1988

Development of a residential building energy analysis program (RBEAP).

Ananth Sastry. Rani
University of Windsor

Development of a

Residential Building Energy Analysis Program (RBEAP).

by

Ananth Sastry Rani

A Thesis

Presented to the University of Windsor

in partial fulfillment of the

requirements for the degree of

MASTER OF APPLIED SCIENCE

in the

DEPARTMENT OF MECHANICAL ENGINEERING

Windsor, Ontario, 1987

ISBN 0-315-43767-7

To my Mother, Rani Radha Sastry

ABSTRACT

The objective of this project was to develop a Residential Building Energy Analysis Program (RBEAP) based on the CIRA model. The RBEAP program was to represent an overall improvement over the CIRA program in terms of user-interactivity and engineering methods. This goal was accomplished in the following steps.

1. The source code developed for the CIRA program was used as a reference for the development of RBEAP in VAX-FORTRAN. The input section was rewritten in order to present the information in screens or windows for better interaction with the program. This was accomplished by using VAX/VMS system routines.

2. The Mitalas Basement model was introduced into the Data Compression program for the calculation of Basement heat loss, thereby improving the overall monthly energy use prediction.

3. The concept of utilization of internal and Solar gains was introduced into the energy calculation program. This considerably reduced the underprediction of the program in comparison with the DOE 2.1A program.

4. The plotting program was rewritten in order to fully utilize the capabilities of the VAX system. These included use of the RGL (Regis Graphics Library) routines for plotting the output data of the program.

5. The program was validated with regard to the effect of

incorporation of utilization factors as well as the Basement model. Houses of varying mass levels and insulation were considered. Also different situation pertaining to climate (location) were analysed. The effect of these changes indicated that for similar houses where CIRA was predicted to be a poor indicator of energy use, RBEAP proved to be very effective in its energy use predictions. The energy use predictions were more closer to DOE 2.1A predictions on both a monthly and a seasonal basis. This was found to be consistently true for different conditions.

In summary it may be concluded that RBEAP can be used with greater confidence in the modelling of residential dwellings than the original CIRA program.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Dr.N.W. Wilson, both for supervising this thesis and his invaluable help in programming which was a major part of this project work. My thanks are also due to Dr.W.T.Kierkus with whom I has several useful discussions.

I would like to thank Philip Aylesworth for his assistance in developing the plotting program of RBEAP.

Financial Support for this work, provided through the NSERC Strategic Grant No. A1243 and operating grant No. G1284 is gratefully acknowledged.

CONTENTS

ABSTRACT iv

ACKNOWLEDGEMENTS vi

CONTENTS vii

TABLES xii

FIGURES xiv

CHAPTER Page

1. INTRODUCTION 1

1.1 Literature Survey 3

1.2 Objectives 11

2. INPUT SECTION 14

2.1 Introduction 14

2.2 A Sample input session with RBEAP 14

2.3 Nature of input 25

2.4 .INF and .EXP files 31

2.4.1 The .INF file 34

2.4.1.1 Conditional fields 34

2.4.1.2 Calculator usage 35

2.5 Explanation of Records 36

2.5.1 Multiple choice questions 37

2.5.2 Numerical data questions 39

2.5.3 Key to symbols used in component .INF files 41

CHAPTER Page

2.6 Modifications 42

2.7 The .EXP file 42

2.8 Subroutine description 43

2.8.1 Screen-Management procedures 43

2.8.2 Description of subroutines 45

2.9 Modifications 52

2.10 HOUSE.DAT file 54

2.11 Closure 56

3. DATA COMPRESSION PROGRAM 57

3.1 Introduction 57

3.1.1 Weather file 57

3.2 Data Compression subroutines 60

3.3 CIRA basement model 67

3.4 Mitalas model 68

3.5 Variable list 74

3.6 Closure 75

4. ENERGY CALCULATION PROGRAM 76

4.1 Introduction 76

4.2 Program organization 77

4.3 Discussion of EGY UTIL 80

4.3.1 Effective Temperature 82

4.4 Variable list and modifications 94

4.5 Closure 94

5. PLOTTING PROGRAM. 95

5.1 Introduction 95

5.2 Keyboard use 95

5.3 Subroutine description 111

5.4 The HOUSE.LOD file 113

5.5 Closure 118

6. RESULTS AND VALIDATION 119

6.1 Introduction 119

6.2 Results for the Passive solar ranch house 120

6.2.2 Free heat analysis 122

6.2.3 Comparison of heating loads as predicted by CIRA, RBEAP and DOE 2.1A 123

6.2.4 Comparison of the effects of indoor temperature swings on heating loads as predicted by RBEAP and DOE 2.1A 133

6.3 Results for the Villages of Riverside house 140

6.3.1 Comparison of Heating loads between CIRA, RBEAP and DOE 2.1A using RBEAP with the Mitalas basement model only

6.3.2 Comparison of Heating loads between CIRA RBEAP and DOE 2.1A using RBEAP with the Mitalas model as well as utilization factors. 146

6.4 Results for the Hastings ranch house 146

6.4.1 Comparison of Heating load between DOE, RBEAP, NBSLD and BLAST. 146

6.5 Closure 150

7. CONCLUSIONS AND RECOMMENDATIONS. 151

7.1 Introduction 151

7.2 Conclusions 151

7.3 Limitations of RBEAP 152

7.4 Recommendations 152

REFERENCES 154

APPENDICES 158

A. Listing of the modified SUBFLOOR.INF file 158

B. Listing of the GENERAL.EXP file 164

C. Screen-Management procedures 171

D. Sample HOUSE.DAT file listing for Case 2 188

E. Variable list for the Data Compression Program, COMP.FOR. 197

F. Shape and Amplitude attenuation factors 203

G-1. Modified HOUSE.LOD file listing for Case 2. 209

G-2 Sample listing of the Related data.pri;n file 219

H. Variable list for the energy calculation program, CEGY.FOR 222

I. Variable list for the plotting program, GRAPH HOUSE.FOR 225

J-1 CIRA input listings for the passive solar ranch house (Case 1). 228

J-2 RBEAP input listings for the passive solar ranch house (Case 1). 237

J-3 CIRA input listings for the passive solar ranch house (Case 2). 239.

J-4 RBEAP input listings for the passive solar ranch house (Case 2). 241
K-1 Comparison of available and useful solar gains and free heats in CIRA, RBEAP and DOE 2.1A 244
K-2 Comparison of Heating loads between CIRA, RBEAP and DOE 2.1A for Case 1 and Case 2. Indoor temperature swing is 0.0 deg C, thermostat 70/70 Mass levels: Light, Medium Heavy. 247
K-3 Comparison of Heating load between RBEAP and DOE 2.1A Temperature swings of 2.75 and 5.5 deg C Mass levels: Light, Medium and Heavy. 251
L-1 CIRA input listings for the 'Villages of Riverside' house (with and without basement wall insulation). 258
L-2 RBEAP input listings for the 'Villages of Riverside' house (with and without basement insulation). 268
M. Comparison of Heating loads between CIRA, RBEAP and DOE 2.1A for 'Villages of Riverside'.
1) Using RBEAP with the Mitalas model only.
2) Using RBEAP with the Mitalas model as well as utilization factors. 270
VITA AUCTORIS 273

LIST of TABLES

Table		Page
2.1	Question Records for multiple choice questions.	32
2.2	Question Records for numerical data questions.	33
2.3	Records for 'GENERAL' component taken from the HOUSE.DAT file	55
3.1	BOSTONTR.CTY weather file	59
3.2	Ground surface temperatures	72
4.1	Comparison of solar utilization factors between CIRA and DOE 2.1A for Case 1.	86
4.2	Comparison of solar utilization factors between CIRA and DOE 2.1A for Case 2.	86
4.3	Comparison of Heating loads between CIRA and DOE 2.1A for Case 1	87
4.4	Comparison of Heating loads between CIRA and DOE 2.1A for Case 2	87
4.5	Coefficients for the Barakat & Sander correlation.	89
4.6	correlation constants for monthly data points.	91
5.1	Example listing of a portion of the HOUSE.LOD file - I.	115

Table		Page
5.2	Example listing of a portion of the HOUSE.LOD file - II.	116

LIST OF FIGURES

Figure		Page
2.1	'Program credits and 'Master Menu' display	16
2.2 -2.3	General 'Help' information.	17
2.4	'Master Menu' display with 'Existing components and 'Possible Answers' windows.	18
2.5	Current Answers for 'GENERAL' component.	18
2.6	Current answers for 'GENERAL'. Example Text question.	20
2.7	Current answers for 'GENERAL'. Example numeric question.	20
2.8	Current answers for 'GENERAL'. Example of error trapping (numeric question).	21
2.9	Current answers for 'GENERAL'. Example of error trapping (text question).	21
2.10	'Master Menu' display for creating a new sub-component.	22
2.11	Question set for a new subcomponent in 'WALLS'.	22
2.13	Current answers for 'SUBFLOOR' component.	23
2.14 -2.15	Help information for a specific queston in 'WALLS'.	24
2.16	'Master Menu' display for the 'ENTER, CALCULATE or QUIT' option.	26

Figure		Page
2.17	Run-time messages	27
2.18	file information	28
2.19	Message when Graphics is initialized.	29
2.20	Output information in 'Graph Data' screen.	29
2.21	Subroutine call sequence for input.	44
3.1	Subroutine call sequence for COMP.FOR.	61
3.2	Mitalas basement model	70
4.1	Call sequence for energy calculation program, CEGY.FOR	78
4.2	Heat balances on space.	84
4.3	House profile for internal gains	92
4.4	Internal gain utilization factor Vs internal gain loss ratio (IGLR).	92
4.5	Solar gain utilization factor Vs. gain load ratio (GLR).	93
5.1-5.3	Output variables in 'Graph Data' screens.	97-98
5.4	'Graph Data' screen when 'Find' key is pressed	98

Figure		Page
5.5	'Graph Data' screen when 'Insert here' key is pressed	100
5.6	'Graph Data' screen when numeric keypad 'Enter' pressed	100
5.7	'Graph Data' screen when 'Select' key is pressed.	101
5.9	One variable graph display	103
5.10-5.12	Two, three and four variables graph display	104-105
5.13-5.16	Stack calculator demonstration	107-108
5.17-5.20	Help available during the plotting session.	109-110
5.21	Call sequence for plotting program, GRAPH HOUSE.FOR	112
5.22	Call sequence for RGL routines	114
6.1	Views of the passive solar ranch house.	121
6.2-6.9	Comparison of available and useful solar gains and free heats for Case 1 and Case 2 (Light constrction Thermostat:70/70)	124-127
6.10-6.11	Comparison of utilization factors for Case 1 and Case 2.	128

Figure		Page

Figure		Page
6.12-6.17	Comparison of Heating loads as predicted by CIRA,RBEAP and DOE 2.1A for Case 1 and Case 2. (Mass levels: Light, Medium and Heavy) (Thermostat setpoint: 70/70)	130-132
6.18-6.29	Comparison of Heating loads as predicted by CIRA, RBEAP and DOE 2.1A for Case 1 and Case 2 (Mass levels: Light, Medium and Heavy) (Thermostat: 70/75, 70/80)	134-139
6.30	Side and front view of the 'Villages of Riverside' house.	141
6.31	Sectional view of the basement of the 'Villages of Riverside' house.	142
6.32-6.33	Comparison of Heating loads for the 'Villages of Riverside' house as predicted by CIRA, RBEAP and DOE 2.1A using RBEAP with the Mitalas model only	144
6.34-6.35	Comparison of Basement heat loss for the 'Villages of Riverside' house for insulated and uninsulated basement.	145
6.36-6.37	Comparison of Heating loads for the 'Villages of Riverside' house as predicted by CIRA, RBEAP and DOE 2.1A using RBEAP with the Mitalas model as well as utilization factors.	147

Figure		Page
6.38	Schematic of the Hastings ranch house.	148
6.39	Comparison of Heating loads for the Hastings ranch house as predicted by RBEAP , NBSLD , BLAST and DOE 2.1A. Locations: Minneapolis and San Francisco.	149

CHAPTER 1

INTRODUCTION

Energy Analysis programs are essential tools in analysing energy use in buildings. Computer simulation of buildings offers numerous advantages over a corresponding experimental study (eg. a monitoring study). It involves lower costs compared to actual monitoring. Modelling of a building can be done in a short time. Energy predictions could prove useful to architects and energy auditors in upgrading and retrofitting existing buildings. A corresponding experimental investigation would take much longer. Arguably, the results of experimentation are the most accurate and realistic for the time period that the monitoring was carried out. However, if energy use for a different time period is required , experimental investigation would have to be carried out again whereas a computer program could make predictions using existing weather data. Moreover building parameters such as areas and resistance values can be easily varied and their effects studied using computer programs.

The calculation of energy consumption in buildings is not an exact science, not because the calculational tools are inadequate, but because the complete input information is in some way or other almost always lacking. In addition, input data formats may be unclear and having large amounts of input data may mask underlying behaviour. The use of most of the programs for energy analysis presents a somewhat formidable obstacle to the first-time user. Frequently it takes so much time and effort to become familiar with just one of these programs, that consideration is not given to the use of other computer programs of a similar nature that may be better suited to the particular purpose. The user is perhaps the most important variable - an unskilled or uncaring user can get bad answers from any program; a skilled user who understands something of the intent of a program can get satisfactory answers for most purposes with surprisingly simple techniques (ref. 2). A further step in aiding the user in modelling residential buildings is the development of user-friendly, interactive programs whose numbers in energy analysis have been very few.

The use of computers for engineering applications has grown at a fast pace over the last few years. Some aspects of most engineering projects today have to do with computer programs. Computer programs can be classified according to the degree of use they will recieve. From this point of view two broad categories can be identified:

1) One-time programs
2) Repetitive use programs.

1) <u>One-Time</u> <u>Programs:</u> These programs are written to perform computations in support of a single project. They are in most cases, intended to generate a limited set of data of a very particular nature.

2) Repetitive Use Programs: These are general purpose, multiple use programs intended to solve the same type of problems many times for multiple users. Typical of this group are general applications like duct design programs and energy analysis programs. The ASHRAE TC 1.5 group for computer applications (ref. 3) has the following recommendations to make regarding programs for HVAC applications:

	One-Time Programs	Repetitive Programs
Assembly Language	Acceptable	No
High Level Language	Acceptable	Required
Modular	Not required	Desirable
Listing with comments	Required	Required
User's Manual	Not required	Required
Engineering Manual	Not required	Required
Test Cases	Required	Required

The program development process during the course of this project adhered to the above mentioned guidelines for repetitive programs.

1.1 Literature Survey:

The existing stock of building energy analysis programs can be broadly classified into two categories as hourly analysis or monthly analysis programs. Available programs in each of the categories will

will now be discussed briefly.

