft, sq ft/ton),
4. Supply air changes per hour,
5. Outside air changes per hour, and
6. Sensible heat ratio.

These parameters not only provide the designer with a sense of reasonability, but serve to verify that the minimum air quantities have been accounted for. Infiltration air quantities should be kept separate from outside air quantities.

Response: Reports are currently being created.

Use of Punctuation and Other Syntax for BIN Files. Editing and checking would be simplified if the use of commas, semi-colons, and other punctuation was described.

Response: These conventions are described in the User Reference Section of the BLAST Manual.

WINDOWS/HIMEM.SYS Conflict. BLAST cannot be run under WINDOWS if the HIMEM.SYS device is active. This may be a major disadvantage to districts that have WINDOWS. It is recommended that Desk View, which is inexpensive and very easy to use and set up, be purchased by users. HIMEM.SYS can then be deactivated and Windows can be operated under Desk View, which can increase productivity significantly. Using Desk View, BLAST can run in the background and Word-Perfect, Arms Word, the C++ editor, and Quatro Pro can be used.

Response: The Corps cannot endorse any one program but this information can be supplied through the BSO as a "user experience."

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Disk Requirements. The BLAST disk requirements for models of useful size is greater than what is available to many Corps engineers. The District was unable to run a model that only had 16 zones because of inadequate hard disk space. Although the generated files that require this space are useful, they reduce the usefulness of the program. Most engineers in the Tulsa District have adequate total hard drive capacity, however, no one has a DOS version that allows use of the whole disk with out partitioning the hard drive. More recent versions of DOS would allow this. Many users with 20 to 60 megabyte hard drives could not get a 16-zone model to run. Lack of disk space does not seem to be a problem for Trace.

Response: BLAST is an hour-by-hour program and the files referred to reflect that detail of data. Trace is a condensed hour-by-hour program and, if it generates similar files, would not take as much space.

Conclusion

The overall performance of the BLAST ice storage model is good. Some areas require further refinement, however, the program is not more difficult to use than Trace and yields results that should be reasonably close to the actual performance.

BLAST is a very sound, user-friendly program. It is one of the few programs that allows the user to edit using any familiar editor. For example, Borland's C++ editor allows the user to optimize the mouse and keyboard. Input editing is possible with Trace, however, Trace's input is not in BLAST's "conversational language," making errors more likely.

Documentation is generally good with the exception that more information is needed in some cases to allow the user to use good judgment in providing input. Designers must be aware that a "properly" designed system will not usually provide enough cooling on the hottest days of the year and will see unmet loads for those days. This should be recognized as a "red flag." If the design is based on the "design day" criteria, the savings in demand charges may be lost; in some cases all savings may be lost. Furthermore, if the installation relies solely on the ice storage system, the building temperature and humidity will rise resulting in claims of design deficiency. If the system is designed to meet the worst case the designer may be accused of "over design." The designer must take appropriate steps early in the design phase to ensure the user gets a useful, fully functional facility.

4   CONCLUSIONS AND RECOMMENDATIONS

The evaluations indicate that the BLAST enhancements are effective and satisfy the users' needs for advanced building energy analysis tools.

The tests revealed bugs in some of the program routines and deficiencies in coding or documentation. Since the conclusion of these tests, the program bugs were resolved and documentation on the new program options was expanded.

Most users reported they were able to install and use the program and its new enhancements relatively quickly compared to other commercial programs, and that BLAST offers a combination of applications, reliability, and accuracy unique among energy analysis programs.   A number of recommendations made by the Districts during their evaluations have either been incorporated in recent BLAST releases or will be incorporated in future releases. Note that improving the BLAST program is an ongoing process; it is recommended that field tests also be conducted to verify the suitability of future enhancements.

To respond to Corps designers' needs and maintain BLAST as a state-of-the-art thermal analysis program, the BSO is continually developing new mechanical system options and other additions to the program. To determine if the program improvements meet Corps designers' needs, field tests (such as reported in this document) are imperative. These field tests uncover deficiencies and bugs in the programs and allow Corps beta testers the opportunity to provide constructive criticism before the programs are released Corps-wide. Due to continual BLAST enhancement efforts, further testing of BLAST enhancements should be conducted yearly pending the availability of funding. It is especially beneficial for the Corps districts to evaluate new enhancements to BLAST because it helps BLAST programmers improve the program to better suit users' needs, it exposes the Districts to new program options, and endorsement by test sites is the best recommendation for a product.

METRIC CONVERSION TABLE

1 in.	=	25.4 mm
1 ft	=	0.305 m
1 cu ft	=	0.028 m³
1 sq ft	=	0.093 m²
°F	=	(°C + 17.78) × 1.8
°C	=	0.55(°F-32)
1 Btu	=	1054.8 joule

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Hittle, Douglas C., *The Building Loads Analysis and System Thermodynamics Program, Version 2.0: User's Manual Volume I and Volume II*, Technical Report E-153/ADA072272/ADA072273 (U.S. Army Construction Engineering Research Laboratory [USACERL] June 1979).

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APPENDIX: Example of Test Procedure

BLAST Enhancement Test Procedure For Thermal Comfort Models

1. Background: This TTTB is one of several being conducted in FY91 to evaluate the effectiveness of selected BLAST enhancements. The results of the demonstration will be used in decisions regarding the release of these enhancements for general use and to guide further development of the BLAST program. Mobile District will develop their own test program and report on the following aspects of the new models:
   - a) Output Report Format - Critique the content and format of the output reports related to the Thermal Comfort Models.
   - b) Program Errors - Document program bugs uncovered during the course of testing.
   - c) BTEXT Format - Suggest improvements to the contents and format of the BTEXT input and default parameters related to the model.
   - d) Model Enhancements - Suggest enhancements or useful additions to the existing model.

2. Objective: The purpose of this particular test is to evaluate the BLAST Thermal Comfort models. The evaluation of the BLAST enhancement should address issues such as:
   - a) Are the thermal comfort parameters/values required for the BLAST input readily available, or was background research required before the models could be used in the BLAST program?
   - b) Were the BLAST Thermal Comfort Models easy to use? Were any problems encountered trying to execute the program?
   - c) Was the output from the BLAST Thermal Comfort Models appropriate and in an easy to read format? Suggestions for improvement?
   - d) How do the BLAST Thermal Comfort Models compare with other commercial programs? Which is easier to use/understand? In your opinion, which program provides better and easier to understand results? If given a choice, which program would you choose and why?

3. Deliverables: TTTB participant will submit:
   - a) Hardcopy of report describing project, analytic approach, results of evaluation.
   - b) Floppy disk with report (in Wordperfect or MicroSoft Word format) and BLAST input decks used for evaluation.

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