1.1 Hourly Energy Analysis Programs:

These programs usually produce the closest comparison between metered energy use and predicted energy use. They usually have the capability to model both residential and commercial buildings. However their complexity causes some limitations such as cost, running time etc. Moreover the target audience of these programs is limited to research establishments and/or Universities because the user has to spend a considerable amount of time in learning how to efficiently use the program. This makes the program less attractive to users who would like a quick, fairly accurate estimate of energy use without involving themselves in substantial time committments imposed by the program itself. Examples of this class of users could be Architects, Energy Auditors, Estimators and Consultants. The following is a brief survey of existing hourly energy analysis programs:

a)DOE 2.1C is a program developed by the Energy in Buildings group of the Lawerence Berkeley laboratory. It is capable of analysing both residential and commercial buildings. Due to its detailed calculation procedures and also because of the good agreement between predicted and metered energy use(ref. 1), it has been accepted as a standard of reference in energy analysis. It was used as the reference program during the course of this project work.

b)DEROB (Dynamic Energy Response of Buildings) was originally developed by the Numerical Simulation Laboratory of the school of Architecture at the University of Texas at Austin. It solves the building heat transfer equations in terms of an RC network. It has been able to predict energy use to within 20% (ref. 4) with respect to actual energy use.

c) BLAST(Building load Analysis and Systems Thermodynamics)is a comprehensive energy analysis program for estimating hourly space heating and cooling requirements, hourly performance of fan systems and hourly performance of conventional heating and cooling plants, total solar energy plants and/or solar energy systems. The execution time for this program is much longer than for the DOE 2.1 program. However, its rigorous and detailed calculation procedures have established it as a fairly popular public domain hourly energy analysis program. A users manual which also gives a general description of program use and capabilities is cited in reference 5.

d) CCB/CALDERA is a building energy analysis program developed by Consultants Computation Bureau of Oakland, California. Input data to the program requires the user to learn a building description language. The program architecture makes efficient use of computer resources thereby reducing execution time. However, the program, after the user-testing phase has not proved to be commercially popular due to inaccurate predictions of energy use in certain conditions. Further details can be found in (ref.6)

e) The National Bureau of Standards Loads Determination program, NBSLD, estimates the energy use by solving simultaneous heat balance equations on an hourly basis. The heat balance approach is more precise than the weighting factor approach(as used in DOE 2.1) but is more time consuming. A comparative study of three computer programs by Carroll(ref. 7) revealed that there was no substantial improvement in accuracy by using the heat balance approach. However, this program has the capability to model complex systems for commercial buildings. Its predictions have shown good agreement with measured energy use.

f) The Energy Systems Analysis (ESA) series is a library of computer programs developed by Ross F. Meriwether and associates, Inc. for hour-by-hour calculation of energy consumption of buildings. This program has shown good agreement with measured energy use. Further details can be found in reference 8

g) ECUBE 75(Energy Conservation Using Better Engineering) is an integrated series of Energy Analysis Programs. It evaluates energy systems to determine which equipment most economically satisfies the energy requirements of a particular structure. It is largely used to simulate commercial buildings which have complex plant and systems equipment (ref. 6).

h) GLAS(Graphic Load Analysis Program) based on Computer Graphic Input techniques has been developed at Cornell University. Data required for Energy Analysis is input through simple visual commands.

The hourly weather data are obtained through Monte Carlo simulation of monthly values or from weather tape. Most of the algorithms are drawn from the NBSLD program. Since GLAS is available on a microcomputer, some of the algorithms have been simplified in order to save computation time. This program has shown good agreement with measured energy use.(ref.9)

1.1.2 <u>Monthly Energy Analysis Programs</u>:

These programs provide fairly accurate predictions of Energy use in comparison with hourly energy analysis programs(ref.10 and ref.11). The input requirements are considerably reduced and these programs are easier to use. Since they are usually written for microcomputers they are more transportable. This makes them available to a wider spectrum of users including individual consulting engineers and architects whose access to mainframe computers may be limited or unavailable.

a) CIRA (Computerised, Instrumented, Residential Audit) is a user-friendly, interactive Energy Analysis program developed at Lawrence Berkeley Laboratory. It calculates monthly and annual heating loads for residential buildings. Some prominent features which distinguish CIRA from existing building energy analysis programs are:

i) It is user-oriented. The user does not have to spend time in learning a specific building description language.

ii) It is an interactive program. If the user does not understand a question, the 'Help' facility provides explanations to the user.

iii) Default values are calculated from answers to previous questions.

iv) The program needs a short simulation time.

This program has shown fairly good agreement in comparison with DOE 2.1 on a seasonal basis(references 10 and 12). However, the agreement on a monthly basis with DOE 2.1 is not very good.

Patwardhan's (ref.12) Master's thesis work at the University of Windsor dealt with the critical evaluation of CIRA with respect to actual metered energy use as well as comparison with the DOE 2.1 program. He concluded that :

1. CIRA can be expected to produce reliable results on a seasonal basis for houses of average construction and low or moderate levels of insulation and Solar and internal gains. However, the deviation from DOE 2.1 predicted energy use on a monthly basis was as high as 33%(ref.12). CIRA fails when required to model tight (low infiltration loss), well insulated houses with high solar and internal gains.

2. The basement heat loss predictions on a seasonal basis were found to be within 10% of that predicted by the reference program, HEATING5. However CIRA significantly overpredicted the heat loss in the fall and winter months. This pattern was reversed in the spring months. Thus CIRA was not a good predictor of monthly basement heat loss. This problem would be reflected in energy use on a monthly basis.

3. The variable base degree-day method of calculating heat loss from the superstructure was judged to be excellent. The treatment of Solar

heat gain and Sky radiation loss were judged to be adequate. However it was noted that there was a need for incorporating appropriate algorithms for calculating Solar and internal gain utilization factors.

b) EEDO is a program compiled by Burt Hill Kosar & Rittleman associates. It is simply the IBM-PC version of CIRA. No changes have been made in the engineering methods.(ref.13)

c) HOTCAN is a program developed by the Division of Building Research of the National Research Council, Ottawa. This program has well developed Basement (ref.14) and Internal Gain(refs.15 and 16) calculation procedures. However the Heat Transfer calculations from the Superstructure are not as well developed as CIRA. For example HOTCAN uses the UA(dT) concept for calculating heat loss which is not as accurate as the Variable Base Degree Day (VBDD) method . Morever the calculation of infiltration heat loss is too simplistic.
This program does not provide 'help' to the user although it does provide default values which are arbitrary numbers and are not calculated from answers to previous questions as in CIRA. The Basement heat loss calculations are available for one set of Soil conductivities only, namely 0.8 W/m^2-K for the upper soil and 0.9 W/m^2-K for the lower soil surrounding the basement. A user's manual and a brief description of the Engineering methods used in HOTCAN can be found in reference 17.

f) TRAKLOAD (ref. 18)is an Energy and Systems analysis program developed by Morgan Systems Corporation. It uses the Bin or temperature frequency method to calculate the design loads for the building structure. The program also calculates peak heating and cooling loads. The monthly outside temperature is derived from the mean of the monthly temperature bin distribution. This program is recommended for analysis of commercial buildings. The basement model does not account for the thermal mass of the soil and is treated as a pure thermal resistance. Ground temperatures are not used to calculate the basement heat loss which could lead to significant errors in computing the heat loss.

g) CARRIER E-20 II: This program uses the Bin method to calculate design peak as well as monthly and annual heating and cooling requirements. A comparison between DOE·2 generated residential design energy budgets with those calculated by the Bin method was done by Kusuda et al (ref.19). They concluded that the Bin method was a good predictor of cooling load but recommended the variable base degree-day method for calculation of heating load. Further details about this program can be found in ref. 20.

h) HEAP (Home Energy Audit Procedure) is a computer program developed by the National Bureau of Standards to determine the month-by-month as well as the annual heating/cooling requirements of residential buildings. The calculation procedure is based upon the simple concept that the daily total heating/cooling requirement is proportional to the daily average temperature difference between indoors and outdoors. The procedure computes the heating/cooling load separately for night and day and is capable of accounting for storage effects. A comparison between HEAP and DOE 2.1 (ref.19) revealed that predictions were outside of ± 15%. Further details about this program can be found in reference 21.

The following conclusions were drawn from the literature survey:

1. In the absence of a better Monthly Energy Analysis program, Hourly Energy Analysis programs are the best predictors of energy use. However the input requirements of hourly programs make them difficult to use.

2. The ideal program would be user-friendly, interactive and provide a realistic prediction of energy consumption This could be designed on an hourly basis or a monthly basis. Incorporation of user-friendly features into a monthly program is more practical due to comparatively reduced input requirements as compared to hourly programs.

OBJECTIVES

The objective of this work was to develop a residential building energy program (hereafter referred to as RBEAP) based on the CIRA model but with substantially improved engineering calculation procedures in the areas in which CIRA exhibits weaknesses. The measure of improvement was to compare the results of this program with the results of the standard reference program , DOE 2.1: Simply stated the objectives of this project are as follows:

a) To develop a monthly energy analysis program which could accurately predict monthly energy consumption.

b) To improve the calculation procedures of the CIRA program with regard to the treatment of:

i) Solar and Internal gains

ii) Basement Heat loss.

b) To develop the program so that it could provide for easier Input/Output operations, source code modification and file management. This was to be achieved by coding the program in VAX-FORTRAN to utilize the flexibility of the VAX/VMS system (A facility of the Faculty of Engineering at the University of Windsor).

These objectives were to be accomplished in two phases:

The original CIRA program (hereafter referred to as CIRA-BASIC) was available on a floppy disk for the CP/M based microcomputers. The program took up nearly 64K of memory and any further modifications generally caused an overflow in memory. Although the later generation of microcomputers that followed could possibly accomodate the changes envisaged in the program, CIRA-BASIC was not reprogrammed for microcomputers due to the fact that the microcomputer could place memory restrictions on possible future changes in the program. Such changes could include reducing the basic calculation time step to a week or a day or incorporating new and improved calculation procedures i.e. this program could be used as a basis for later development. It was therefore decided to recode the program in FORTRAN for the recently acquired VAX 11/785. This would eliminate the constraint of computer memory and at the same time provide for useful VAX/VMS utilities such as screen-management procedures which were extensively used in the Input section of the program and RGL subroutines(VAX Graphics Object Library) which were used to graphically manipulate the output. A further advantage would be the ease of modifying source code and program characteristics due to the flexibilty of the VAX/VMS system.

Once the FORTRAN version was thoroughly tested to ensure that results produced by it compared accurately with the BASIC version, engineering changes were incorporated into the program. The results for three test houses were then compared with those produced by the standard reference program DOE 2.1A.

This thesis report is divided into seven chapters.
Chapter 1 deals with a general introduction and statement of objectives for this project. Chapter 2 is a discussion of the Input section of the program. Chapter 3 deals with the Data Compression portion of the program. Chapter 4 is a discussion of the Energy calculation program. Chapter 5 describes the capabilities of the Plotting program. The results of modelling houses on the program are discussed in Chapter 6. The final conclusions and recommendations are presented in Chapter 7.

CHAPTER 2

INPUT SECTION

2.1 INTRODUCTION:

This chapter discusses in detail the nature and prominent features of the input section of RBEAP. It also discusses the programming considerations and file(s) structures necessary to provide this level of interactivity and user-friendliness between the user and the program. This Chapter is divided into three main sections:

a) The first section is a description of a sample input session with RBEAP.

b) The second section is a description of the .INF and .EXP file structures.

c) The third section describes the function of subroutines used by the input section.

RBEAP does not use a building description language. The complete building is described in components which can be selected interactively from the screen-display. The components are:

GENERAL	WALLS	WINDOWS	ROOF-CEILING
HVAC-SYSTEM	LANDSCAPE	ECONOMIC	INFILTRATION
SUBFLOOR	APPLIANCES	ACTIVE-SOLAR	
PASSIVE SOLAR	DOORS		

2.2 A SAMPLE INPUT SESSION WITH RBEAP

The following is a description of the input section as perceived by the user. After logging on to the VAX 11/785, the user is require to type @RBEAP at the DCL command level (at the $ prompt). The following sequence of events will occur. Successive screen images are shown in figures 2.1 through 2.20. First the credits for the program will appear followed by the 'Master Menu' display. The screen display would be as in figure 2.1. At this point the user can request detailed, brief or no instructions by moving the highlighting bar with the arrow keys and pressing the RETURN key to select the desired option. The 'Long' instructions options (fig. 2.2 and 2.3) is a detailed explanation of how the program may be used. If the viewer chooses the 'Long' instructions option and desires to proceed to the next menu while reviewing the 'Help' information, he may do so by pressing the RETURN key. Help at any later stage of the program (while answering questions, plotting etc.) is available by pressing the 'Help' key on the VT-240 terminal. If the user selects the 'No' instructions option the screen will be erased and the next display is as shown in figure 2.4. The screen consists of the 'Possible Answers' window and the 'Existing Components' window. The 'Existing Components' window would be blank if the user is entering information for the first time.

At this point the user can choose to enter components by scrolling with the arrow keys on the 'Possible Components' window and pressing RETURN to make a selection, quit by pressing Ctrl-C or continue to the next menu. If the user chooses to enter or review existing house data, he may do so by scrolling to the particular component and pressing the RETURN key. For example, if 'GENERAL' were the component

THE UNIVERSITY OF

WINDSOR

RESIDENTIAL BUILDING ENERGY ANALYSIS

PROGRAM

BY

N.W.WILSON, ANANTH S.RANI & PHILIP AYLESWORTH

Press any key to continue

Figure 2.1
Program Credits

Master Menu

Welcome
to the
University of Windsor
Residential Building Energy
Analysis Program

Possible Answers
Long instructions
Short instructions
No instructions

Long, Short or No INSTRUCTIONS ?

Keyboard Use
UP or DOWN arrows to change selection, RETURN to choose, ctrl D for default

Figure 2.1

Master Menu display

Help Information

keys will move the high-lighting from one answer to the next. When the answer that you wish to choose is high-lighted, press the RETURN key to select that answer. The box will disappear from the screen and the selected answer will appear next to the question that was being asked.

In some cases, an answer may be high-lighted with black characters on a green background. This indicates the current answer to the question. To select this answer, move the black-on-red high-lighting to the answer and press the RETURN key.

For example, the question might be:

Window GLAZING.................................?

The list of possible answers would then contain

Single pane
Double pane

Press any key except <RETURN> to continue
Press <RETURN> for next menu

Figure 2.2

General 'Help' Information

Help Information

MISTAKES

If you make a mistake, there are ways to correct it. If you are creating a component, simply continue with answering the rest of the questions. When all of the questions have been answered, you will be informed of this, and the current questions and answers will be displayed again. At this stage, the top line of the display will be high-lighted in black-on-red, and the bottom two lines of the display will be:

DELETE Component
SAVE this information

The arrow keys may be used to move the high-lighting to the approriate question, then the RETURN key should be pressed. The possible answers will then be shown, and a selection can be made as is described above. Selecting the SAVE option will result in saving the modified information.

Press any key except <RETURN> to continue
Press <RETURN> for next menu

Figure 2.3

General 'Help' Information

```
-------------------------------------Master Menu-------------------------------------

   Existing Components                                    Possible Answers
      General                                             General
      Walls                                               Economic
      Windows                                             Windows
      Infiltration                                        Doors
      HVAC_system                                         Walls
      Landscape                                           Roof_Ceiling
      Roof_Ceiling                                        Subfloor
      Appliances                                          Passive_Solar
      Economic                                            Greenhouse
      Doors                                               Active_Solar
      Subfloor                                            HVAC_system
                                                          Infiltration
                                                          Landscape
                                                          Appliances
                                                          Continue

------------------------------------Keyboard Use-------------------------------------
 UP or DOWN arrows to change selection, RETURN to choose, ctrl D for default
```

Figure 2.4

'Master Menu' display for 'Existing Components' and 'Possible Answers'

```
---------------------------Current Answers for General---------------------------
NAME of this house ................ VRWB
What CITY ......................... Detroit
AZIMUTH of north face ............. 0.0               degrees
Indoor temperature swing .......... 0.0               degC
What type of THERMOSTAT ........... Heating only
Heating THERMOSTAT setting ........ 21.111            degC
Heating NIGHT setting ............. 21.111            degC
Avg Indoor SUMMER temperature ..... 25.555            degC
Total house FLOOR AREA ............ 134.059           sqm
Avg. thickness of floor slab ...... 127.              mm
House MASS ........................ Light
Solar STORAGE factor .............. 0.22              unitless
SPECIFIC THERMAL MASS ............. 38.7999           kJ/K-sqm
SAVE this information
```

Figure 2.5

Current Answers for 'GENERAL' component

of interest, the screen display would be as in figure 2.5. The label appearing at the top of this display would be 'Current answers for General', if 'GENERAL' already exists in the House.Dat file. Otherwise the label would be 'Creating New Component General' and the user would be required to answer the necessary questions. Typical 'Possible Answers' windows for both text and numeric questions are shown in figures 2.6 and 2.7. For a question that requires textual information, the user is required to choose answers from the 'Possible Answers' window only, whereas for numeric questions the user can input the values. Two examples of error trapping in the input section of the RBEAP program are shown in figures 2.8 and 2.9. If the user-input numeric value is greater than the 'Maximum Value' as displayed in the 'Possible Answers' window, a message indicating that the user-input value is out of range will be typed on the screen. Also if a textual answer is typed in response to a numeric question, the user will be informed of this. Components such as 'GENERAL', 'APPLIANCES', 'HVAC-SYSTEM' are single-entry components, i.e., there are no sub-components. Components such as 'WALLS', 'WINDOWS' are multiple-entry components, i.e, there may more than one sub-component. Figures 2.10 and 2.11 show the process by which a new component in 'WALLS' is created. Note in figure 2.11 that when information is entered for the very first time, the user is placed in 'EDIT' mode at the end of question-answer session. Figure 2.13 is the question set for the 'SUBFLOOR' component when the subfloor type has been chosen to be a Basement. Figures 2.14 and 2.15 show how specific help information is available at every stage of the program. In

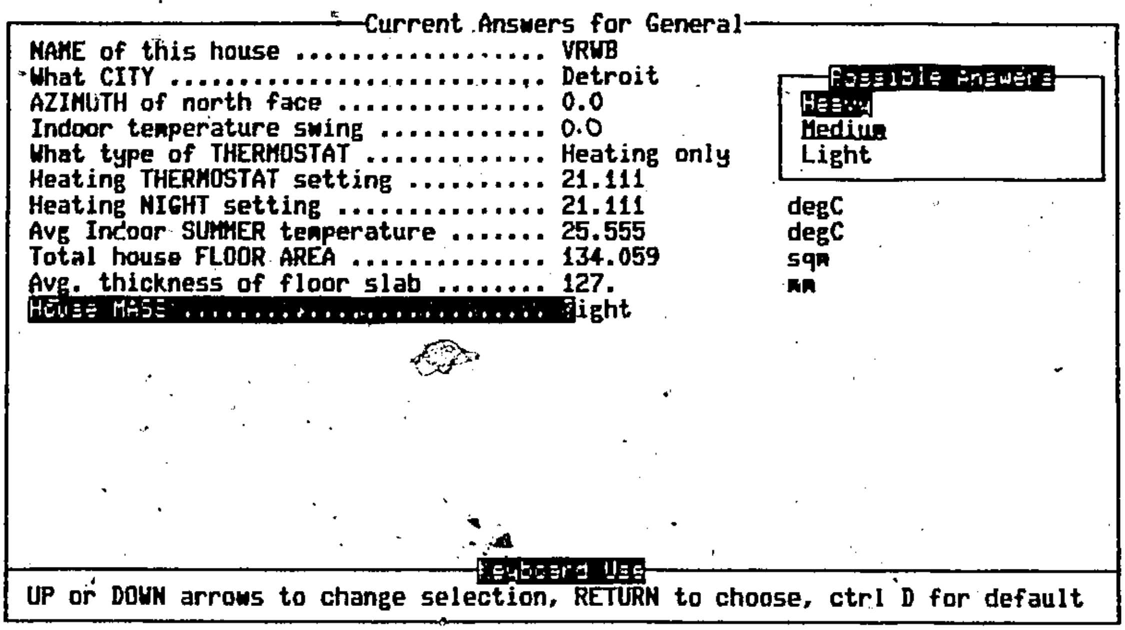


Figure 2.6

Current Answers for 'GENERAL'. Example Text question

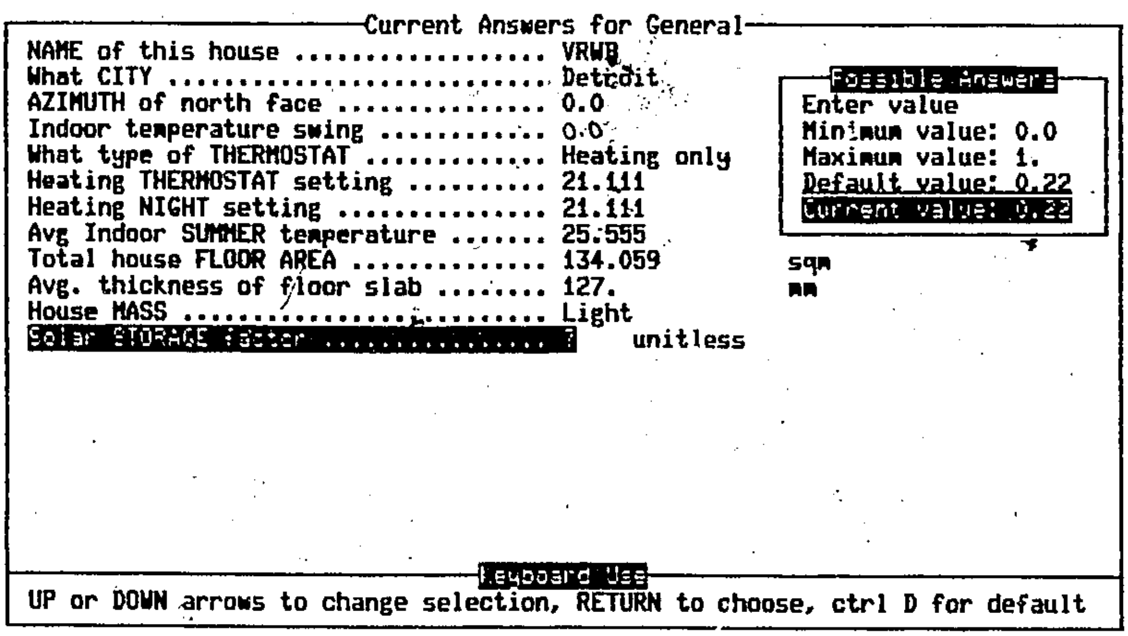


Figure 2.7

Current Answers for 'GENERAL'. Example numeric question

```
                    Current Answers for General
NAME of this house .................. VRWB
What CITY ........................... Detroit
AZIMUTH of north face ............... 0.0               degrees
Indoor temperature swing ............ 0.0              degC
What type of THERMOSTAT ............. Heating only
Heating THERMOSTAT setting .......... 21.111            degC
Heating NIGHT setting ............... 21.111            degC
Avg Indoor SUMMER temperature ....... 25.555            degC
Total house FLOOR AREA .............. 134.059           sqm
Avg. thickness of floor slab ........ 127.              mm
House MASS .......................... Light
Solar STORAGE factor ................ Out of range     unitless

                    Press any key to continue
```

Figure 2.8

Example of error trapping. Numeric question

```
                    Current Answers for General
NAME of this house .................. VRWB
What CITY ........................... Detroit
AZIMUTH of north face ............... 0.0               degrees
Indoor temperature swing ............ 0.0              degC
What type of THERMOSTAT ............. Heating only
Heating THERMOSTAT setting .......... 21.111            degC
Heating NIGHT setting ............... 21.111            degC
Avg Indoor SUMMER temperature ....... 25.555            degC
Total house FLOOR AREA .............. 134.059           sqm
Avg. thickness of floor slab ........ 127.              mm
House MASS .......................... Light
Solar STORAGE factor ................ ?esr             unitless

                    Please Give a Numeric Answer
                    Press any key to continue
```

Figure 2.9

Example of error trapping. Text question

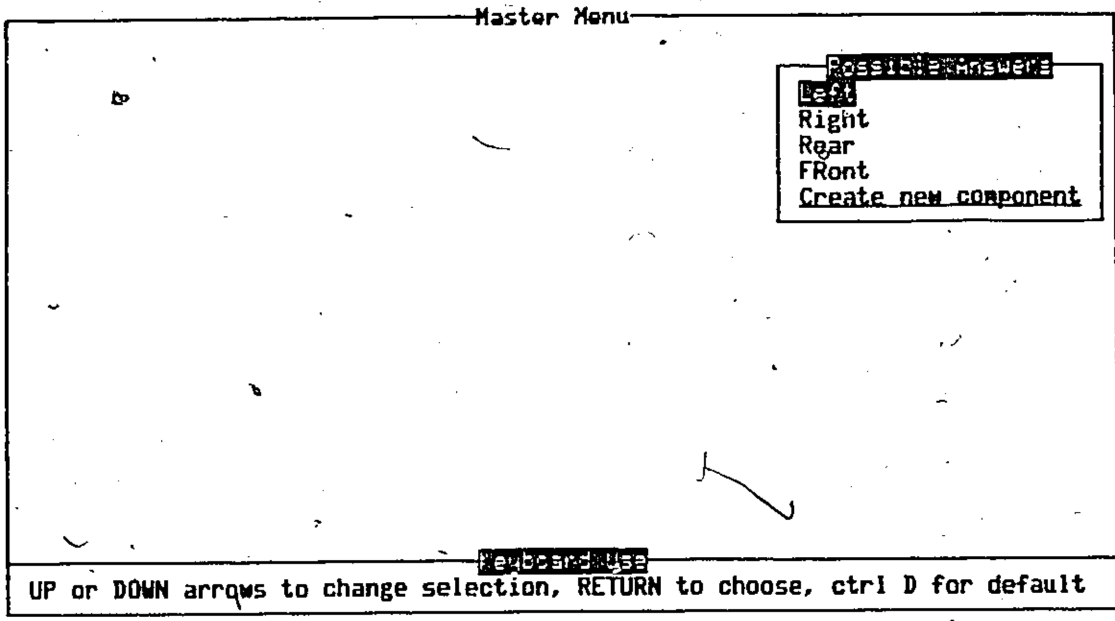


Figure 2.10

'Master Menu' display for creating a new sub-component

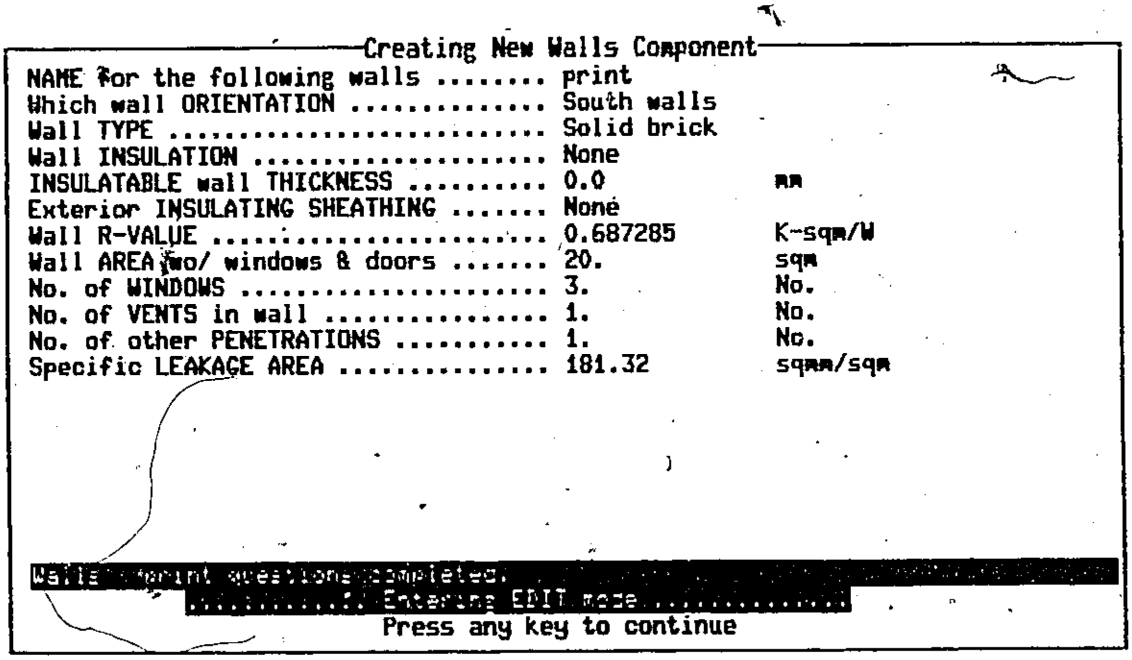


Figure 2.11

Question set for a new sub-component in walls

Current Answers for Subfloor

Subfloor NAME	VRHEBASE	
Subfloor TYPE	Basement	
Soil TYPE	Well-Drained Clay	
Where is the Basement INSULATION	Inside	
Basement temperature	21.1111	degC
Above Grade wall Rvalue	0.35245	K-sqm/W
ABOVE-Grade HEIGHT	0.3048	m
Exposed PERIMETER	27.432	m
Floor AREA (Joists)	45.894	sqm
Floor sp. LEAKAGE AREA	313.33	sqmm/sqm
No. of WINDOWS	0.0	No.
Wall specific LEAKAGE AREA	1435.19	sqmm/sqm
Area A2	16.4592	sqm
R-value for A2	0.854701	K-sqm/W
Area A3	33.708	sqm
R-value for A3	0.854701	K-sqm/W
Area A4	23.432	sqm
R-value for A4	0.2326	K-sqm/W
Area A5	22.462	sqm
R-value for A5	0.2326	K-sqm/W
DELETE Component		
SAVE this information		

Figure 2.13

Current Answers for 'SUBFLOOR' component

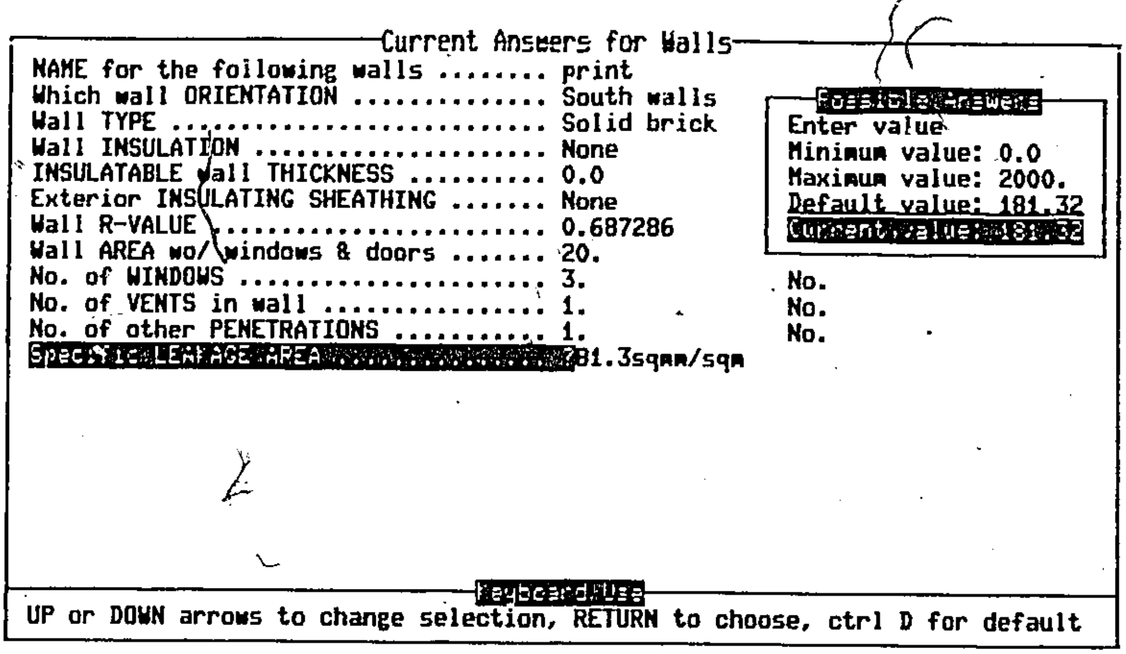


Figure 2.14

Question in 'Walls' component

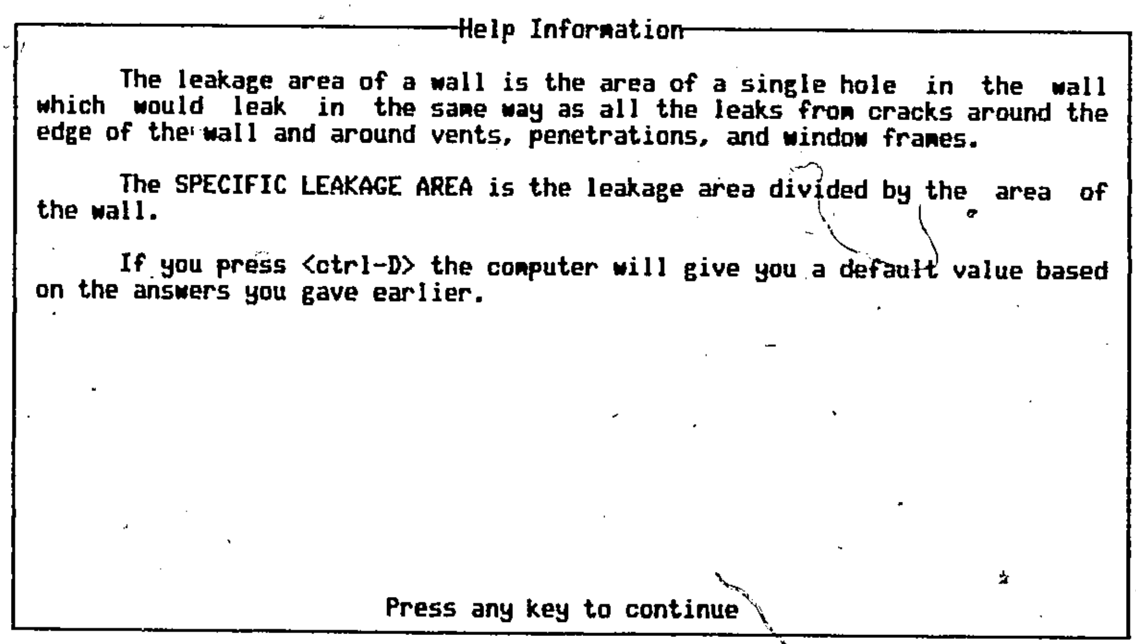


Figure 2.15

Corresponding 'Help' screen

figure 2.14, the user is required to answer the question pertaining to Specific Leakage area. If the user is unsure as to the meaning of the terms, he/she may call for help by pressing the 'Help' key on the VT-240 terminal. The display would be as in figure 2.15.

If the 'Continue' option is chosen when all components have been entered or edited, the next display would be as in figure 2.16. Again as can be seen from the figure the user can choose to re-enter components, quit or proceed to the Energy Calculation section.

If 'Calculate Energy' option is specified, messages will be typed on the screen indicating the progress of the program (fig. 2.17).

The next screen contains information on the various files created by RBEAP and a brief description of their contents(fig.2.18). The plotting program is the next run in the batch mode. The terminal is now intialized for graphics and a few directive messages are typed as in figure 2.19. The next screen is the output of the program labelled 'Graph Data'(fig.2.20). The user can plot displayed variables calculate between columns or save the screen for later printing. These and other features of the program are described in detail in Chapter 5.

2.3 NATURE OF INPUT:

In developing RBEAP, much effort was devoted to simplify the tedious process of entering the appropriate building data. Prominent among the features that distinguish RBEAP from other computer programs are:

Friendliness: The user is not required to learn a specific building description language. Questions are asked in plain english. The user

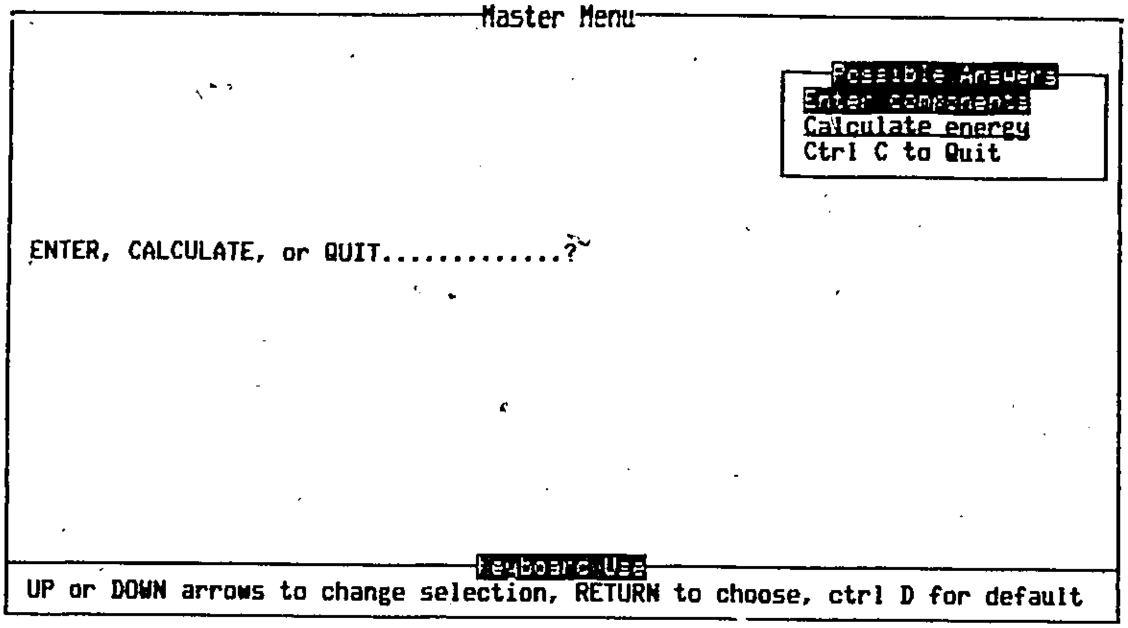


Figure 2.16

'Master Menu' display for 'Enter, Calculate or quit' option.

Figure 2.17

RBEAP DATA COMPRESSION

READING DATA

COMPRESSING

WRITING

ENTERING ENERGY CALCULATION PROGRAM

CALCULATING

WRITING

PLOTTING

File Information

The following files have been created during program execution.

1. House.dat;n (n is the version number of the file).
   This file contains the input data for the house. It can be edited with the full screen editor. Editing is encouraged only if the user is familiar with the records and data positions occupied by house.dat values.

2. House_std.dat;n
   This file contains the standardized house.dat values after data compression.

3. House.lod;n
   This file contains the calculated values such as heating loads, solar gains etc.

4. qbase_(Subfloor name).dat;n
   Subfloor name is the name given to the subfloor by the user. This file contains information about the heat losses through various segements of the basement. The monthly loss through each segment as well as the total monthly heat loss is stored in this file.

PRESS ANY KEY TO CONTINUE

Figure 2.18

File Information

File Information

The following files have been created during program execution.
Misc.dat:
This file contains information about the following variables:
1.Effective Temperature 2. Solar storage factor

PRESS ANY KEY TO CONTINUE

Figure 2.19

NOTE: If the terminal you are using is not a VT-125, you will receive the error message below. Bypass this message by pressing <RETURN>.

24% HGL Terminal is not a VT-125.

Figure 2.20

Output information in 'Graph data' screen

Graph Data

	1 Dload GJ	2 Nload GJ	3 DayOn %	4 NitOn %	5 SpEgy GJ	6 infil ac/hr	7 T gas therm	8 Telec kWh	
Jan:	5.2	6.2	43.9	52.3	11.3	0.68	0	4221	:Jan
Feb:	4.0	5.4	37.3	50.5	9.3	0.69	0	3564	:Feb
Mar:	2.4	4.3	20.4	36.4	6.7	0.55	0	2932	:Mar
Apr:	1.0	2.3	9.2	20.2	3.3	0.48	0	1969	:Apr
May:	0.0	0.0	0.0	0.0	0.0	0.45	0	1074	:May
Jun:	-0.4	-0.1	0.0	0.0	0.0	0.30	0	1039	:Jun
Jul:	-0.6	-0.3	0.0	0.0	0.0	0.34	0	1074	:Jul
Aug:	-0.5	-0.2	0.0	0.0	0.0	0.33	0	1074	:Aug
Sep:	-0.1	-0.0	0.0	0.0	0.0	0.38	0	1039	:Sep
Oct:	0.8	1.7	6.4	14.4	2.5	0.44	0	1755	:Oct
Nov:	2.2	3.2	19.1	28.4	5.4	0.49	0	2542	:Nov
Dec:	4.2	5.0	35.4	42.9	9.2	0.58	0	3632	:Dec
SUM:	18.2	27.5	171.7	245.1	47.8	5.70	0	25912	:SUM
MEAN:	1.5	2.3	14.3	20.4	4.0	0.48	0	2159	:MEAN

simply answers the questions displayed on the screen.

Helpfulness: If the RBEAP user does not understand some of the questions, he/she can call for help with a simple keystroke which can provide information on how to respond to the question.

Possible Answers: The list of possible answers to a question is displayed on the screen for selection by the user. This is useful when the user understands the question but cannot remember the possible choices to respond to the question.

Dynamic Defaults: This is by far the most user-friendly feature of the input section. It aids both the lay as well as the technical user.

For example suppose it is required to find the R-value of a 2'x 6' frame wall whose 5.5 inch cavity is insulated with 4 inches of vermiculite and one inch of exterior insulation sheathing. The lay user would find the above sequence of information slightly vexing, the professional user would still have to reach for a handbook in order to find the R-value. However RBEAP provides the answer again by a simple keystroke. These values are called dynamic defaults because they are calculated in response to previous questions and are not arbitrary 'most probable' numbers.

Editing Input: Often the user may want to correct previously entered data, change it or reuse data from an existing house. RBEAP screen displays are such that the user has minimum difficulty in doing so. If the user makes a mistake in response to a question he/she should simply continue answering the questions until the set of questions for the particular component have been completed following which the user can change the response to the incorrectly answered question. The questions required to describe each component in RBEAP are stored in files with the file-name extension .INF. (eg. WINDOWS.INF). The help files for each component are stored in files with the file-name extension .EXP (eg. DOORS.EXP) These are described now before proceeding to the description of the Input program.

2.4 .INF AND .EXP FILES:

These files are quite similar to the ones used in the original CIRA program (ref. 23), except that the .INF files drawn from the CIRA program contained the information for each question serially in the same record, whereas RBEAP stores the information record-by-record to facilitate easier I/O operation. The .INF files store information on the text of the question, the next question, possible answer list, default values (unconditional/conditional), name of 'Help' file to be accessed, minimum and maximum values for the answer and data position for result. These terms are better understood with reference to Tables 2.1 and 2.2. Table 2.1 lists the contents of each record and a brief description for a typical textual multiple choice question. Table 2.2 lists the records for a typical numeric question. There are 10 records for each question set. Theses records are explained in detail for multiple choice questions in section 2.5.1 and for numerical data questions in section 2.5.2. There are a total of 15 .INF files, each storing information on Windows, Doors, Appliances etc. An example .INF file, SUBFLOOR.INF is listed in Appendix A.

Table 2.1

Question Records for multiple choice questions.

Record #	Content.	Description.
1	$05	Textual Multiple choice question which is not ghosted
2	What type of thermostat	Text of question
3	\THERMOSTAT	Help file for question
4	NHCD	Code letters for answers
5	D	Default value
6	#11\$05=NC>#06\	Next Question number
7	Blank.	Retrofits not implemented. No action required.
8	17	Data position for result
9	\NNone\DDual Heating and Cooling\ \HHeating only\CCooling only\	List of answers plus code letters
10	\\	No associated values required

Table 2.2

Question Records for Numerical Data questions.

Record #	Content.	Description.
1	#19	Question number
2	Specific Thermal Masss	Text of question
3	KJ/K-sqm\20.428/\20.428*	Unit Conversion
4	\TMASS	Help file for question
5	0	Minimum value
6	200	Maximum Value
7	77.6\$17=H>116.4\$17=L>38.8\	Conditional default values.
8	$26	Next Question number #
9	Blank	No calculation required
10	11	Data position for result

SUBFLOOR.INF, is listed in Appendix A. The .EXP files contain help information on each component. These files are divided into subsections such that the help information displayed on the screen is specific to the particular information that the user requests.

2.4.1 The .INF file:

Before examining the .INF file records in detail in section 2.5, it is appropriate to clarify two basic ideas which are fundamental to the operation of these question specifications. The first is that certain fields can be made to depend upon the answers to previous questions. These are called conditional fields.

2.4.1.1 CONDITIONAL FIELDS:

The general syntax for a field of this type is:

$result_0$\$condition_1$>$result_1$\condition2>$result_2$\....\

This field is interpreted as 'Use $result_0$ unless the $condition_i$ is true, in which case use $result_i$.

$Condition_i$ is of the form:

T

nn

o

aa

where,

'T' is the type of question, $ for text question

\# for numeric

this condition depends upon

'nn' is the two entry question number [eg. 05]

'o' is the logical operator [eg. (,< or > for numerical questions and = and "(equal and not equal) for multiple choice questions.

'aa' is the answer to be compared.

These field are evaluated from left to right and the first condition that is found to be true is used. If none are true the result$_0$ is used. These fields can be understood with reference to the following example question drawn from the GENERAL.INF file:

#13\$05=HN>#07\

The conditional field is enclosed in backslashes(\). This statement would be interpreted as: Next question is #13 but if the answer to text question number 5 was either of 'H' or 'N', then the next question number would be #07. In this file text question ($05) is 'What type of thermostat'. The possible answers are None,Dual Heating and Cooling, Heating only, Cooling Only. The code letters for these answers are N,D,H,C respectively. More explicitly, if the answer to question number 5 was either a 'Heating only' thermostat or there was no thermostat, the next question that would appear on the screen would be question #07.

2.4.1.2 Calculator Usage:

The calculator is used primarily in the default field of numeric questions. This structure allows numeric values to be calculated using the answers to previous questions (ref. 23). The general syntax for this type of entry is:

{ any valid RPN string including V,T,I and F variables}

RPN refers to reverse Polish notation. The following are valid RPN operators.

! enter	* multiply	/ divide	+ plus
- minus	' absolute value	| invert	^ is y^x
@ change sign	> is x>y	< is x<y	= is x=y
# is x = y	) is x>= y?	(is x<=y	L ln(x)
X exp(x)	~ exchange x and y		

All the above operators work exactly like those in a Hewlett Packard calculator (complete with 4 internal registers) except for the logical operations. Rather than branching as in an HP calculator, a "true" result of a logical test places "-1" into the x register, while a false result places a "0" there, while all upper registers are 'rolled ' down one step.

Consider the default calculator string drawn from the ECONOMIC.INF file: {V08!12/6.37*22/}. This means the default value is equal to the value given in response to numeric question 8 divided by the number 12, multiplied by 6.37 and divided by the number 22 again.

2.5 EXPLANATION OF RECORDS:

There are two types of input questions used in the RBEAP input program. Multiple choice and numerical data questions. Each question has ten records which contain supporting information pertinent to the question being asked.

2.5.1 **Multiple choice questions:**

These are listed in Table 2.1 (Page 32)

Question Record 1: Question Number

The question number is used to identify the question and to determine whether it is a numerical or multiple choice questions. A multiple choice question is identified by a $ preceding the question number. A numeric question will have a # preceding the question number. In addition a question may be ghosted or not asked explicitly on the screen, if a G is placed after the question number:-for example $01G.

Question Record 2: Text of Question

The text of each question, is located in the second record. If the question is not a ghost question, this text will appear on the screen when the computer is considering the particular question.

Question Record 3: Help File for question

The help file for the question is identified by the component name followed by a backslash (\). Help for a particular section is made available by including the help section followed by a backslash (\). The example help section shown in Table 2.1 is \THERMOSTAT.

Question Record 4: Code Letters for Answers

The code letters listed in this record are abbreviations for the possible answers to the questions which are displayed on the right hand corner of the video terminal. The code letters in the example multiple choice questions are NHCD(None,Heating only,Cooling only,Dual Heating and Cooling). These can be made conditional.

Question Record 5: Default Value

The default represents a good estimate for an answer to the question. The default value is the value given when either the question is ghosted or when the user responds with a Ctrl-D keypress to choose the default. The default values can be made conditional. The default value in this example is Dual Heating and Cooling identified by the code letter D.

Question Record 6: Next Question Number

The next question number is the number of the question that follows the current question. This can be made conditional if necessary. In this example, the next question is #11 but if the answer to this question were either of 'N' or 'C' i.e. no thermostat or 'Cooling Only' thermostat, then the next question should be #06. The question numbers need not be in a particular order except that the first conditional that is found to be satisfied will be followed.

Question Record 7: Future Expansion

CIRA included a retrofit option and used this record for specifying "unactions". The unaction required is the set of operations to be performed when mutually exclusive retrofits are installed. RBEAP does not have a retrofit option and this is a blank record.

Question Record 8: Data Position for Result

The number that appears in this record pertains to the position occupied by the result in the HOUSE.DAT file which is produced by the program.

Question Record 9: List of Possible Answers

The list of possible answers contains the complete set of code letters and answers for the question. In this example these are \NNone\HHeating only\CCooling only\DDual Heating and Cooling\. The first letters after the backslash (\), i.e N,H,C,D in this case form a superset of the code letters for answers. If a letter does not appear in the Code Letters for Answers list, the corresponding text will not appear in the 'Possible Answers' display. In each case the text enclosed by backslashes, except for the first character after a backslash, occupies one line on the display of Possible Answers.

Question Record 10: Associated Values

The associated value is the number associated with the answer to a multiple choice question. These values are generally used in subsequent numeric questions to calculate default, minimum and maximum values. There are no associated values for this example question. Consider, however the list of possible answers drawn from the GENERAL.INF file, namely \DDetroit\TToronto\OOttawa\WWinnipeg\. The code letters in this case are D,T,O and W. The associated values which can be found in Question Record 10 are the altitudes of these cities above sea level. This information is used later on for calculating barometric pressure. This associated value information also makes reduntant a question requiring the user to input the altitude for the particular city.

2.5.2 Numerical Data Questions

These are described in Table 2.2 (page 33)

The question number and Text have been previously described in section 2.5.2.

Question Record 3: Unit Conversion

This performs the calculation to transform the user-supplied numerical result to the value to be stored in house.dat. In the current version of RBEAP the user-supplied SI value is converted to British units before being stored in House.Dat. This record also contains the units for the particular value that the program requests from the user. In this example, the units are KJ-sqm/KW. This operation can be avoided if the calculator conversion string is left blank.

Question Record 4: Help File for Question

The help file for the question is identified by the component name followed by a blackslash (\). Help for a particular section is made Help for a particular section is made available by including the help section followed by a backslash (\). The example help section here is \TMASS which contains help information on the definition of specific thermal mass of a building.

Question Record 5: Minimum Value

This is the minimum acceptable answer which must be given in reponse to the particular question. This is displayed on the screen in the 'Possible answers' window. The minimum value in the example question is 0. This can be made conditional. This minimum value can also be obtained through calculator usage based on answers to previous questions.

Question Record 6: Maximum Value

This is the maximum acceptable answer. This is displayed in the 'Possible answers' window. The maximum value for this example is 200 This can be obtained conditionally or through calculator usage.

Question Record 7: Default Value

The default value is a good estimate for an answer to a question. It is made conditional when certain information has been already elicited from the user. For eg. the default value for floor area is an unconditional default and will consist of an appropriate number such as 1000 sqft. The user is required to carefully input responses to such questions. However the default value for specific thermal mass of the house can be calculated from answers to previous questions. In the example question, the default value is 77.6 but if the answer to question 17($17) was H('Heavy'), the default is 116.4, if the answer to question 17($17) is L('Light'), the answer is 38.8.

The remaining records contain information on Next Question number, Unaction required, Data position for result which have been previously described in section 2.5.1.

2.5.3 Key to Symbols used in <Component>.INF Files

#n	is the numerical data question n.
#nG	numerical data question n is "ghosted".
$n	is the multiple choice text question n.
$nG	multiple choice question n is "ghosted".

Vn is the value given in response to question n

Tn is the total associated value for the response to the multiple choice question $n.

In is the integral part of $n

Fn is one thousand times the fractional part of $n.

Dn is the data stored in the house.dat file in record number n.

2.6 **MODIFICATIONS:** The .INF files can be modified to create new question sets, replace existing information, modify default attributes etc. This can be achieved fairly readily with some basic knowledge of the VAX EDT full-screen editor and a good understanding of the data structure of the .INF files as described above. One such modification already made is that corresponding to the SUBFLOOR.INF file (Appendix A). The new question set requests user-input with regard to the Basement description, vis-a-vis, the model due to G.P.Mitalas (ref. 24). This form of conditionals can be incorporated into any general program where interactive input is desired.

2.7 THE .EXP FILE

The main help section for each component is enclosed within > < symbols. An example is >WINDOWS<. Further help sections within this main section are also contained within > < symbols. An example is >ORIENT<. These help sections are accessed through the PRINT EXPLAINS subroutine. An example .EXP file, GENERAL.EXP, can be found in Appendix B.

2.8 **Subroutine Description:**

The subroutines called by Input are given in the flow diagram in figure 2.21. A description of the subroutines and their function(s) follows. As shown in the Call Sequence, frequent use is made of the Screen Management procedures. These procedures are described first before proceeding to the main description.

2.8.1 Screen-Management Procedures:

The VAX/VMS system-services provide for the development of a set of subroutines which can be used for sophisticated screen management. These are described in this section. The call sequences for these subroutines are described in detail in Appendix C.

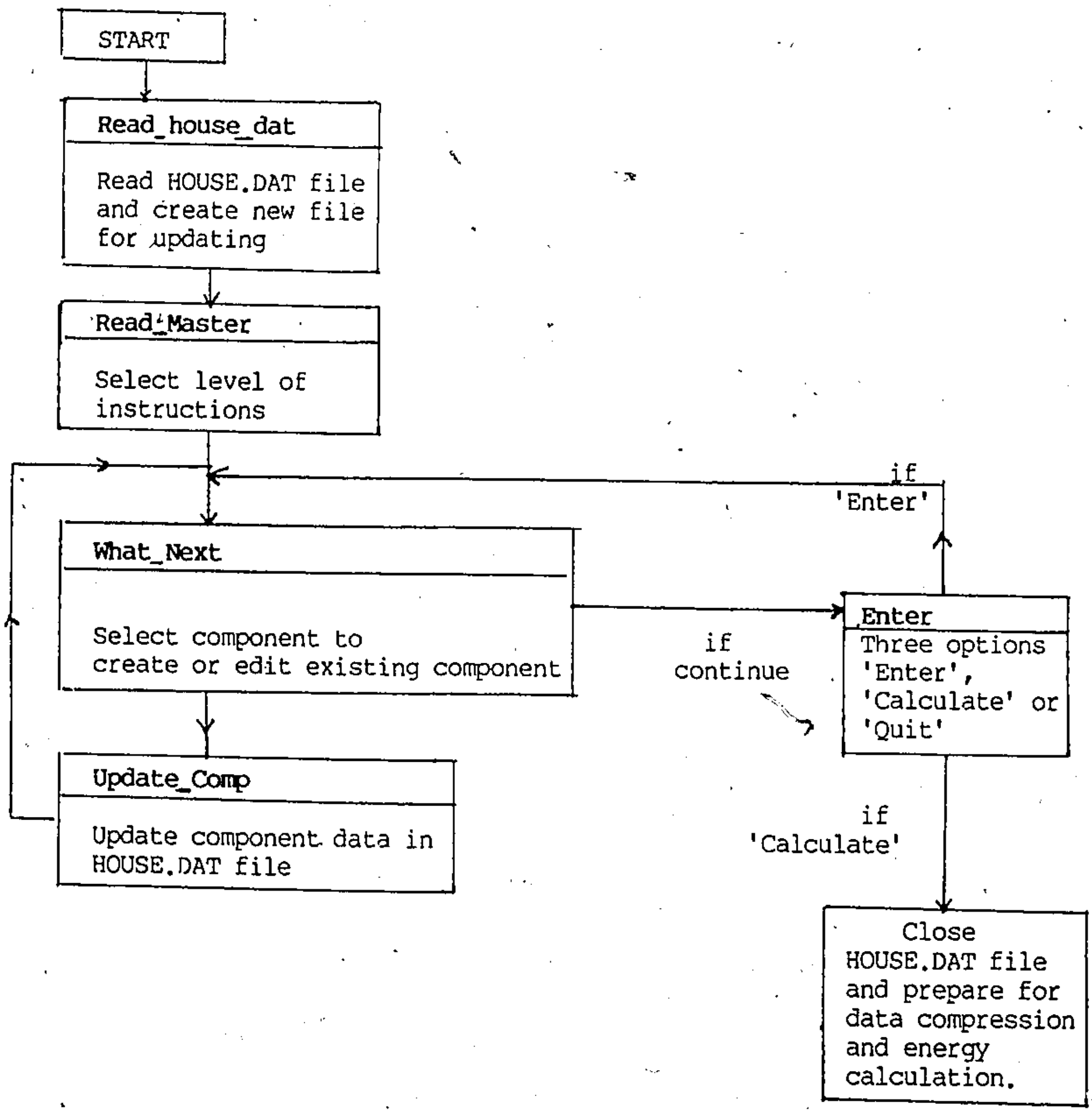
The Screen-Management facility provides two important services:

Terminal Independence

The screen-management procedures provide terminal independence by allowing the programmer to perform commonly needed screen functions without concern for the type of terminal being used. All operations including input and output, are performed by calling a procedure, the caller's terminal-independent request(for example to scroll to a part of a screen), into the sequence of codes needed to perform that action. If the terminal being used does not support the requested operation in the hardware, the screen-management procedures accomplish the action by emulating it in software.

Figure 2.21

Subroutine Call Sequence for Input



Composition Aids

These procedures assist in composing complex images on a screen. These are useful in situations when it may be required to solicit user-input from one part of the screen, display results in a second part of a screen and maintain a status display in a third part of a screen. A comprehensive description of these procedures can be found in reference 22.

2.8.2 Description of Subroutines:

A description of the important subroutines used in the Input section of the program follows. Subroutine and variable names are indicated in bold font.

READ_HOUSE_DAT: This Subroutine reads the House.Dat file if it exists in order that existing components can be made available in subsequent displays. If no components exist, the 'Existing Components' window will be blank. The input argument to this routine is the integer **ncomp** which indicates the number of components in the HOUSE.DAT file.

WRITE_HOUSE_DAT: The purpose of this subroutine is to create a working file while the input operation is in progress. The input argument is the integer variable **ncomp.**

READ_ MASTER: This subroutine first calls the read questions routine. The input argument to **READ_QUESTIONS** is the file MASTER.INF. The information from the MASTER.INF file is displayed on the screen using screen-management procedures. This routine now calls the **SELECT_ANSWER** subroutine in order to determine the users keyboard response. The 'Long', 'Short' or 'No' instructions option can be selected now. The PRINT EXPLAINS subroutine is also enabled. This makes the 'Help' key on the VT-240 terminal active and has arguments described as follows.

Input Arguments:

ch	character	code letter which appears in the answer list.
iend	integer	counter of last line on the display

The remaining arguments are passed thru the common block 'quest'. This common block resides in the 'COM HOUSE.FOR' file. It can be activated in a FORTRAN program by using the 'Include' statement.

READ_QUESTIONS:

This routine reads the .Inf files. The input argument to this routine is the non-extended name of the file(eg. 'WINDOWS','DOORS' etc).The output arguments are returned thru the common block 'QUEST'. These are:

iquest	integer	question number index
quest_type(30)	character	question type either $ for string or # for numeric.
quest_text(30)	character	text of the question
unit_str(30)	character	Units for the numeric question

Conv_up_str(30)	character	Calculator string for conversion of the answer to a numeric question from user supplied units(SI) to program required units(British)
Conv_down_string(30)	character	Calculator string for conversion from British units to SI before displaying on the screen
Help_file(30)	character	Extended name of the help file.
Help_section(30)	character	Name of the section to be searched
ghost(30)	character	Indication of whether the question is to be to be ghosted or not. i.e. whether it will will be explicitly asked on the screen or not.
min_value_str(30)	character	Calculator or conditional strings
max_value_str(30)	character	associated with the minimum values, maximum value
default_value_str(30)	character	or default value for textual answer.
min_value(30)	real	The minimum, maximum and
max_value(30)	real	default value for a

default_value	real	numeric answer.
next_question_type	character	$ for string or # for numeric.
next_question_cond	character	conditional string.
next_question	integer	The next question number.
result_position(30)	integer	Row or record number for storing the answer in the HOUSE.DAT file.
code_letters(30)	character	code letters for possible answers
code_letters_cond(30)	character	Conditionals associated with the code letters.
default_letters(30)	character	default letters for string questions
default_letters _cond(30)	character	Conditionals associated with with default letters
list_possible_answers	character	possible answer list for string questions
Associated_value	character	contains an associated value string.

These variables are easily understood with reference to any .INF file. The above variable list is the common block 'QUEST', which resides in the COM QUEST.FOR file.

WHAT_NEXT: This routine uses Screen-Management-Procedures to create the 'Existing Components' window on the left hand side of the video screen. **SELECT_ANSWER** is also enabled . The user now makes the choice to enter components, quit or continue. The keyboard response is used by WHAT NEXT to decide the future status of the display. For eg. if the user scrolls down to appliances and presses <RETURN>, the next display is 'Current Answers for Appliances' if APPLIANCES already exists . If APPLIANCES does not exist control is passed to **UPDATE_COMP.**

The input argument is:

last_comp	character	Last component that was entered

The output arguments are:

exist_comp	character	Existing component list
comp_name	character	component name

UPDATE_COMP: This subroutine will create a component if it does not exist. It also controls the editing on the display after questions have been answered. It periodically updates the working house.dat file each time the user completes a component and saves it.

SELECT_ANSWER is called for the program to decide the users choice from the 'Possible Answers' window. Subroutine GET VALUE is called to get the maximum, minimum or default value to a numeric question. Use is made of the stack calculator in decoding the default value string as stored in the .INF file.

The input arguments are:

comp_let	character	Code letter for component
Exist_comp	character	Existing component list
Comp_name	character	Component name

The remaining arguments are passed thru two common blocks 'QUEST' and HOUSE DAT'. The 'QUEST' common block has already been described. The 'HOUSE DAT' common block passes the input data of the house through the variables **house_str(30,25)** and **house_val(30,25)**. **House_str(30,25)** is a variable of character type and stores non-numeric house data to maximum of 30 components and 25 answers for each component. **House_val(30,25)** stores numeric answers to a maximum of 30 components and 25 answers for each component

Output: Screen-Management through the use of **SELECT_ANSWER.**

ENTER: This routine writes a one line string to the display indicating briefly the choice the user has made. It will also return the user to the menu where component entry is possible if the user so chooses when the 'Enter, Calculate or Quit' question is asked. The arguments are passed through the common block 'QUEST'. The input arguments are:

ch	character	choice made by user.
iend	integer	position of last line on display.

Output: Screen-Management thru the **SELECT ANSWER** subroutine.

All the above subroutines are not clubbed together in one file but are present as separate files in order to make the program more modular. Debugging or changing the input would be easier since it would be necessary to recompile selected modules only and not the whole program.

SELECT_ANSWER: This routine shows a selection from a supplied set of text strings. These are shown in an automatically sized window in the left hand corner of the screen.

Calling Sequence: **Call Select_Answer (DispID, Bufans, Default, Memory, Answer, Pos_Ans_list, Filename, Section)**

Input Arguments:

DispID	integer	Id. of virtual display.
Bufans	character	List of possible text strings to be displayed.
Default	character	Code for default answer in the list
Pos_Ans_list	character	List of code letters from those appearing in bufans
Filename	character	Name of the 'HELP' file to be accessesd.
Section	character	Name of the section within the help file.

Output Arguments:

Memory	character	Code letters for item which has been selected from list.
Answer	character	Text of item which has been selected from list.

PRINT_EXPLAINS:

The function of this subroutine is to access a specified help file, overlay the whole screen with information and wait for the user to read the screen.

Calling Sequence:

Call **print_explains (filename,section,subsection)**

Input Arguments:

Filename	Character	Name of the Help file. The filename must have an extension .EXP
section	character	Name of the section within the help file.
Subsection	character	Name of subsection within a section

2.9 **MODIFICATIONS:** Modifying these subroutines can be done using the VAX EDT editor. It might be noted that the Subroutines described are the main subroutines and they have to linked with other files before an executable image file is produced. Normally the link that produces the run file INPUT.EXE is:

$ Link Input, Subr/lib.

Subr is an Object code library which contains the following files.

ANSWER_FROM_LIST	CLEAR_SCREEN	CLEAR_STACK
CREATE_DISPLAY	DELETE_DISPLAY	DELETE_HOUSE_DAT
ENTER	ERASE_DISPLAY	FNOP
GET_KEY	GET_POSSIBLE_ANSWER_LET	GRT_VALUE
HOLD_DISPLAY	HOU_VAL_STR	NEXT_QUEST
PASTE_DISPLAY	POP_DISPLAY	PRINT_EXPLAINS
PRINT_STACK	PUSH_STACK	READ_DISPLAY
READ_HOUSE_DAT	READ_MASTER	READ_QUESTIONS
SELECT_ANSWER	STACK_CALCULATOR	UPDATE_DISPLAY
UPDATE_COMP	UPDATE_STRING	WHAT_NEXT
WRITE_HOUSE_DAT	WRITE_TO_DISPLAY	

As can be seen most of the subroutines previously described reside in this library as object code. If the user desires to make a change in any of the Subroutines, then the run file INPUT.EXE can be produced in either of two ways:

a) By typing in Link Input, File Name (modified),Subr/lib.

b) By compiling the modified file and inserting the modified object code into Subr/lib. This can be accomplished with the following two commands.

(i) Fortran File name (modified)

(ii) Lib/replace Subr/lib File name (without extension).

2.10 HOUSE.DAT FILE:

This file contains the final input data . When required in a FORTRAN module the HOUSE DAT values are passed through the 'HOUSE DAT' commom block. Each component and its corresponding entries is stored in this file. The entries are in British units. 25 records are available to store the entries from each component. A maximum of 30 components/subcomponents can be stored. An example HOUSE.DAT listing can be found in Appendix D. A description of user-input values for the 'GENERAL' component as they appear in the HOUSE.DAT file follows. The records are shown in Table 2.3

Record # 1 contains the entry 'status' of the component . This integer value indicates when the particular component was entered in sequence. For eg. if 'GENERAL' was entered first, 1 is stored in this record. However if 'GENERAL' is entered sixth, 6 is stored in this record. This entry establishes the value of the variable 'Kind' as used in House Val(kind,25) and House str(kind,25). Record # 2 contains the component name ('GENERAL','WINDOWS',etc). Record # 3 contains the name given by the user to the particular component.('North1','South2', for walls etc. Records 3 thru 25 contain the user-input values. These data positions are controlled by the corresponding .INF file, GENERAL.INF. For example, the data position for user-response to the question 'Indoor Temperature Swing' is 22. Therefore this value must occupy Record #22 in the GENERAL component in the HOUSE.DAT file. The above information may be useful to the intrepid user interested in making changes in the core of the program. It is also useful if changes are required to be made in

Table 2.3

Records for 'GENERAL component taken from the HOUSE.DAT file

Record	Content
1	4
2	General
3	Case 2
4	D
5	45.3
6	0.0
7	412.899
8	69.9998
9	69.9998
10	80.0006
11	80.0006
12	^@
13	1175.99
14	L
15	0.22
16	1.79
17	D
18	^@
19	^@
20	^@
21	W
22	0.0
23	127
24	0.36
25	^@

input data without running the program itself.

^@ indicates a null entry. This would happen if, depending on a previous answer, a particular question(s) were not asked. For example if the user specifies the subfloor to be slab-on-grade type , the total number of questions in the question set is only 6 compared to 22 if the subfloor were of basement or crawlspace construction.

2.11 <u>CLOSURE</u>:

This Chapter has discussed the function(s) of the subroutines in the input section of the program. It has also given sufficient information for both, the casual user to run it, as well as to enable more intrepid users to make changes to custom design the Input section for specific applications.

CHAPTER 3

DATA COMPRESSION PROGRAM

3.1 INTRODUCTION

This chapter discusses the function of the subroutines which are used in the data compression program. The Data Compression program (FORTRAN file name: COMP.FOR) standardizes the HOUSE.DAT and weather file values. This is necessary because all the values in the weather file do not implicitly relate to the house geometry, orientation etc. The HOUSE.DAT values are accumulated (for example leakage areas and Solar apertures are added up) and the variables are set up for the final energy calculation. This chapter also discusses the changes made in the engineering methods as compared to the original CIRA program. Specifically the Basement model has been replaced with the one developed by G.P.Mitalas (refs. 14 and 24). Also the heating/cooling season indicator calculation has been made more realistic by including utilization factors. The changes in engineering methods and the corresponding subroutines are discussed in detail. The engineering methods for the other subroutines can be found in the CIRA reference manual (ref.23)

3.2 **WEATHER FILE:** This is the basic data file necessary for energy calculation. These files have the extension .CTY (example: DETROIT.CTY). These files are compiled from Test Reference Year(TRY) data or other sources. Each line in the weather file contains 12 values which are the monthly averages for the particular weather data. These averages are computed from hourly values of weather data.

The weather file used in RBEAP is identical to the ones used in the CIRA program. An example weather file for Boston is shown in Table 3.1. The following is a brief description of the weather file.

Line A This line contains the monthly average specific infiltration ($m^3/hr\text{-}cm^2$) due to the stack effect under reference conditions.

Line B

This line contains the monthly average specific infiltration ($m^3/hr\text{-}cm^2$).

Lines C through F

These lines contain values of the variable base degree day coefficients. Line C lists the values for daytime heating (8 a.m. - 8 p.m); Line D the night-time heating values; Line E the day-time cooling values; Line F the night-time cooling values.

Line G

The 12 values in this line are the monthly day-time (8 a.m. - 8 p.m.) outside temperatures. (deg. F)

Line H

This is the average monthly night-time (8 p.m. to 8 a.m.) outside temperatures. (deg. F)

Line I

This line contains the monthly average wet-bulb temperatures(deg. F)

Table 3.1

Sample Weather File: BOSTONTR.CTY

A	.192	.190	.156	.132	.086	.075	.065	.064	.071	.134	.160	.195
B	.178	.159	.212	.186	.201	.184	.166	.168	.152	.166	.172	.172
C	.90748E-02	2.0493	19.5									
D	.79950E-04	3.35502	24.5									
E	.66494E-05	3.94852	30.0									
F	.14893E-05	4.26211	31.5									
G	34.3	35.6	47.4	55.5	68.8	71.3	80.9	79.4	72.6	54.5	45.0	32.4
H	30.3	30.4	38.1	42.8	55.2	58.7	66.2	66.0	59.8	42.9	40.0	29.7
I	466.3	-413.2	92.5	8.5	2.3							
J	496.8	-346.5	54.5	-5.4	11.6							
K	705.1	-374.9	-4.7	1.9	8.2							
L	958.7	-366.4	-93.3	-.3	-8.7							
M	1059.5	-239.3	-154.4	12.6	-17.9							
N	1068.9	-159.9	-162.8	-7.6	-12.1							
O	1033.4	-169.0	-117.6	.1	-11.9							
P	1046.1	-331.6	-123.3	-2.8	-7.2							
Q	792.1	-410.5	-21.6	-1.8	4.8							
R	639.1	-470.1	53.4	3.0	10.7							
S	411.7	-319.5	73.5	1.2	4.1							
T	375.9	-317.5	80.3	-10.9	12.6							
U	522.	631.	1036.	1612.	1806.	1906.	1684.	1810.	1258.	881.	490.	427.
V	232.	329.	514.	700.	924.	980.	117.	824.	523.	329.	271.	217.

CIRA 1.0 LOC=TRY BOSTON,MA, LAT=42.4, TWHT=22, YEAR=1969, ALT=15

<u>lines J-U</u>

These lines contain the solar flux coefficients. The rows correspond to the 12 months of the year, begining with January, while the columns correspond to the coefficients.

<u>Line V</u>

Line V is the average monthly horizontal total solar flux (Btu/ft^2-day).

<u>Line W</u>

Line W is the average monthly diffuse solar flux.(Btu/ft^2-day)

<u>Line X</u>

Line X contains the name of the city and state abbreviation, the latitude, tower height of the wind recording instrument and the altitude of the weather measurement site.

3.3 **DATA COMPRESSION SUBROUTINES:**

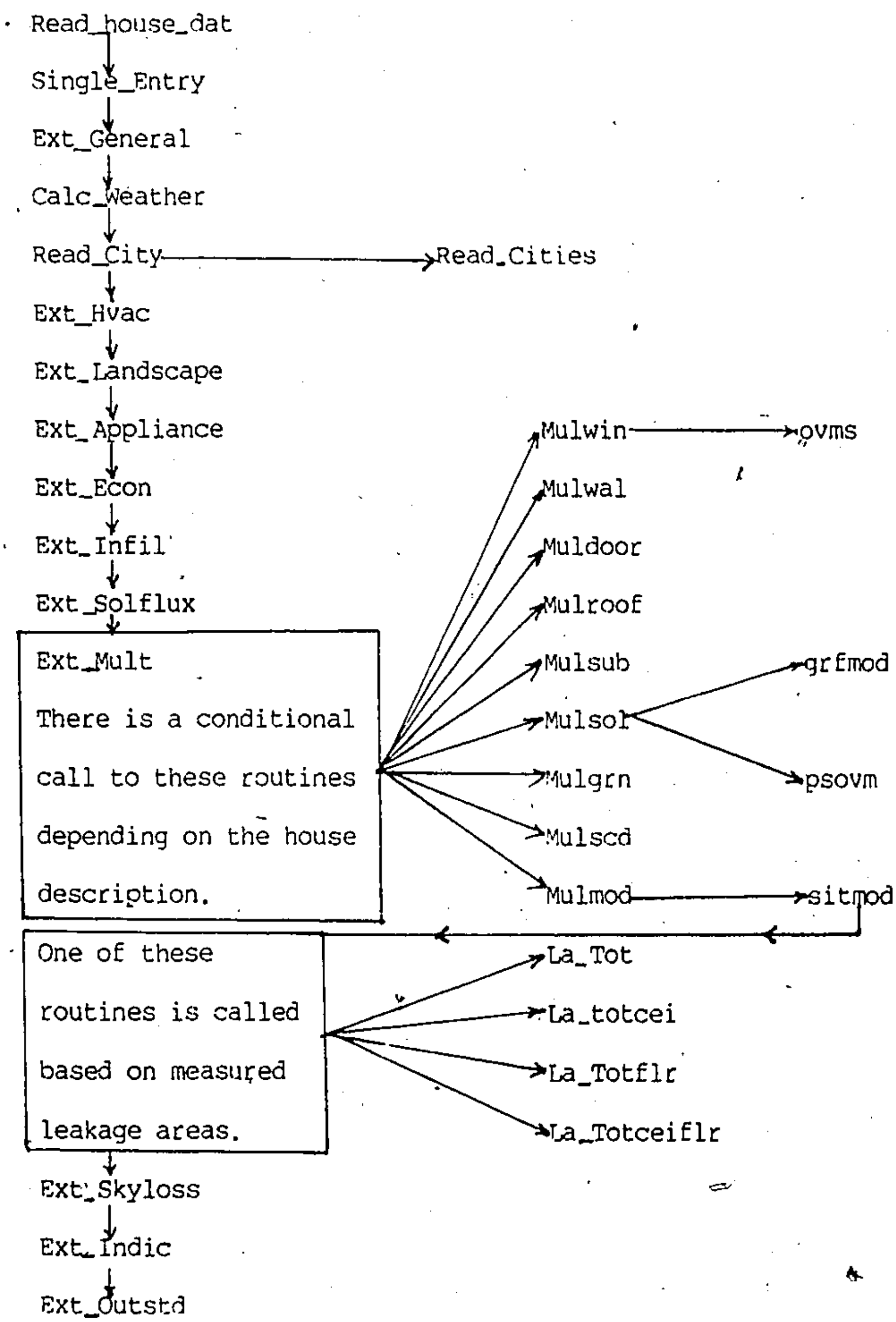
The Subroutine call sequence for COMP.FOR(the main program for data compression) is given in fig. 3.1. The engineering methods for these subroutines can be found in reference 23. A complete listing of the variables used in COMP.FOR can be found in Appendix E. A desciption of the subroutines follows.

READ_HOUSE_DAT: The function of the Read House Dat subroutine has been described earlier in Chapter 2. It reads the HOUSE.DAT data file

Figure 3.1

Subroutine Call Sequence for

Data Compression Program



for existing information on the house.

SINGLE_ENTRY:

The function of this subroutine is to store an array identifier, which identifies the entry point (i.e. to establish the value of the variable 'Kind') of the component, for later use in the program. It also identifies the heating and cooling system type from HOUSE.DAT input. As mentioned earlier in Chapter 2 user-input HOUSE.DAT values are activated in the FORTRAN programs by passing the variables **House__val(kind,25)** and **House__str(kind,25)** through the common block 'HOUSE.DAT'.

EXT_GENERAL:

This Subroutine accepts the HOUSE.DAT values as input and assigns appropriate values for the floor slab thickness, Indoor temperature swing, Heating/Cooling indoor temperatures etc.

CALC_WEATHER:

This Subroutine accepts HOUSE.DAT values as input and returns monthly sub-elevations, barometric pressure as a function of altitude, rhocp std(product of specific heat and density of air), as a function of barometric pressure.

EXT_HVAC:

This subroutine accepts HOUSE.DAT as input and returns the distribution type, distribution loss(cooling & heating), rated capacity and rated efficiency of the HVAC system.

EXT_ECON:

This routine accepts HOUSE.DAT values as input and calculates the present worth factor(PWF) for use in calculating the energy/fuel costs.

EXT_INFIL:

This routine accepts house.dat values and performs the following operations:

a) Using input values it gives the terrain and shielding class numbers which are to be used in future calculations.

b) Calculates the average winter wind specific infiltration from the weather file.

c) Calculates the outside film coefficient for convective heat transfer.

d) determines the winter and summer exhaust and fan supply values from user input as well as determining any unbalanced infiltration.

EXT_SOLFLUX: This routine reads the weather file for the solar-flux coefficients(lines J-U) and then reconstructs the fluxes depending on the user-specified azimuth. The Balcomb correction factor is used for the south facing walls.

EXT_MULT: This routine accumulates the house data by combining the four walls into one, adding up the leakage areas of ceiling, floor and roof, adding up the UA product (product of Areas and Overall heat transfer coefficient) and adding up the contributions of each component to the solar aperture which is used for calculating solar gain. The following routines are used for this purpose:

a)**MULWIN:** This routine will accumulate the contribution of windows to the UA value, leakage area and solar aperture. It also calls Subroutine OVMS, which computes the overhang modifier for South facing windows. The overhang modifier describes the effects of overhangs such as awnings and roof overhangs. A value of one indicates no obstruction. A value of 0.5 indicates that half as much Solar flux reaches the house surface as in a totally unobstructed situation.

b)**MULDOOR:** This routine will accumulate the contribution of doors to the UA value and leakage area.

c)**MULWAL:** This routine will accumulate the contribution of doors to the UA value, leakage area and Solar Aperture.

d)**MULROOF:** This routine accumulates the contribution of the roof to the UA value, leakage area and Solar aperture.

e)**MULSUB:** This routine uses the method due to Mitalas (ref. 24) to calculate the heat loss from the basement. Leakage areas are accumulated to the Total leakage area but the UA values are not accumulated. This is because, RBEAP, unlike CIRA is not using air temperatures to calculate the Basement heat loss. The Muncey and

Spencer equation used for the effective thermal resistance for Slab-on-grade floors has also been modified to account for floor slab thickness. It is discussed in detail later in this Chapter. (see sections 3.3 and 3.4)

f)**MULSOL:** This routine is used for calculating the effects of a Passive Solar system. The passive solar system (restricted in RBEAP to Trombe walls, water walls and greenhouses) is treated using the correlation method developed by Balcomb et al (ref. 25). This routine calls **GRFMOD** (to calculate the effects of ground reflectivity on reflected solar flux incident on Solar walls) and **PSOVM** (to calculate the overhang modifier for the Passive solar system). The contribution of the Passive solar system to the leakage is also accumulated.

g)**MULGRN:** This routine accumulates the leakage area contribution from the greenhouse. It also computes(but does not accumulate) the UA values, modified Solar fluxes due to greenhouse walls and roof and effective greenhouse area. These variables will be used in Energy calculation if a greenhouse was input by the user.

h)**MULSCD:** This routine computes and modifies data pertaining to Active solar systems such as solar collectors. The Active Solar systems for space and water heating are treated using the method from reference 26. These variables will be passed on to the Energy Calculation program and used if an Active Solar system was input by the user.

LA_TOT, LA_TOTCEI, LA_TOCEIFLR: There is a conditional call to these routines depending on how the leakage are is measured. **LA_TOT** is called if total leakage area was measured, **LA_TOTCEI** is called if the Total leakage area as well as the ceiling leakage area was measured and **LA_TOCEIFLR** is called if Total, ceiling and floor leakage area were measured.

EXT_SKYLOSS: This routine calculates the radiation loss to the sky. The input to this routine is Barometric presssure, wet bulb temperatures and monthly average daytime and nighttime temperatures from weather file and accumulated wall and ceiling UA values. This routine calls **SATVAP** which is used to compute the vapor pressure of water in the atmosphere. The clear sky emissivity is calculated from vapor pressure of water using the relation developed by Brunt(ref.27a) as validated and differentiated into day and night by Berdahl and Fromberg(ref. 27b).

EXT_INDIC: This routine calculates indicators based on indoor and outdoor temperatures, solar and internal gains to determine in advance which month would be a heating month and which would be a cooling month. The method previously used in the CIRA program was to pass the unmodified Solar and Internal gains into this routine. However in RBEAP the Solar and Internal gains are modified by using utilization factors. This modification becomes important in situations when modelling tight, well insulated houses with high Solar and internal gains. Under such conditions RBEAP and CIRA do not make similar indications as to the choice of which month would be heating and which would be cooling.

3.3 CIRA BASEMENT MODEL:

The basement model used in CIRA is not very comprehensive. The Overall U-value of the basement is calculated using the method recommended by ASHRAE (ref. 28). In this method an equivalent thermal resistance due to the soil, floor slab and basement walls is computed and then accumulated into the total UA value of the house. Therefore the contribution of the basement to the total heat loss is obtained by multiplying the UA with Variable Base Degree Days which in turn are derived from air temperatures and free heat. The error in this method is that it predicts that peak basement heat loss occurs in the month of minimum outdoor temperature. Previous work (refs. 14 and 24) has indicated that due to the thermal mass of the soil, the peak basement loss usually occurs in the month following the month of minimum outdoor air temperature. Other assumptions used in the CIRA model include:

a) A value of 0.9m for the depth of the foundation below ground when the subfloor is of slab-on-grade construction.

b) A value of 0.127m for the floor slab thickness

c) A value of 1.33 W/m^2C for the U-value of the subfloor wall that is below grade.

d) A value of 2.1m for the basement depth from floor slab to basement floor.

Patwardhan (ref. 12) made a critical evaluation of the CIRA program. He compared the basement loss from CIRA with that predicted by a reference program HEATING5 (ref.29). He concluded that:

The seasonal heat loss from the basement as predicted by CIRA was in fair agreement with HEATING5. This was due to overprediction of heat loss in one month (the month of minimum outdoor temperature) and underprediction in other months. However the agreement on a monthly basis was not good, the variation from HEATING5 predictions being as much as 38%.

He recommended that:

a) Ground temperatures rather than air temperatures be used to compute below-grade heat loss.

b) There should be a provision to model the basement as a separate conditioned space.

c) The time lag due to the thermal mass of the soil should be adequately reflected in the basement heat loss computational procedure.

The CIRA basement model was therefore discarded and replaced with the model developed by G.P.Mitalas (refs. 14 and 24).

3.4 **MITALAS MODEL:** This method uses a periodic heat flow calculation approach, i.e., by using attenuation and time-delay factors to account for the variation of ground temperature and thermal mass of the soil. The terms in the equations that follow are better understood with reference to figure 3.2.

For the purpose of calculation the inside surface of the basement is divided into 5 segments as shown in fig. 3.2.

A1 = inside surface area of wall above grade

A2 = upper inside surface area of wall below grade

A3 = lower inside surface area of wall below grade

A4 = surface area of floor strip 1m wide adjacent to wall

A5 = surface area of the remainder of the floor.

Segment A1 is considered as part of the above grade heat loss and its UA contribution is accumulated into the total UA of the house.

The following equations can be written for the heat loss through each of the other segments.

$$Q_2 = A_2 [S_2 (T_b - T_g) - V_2 B_2 T_v \text{ SIN } (30 (t + dT_2))]$$

$$Q_3 = (A_3 + X_3) (T_b - T_g) - V_3 B_3 T_v \text{ SIN } (30(t + dT_3))$$

$$Q_4 = (A_4 S_4 + X_4 V_4) (T_b - T_g) - (A_4 + X_4) V_4 B_4 T_v \text{ SIN}(30 (t + dT_4))$$

$$Q_5 = A_5 ((S_5 + X_5) (T_b - T_v) - (V_5 + X_5) B_5 T_v \text{ SIN}(30 (t + dT_5))$$

where:

t = time in months (Jan=9, Feb=10, Mar-=11....Dec=20)

S_n = Shape factor for the steady-state heat loss component [W/m^2-k] (Appendix F).

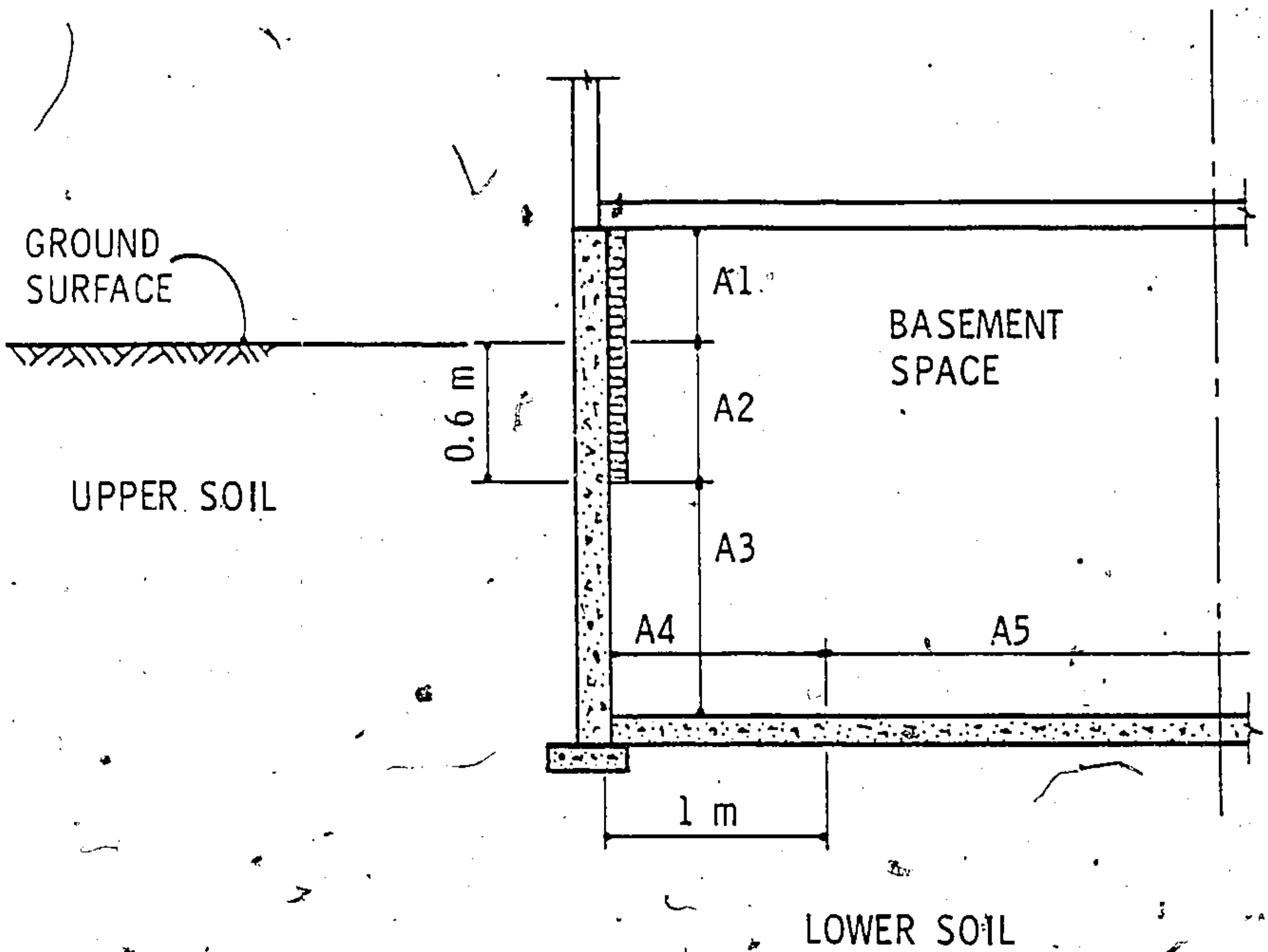
T_b = Basement air temperature (deg C)

T_g = Ground surface temperature averaged over time and area, equalling mean ground temperature (deg C)

V_n = Shape factor for the periodic heat loss [W/m^2-k] (Appendix F)

B_n = Amplitude attenuation factor (Appendix F).

Figure 3.2
Mitalas basement model



T_v = Amplitude of the first harmonic of the ground surface temperature. (deg C)

dT_n = Time lag of the heat flux harmonic relative to the surface temperature

X_n = Corner allowance factor (Appendix F).

Finite element numerical methods were used by Mitalas to determine the shape, attenuation and delay factors. The shape factors can be calculated as a function of thermal resistance by using the following relations:

$$S_n = 1/(a_n + b_n.R)$$
$$V_n = 1/(c_n + d_n.R)$$

where a_n, b_n, c_n and d are constants specific to the basement thermal insulation system.

The corner allowance factor, X, corrects for the effect of three-dimensional heat flow at corners. These are given by the following relations.

$$X_3 = nC_3$$
$$X_4 = nC_4$$
$$X_5 = nC_5$$

C,V are factors taken from Appendix F and n is equal to the number of corners

The annual mean ground temperatures and amplitude values of the first and second harmonics for several Canadian locations can be found in Table 3.2.

Overall this model has been validated to predict the monthly basement

Table 3.2

Ground Surface Temperatures

Source: G.P.Mitalas (Reference 24)

Location	Annual Mean Ground Temperature deg C	Amplitude of first Harmonic deg C	Amplitude of second Harmonic deg C
Charlottetown,PEI	7.5	10.1	1.6
Fredericton, N.B.	7.7	11.9	1.5
Toronto, Ont.	11.1	12.1	2.3
Kapuskasing, Ont.	5.9	10.6	2.4
Vineland, Ont.	10.6	11.0	0.9
Ottawa, Ont	8.9	11.4	1.8
Winnipeg, Man.	6.1	12.4	1.2
Saskatoon, Sask.	5.9	14.6	1.2
Regina, Sask.	4.9	14.0	0.9
Swift Current,Sask.	5.7	11.4	1.2
Lacombe, Alta.	6.3	12.2	2.2
Edson, Alta.	5.2	8.9	1.7
Peace River,Alta.	5.3	12.0	1.5
Calgary, Alta.	6.3	12.2	0.9
Summerland, B.C.	12.3	11.9	0.9
Vancouver, B.C.	10.3	8.5	0.9
MEAN	8.5	11.5	1.9

loss to within 10% provided that the basement being modelled is within the scope of the method (ref. 24). The Mitalas model howver has certain restirctions. The shape factor equations have been derived for two sets of soil conductivies only. The first set assumes a soil conductivity of 0.8 W/m-K for the upper soil surrounding the basement and 0.9 W/m-k for the lower soil. The second set assumes soil conductivities of 1.2 and 1.35 W/m-k respectively. These soil conductivities, according to Mitalas, represent a fairly broad spectrum of Soil types for Canadian locales. However, the method is prone to error if the conductivity of the soil surrounding the basement is vastly different from the above mentioned sets. The Mitalas model also cannot adequately account for ground water flow beneath the basement. It might be mentioned that this method was chosen because it has gained widespread acceptance for the purpose of basement heat loss prediction.

The equivalent resistance for slab-on-grade floors in CIRA is determined by using an algorithm developed by Muncey and Spencer (ref. 30) and adapted to microcomputer use by Kusuda (ref. 31). The following equation is used:

$$R_s = p F_c / K_g \{ .1208 + .0195 \ln(K_g / p C_f) + .0011 [\ln (K_g / p C_f)]^2 + .2347 (t / p) - 20.336 (t / p)^2 - .1421 (t / p) \ln (K_g / p C_f) \}$$

where:

R_s is the modified thermal resistance [m^2-C/W]

t is the average floor slab thickness [m]

K_g is the soil thermal conductivity [W/m-C]

p is the slab perimeter length [m]

C_f is the slab thermal conductance between the room air and the slab-soil interface. W/m^2-C i.e. $(R_{slab})^{-1}$ $[W/m^2-C]$

F_c is the non-dimensional shape correction factors

$$F_c = .0904 + 1.1115x - .2038\,x^2$$

and:

$$x = \text{floor area} / (p/4)^2$$

R_s is combined with the slab thermal conductance to get the overall subfloor U-value for slab-on-grade, U_{sf}:

$$U_{sf} = (R_s + R_{slab})^{-1}$$

As mentioned earlier CIRA assumes a constant floor slab thickness of 0.127m . A sensitivity check showed that the range of possible floor thicknesses (0.1 -0.4m) could change the value of R_s by 18%. In RBEAP, the user can input the floor slab thickness in the 'GENERAL' component. This input is used in the Subroutine MULSUB to make an accurate determination of the Equivalent Resistance of the floor slab.

3.5 **VARIABLE LIST:** The variables used in data compression and a description can be found in Appendix E. Modification to COMP.FOR may be made after studying this variable list. The link instruction is @COMP after the program has been compiled.

3.6 CLOSURE:

An overall description of the Data Compression program has been given in this chapter. The FORTRAN source code is approximately 2951 lines. The subroutines drawn from the original CIRA program have been discussed briefly whereas modifications have been discussed in detail. The variables have been now set up for the energy calculation program. The next chapter discusses the function of the energy calculation progam CEGY.FOR.

CHAPTER 4

ENERGY CALCULATION PROGRAM

4.1 INTRODUCTION

This chapter discusses the functions of the subroutines used in the energy calculation section of the program. Subroutines drawn from the original program are discussed briefly, whereas new engineering changes are discussed in detail. Some of the calculations such as those for air infiltration, total solar radiation distribution and degree-day coefficients are done in advance for standard conditions. The precalculated values are corrected to reflect the building and site characteristics under consideration. A detailed explanation of the engineering methods can be found in reference 23.

Highlights of the Heating/Cooling algorithms are:

a) The concept of using effective outdoor night and day temperatures that are functions of outdoor temperature, solar and internal gains, sky radiation losses. The effective temperature concept is discussed in detail in Section 4.3.1.

b) Variable - base heating and cooling degree-days calculated from effective monthly temperatures using an empirical correlation formula. The loads calculated using the degree-days are further modified to account for thermostat setbacks, if any, using the concept of effective thermal mass of the house.

c) Using Solar and Internal gain utilization factors from empirical correlations to calculate 'useful' solar and internal gains.

d) The calculation of output capacities and seasonal efficiencies as functions of indoor and outdoor temperature and of part-load ratio.

4.2 PROGRAM ORGANIZATION

The call sequence which is generated by the energy calculation program (CEGY.FOR) is as shown in figure 4.1. The required variables, previously calculated in COMP.FOR, are passed to these routines. A brief description follows:

EGY_INFOTP:

This routine calculates the infiltration rate and building load coefficient for the house. Air infiltration is computed using the Sherman and Grimsrud model (ref. 32).

EGY_SOLGAIN:

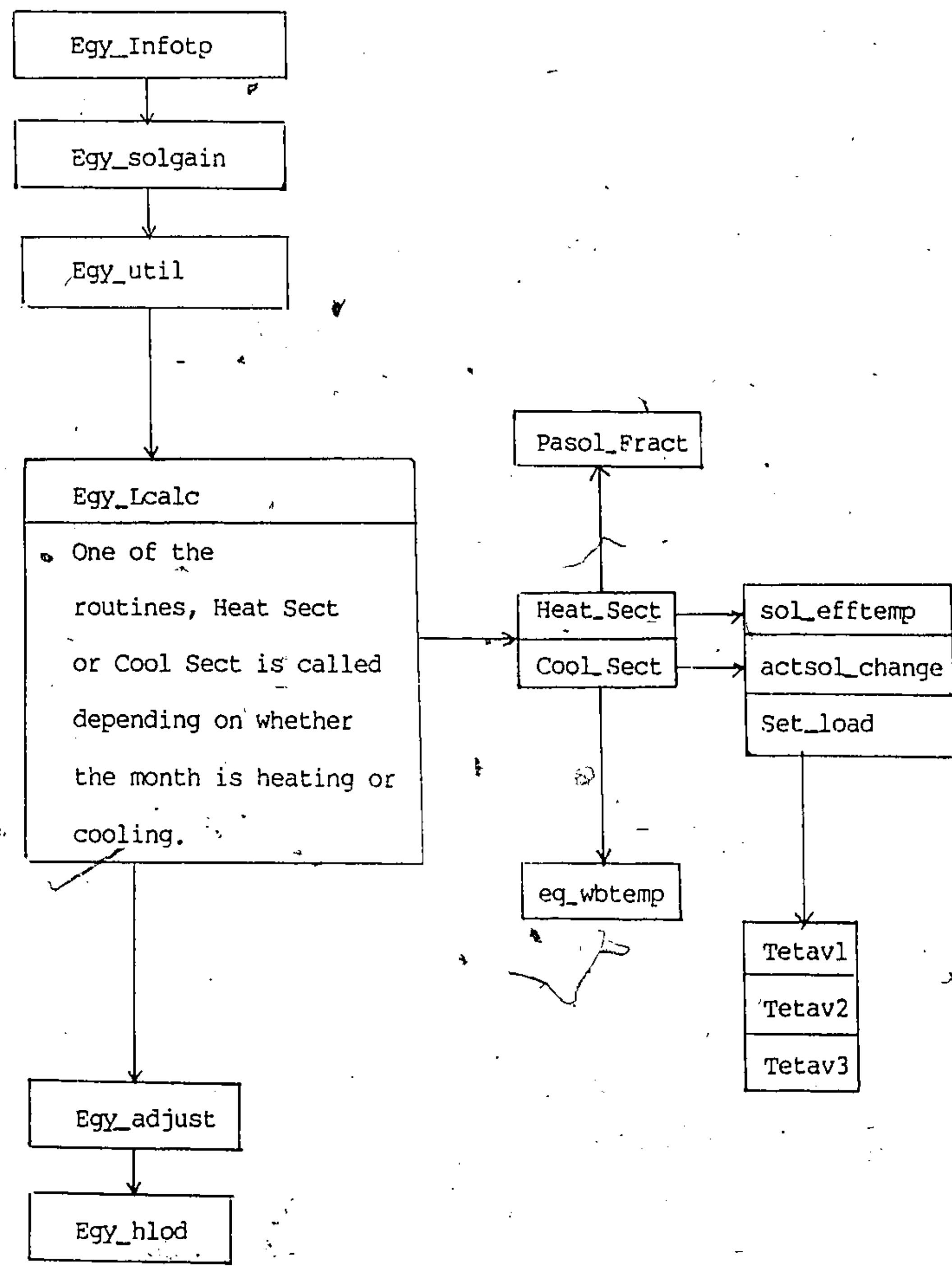
This routine calculates the total solar gain due to all directions (North, East, West, South and Horizontal) based upon the solar flux, total solar aperture and situation modifiers which are calculated in COMP.FOR

EGY_UTIL:

This routine calculates utilization factors based on the correlations developed by Barakat & Sander. The useful solar gain is passed on to the loads calculation subroutine **EGY_LCALC.** This was an important

Figure 4.1

Call Sequence For Energy Calculation Program, CEGY.FOR



change made in the energy calculation program. This method is discussed later on in this chapter.(see section 4.3)

EGY_LCALC:

This is the core of the energy calculation program. It calculates the heating/cooling loads. One of the subroutines **HEAT_SECT** or **COOL_SECT** is called depending upon the advance choice made by the gram as to whether the month would be a heating or a cooling month. **SOL_EFFTEMP** calculates the effective temperature(day/night) and corrected values of the solar storage factor. **SET_LOAD** calculates the degree days and the loads (both day and night). The loads are corrected for stored heat/cool before being returned to the main program. **ACTSOL_CHANGE** is a routine for calculating the contribution of active solar features to reducing the heating load using the f-chart method (ref. 26). **PASOL_FRACT** calculates the effect of passive solar features (such as greenhouses etc) in reducing the heating load. **EQ_WBTEMP** determines performance characteristics if an evaporation cooler is the cooling unit. **TETAV1, TETAV2** and **TETAV3** are routines to calculate the effect of the thermal constant on the indoor temperature response.

EGY_ADJUST:

This routine calculates, based on user input, adjustment factors to match the utility bills to actual use. This routine is useful in situations where retrofitting the house is required (retrofitting not currently implemented in RBEAP).

EGY_HLOD:

This routine will write the ouput variables of CEGY.FOR to a file called HOUSE.LOD. A sample HOUSE.LOD file can be found in Appendix G-1 This file is read by the plotting program (FORTRAN file name: GRAPH HOUSE.FOR) to display the calculated variables. A detailed discussion of this routine and the data structure of the HOUSE.LOD file can be found in Chapter 5.

4.3 DISCUSSION OF EGY_UTIL:

The incorporation of this routine (not available in CIRA or EEDO) had a significant effect on the heating load prediction. This routine calculates utilization factors based on the correlations developed by Barakat & Sander (refs. 15 and 16). A detailed discussion of the engineering background and justification for implementing this routine in RBEAP is now given.

CIRA (ref. 23) uses a steady state calculation method to find day and night heating/cooling loads. The day period is defined as the time between 8 a.m. to 8 p.m and the night from 8 p.m to 8 a.m. Monthly degree days and degree nights are calculated from effective temperatures which in turn are derived from indoor temperature, solar and internal gains, radiation losses from the building skin and the thermal characteristics of the building.

The general heat loss equation for one-dimensional steady-state heat transfer from a building envelope used in CIRA is:

$$H = (Q_c + Q_i) - (S_g + F) \qquad .....4.1$$

where:

H is the heating load (GJ)

Q_c is the conduction heat loss (GJ)

Q_i is the infiltration heat loss (GJ)

S_g is the solar gain (GJ).

F is the internal gain due to lights, people equipment etc.(GJ)

Equation 4.1 may be written more explicitly as follows:

$$H^d = (UA + DCQ)\ (t_i - t_o^d) - (S^d + F - dR^d) \quad .....4.2$$

$$H^n = (UA + DCQ)\ (t_i - t_o^n) - (S^n + F - dR^n) \quad .....4.3$$

where:

UA is the conduction coefficient (W/C)

DCQ is the infiltration heat loss coefficient (W/C)

D is the density of air (Kg/m^3)

C is the specific heat of air (J/Kg K)

Q is the air exchange rate (m^3/S)

t_i is the indoor temperature (deg C)

$t_o^{d/n}$ is the outdoor temperature (deg C)

$S^{d/n}$ is the solar gain (W)

F is the internal gain (W)

$dR^{d/n}$ is the sky radiation loss (W)

The superscipts d and n denote day and night respectively. The distinction between the day and night solar gain is accomodated using a solar storage factor, B. It is defined as the fraction of the solar energy received over a 24 hour period which is released during the night. Numerical values of this factor, dependent upon the thermal storage of the house, are derived from the correlations of computer runs using the BLAST program (ref. 23). Equations 4.2 and 4.3 can now be written as :

$$H^d = (UA + DCQ)(t^i - t_o^d) - [2(1-B)S + F - dR^d] \quad \ldots\ldots 4.4$$

$$H^n = (UA + DCQ)(t^i - t_o^n) - [2BS + F - dR^n] \quad \ldots\ldots 4.5$$

where:

B = solar storage factor = $S^n/(S^d + S^n)$

S = Average daily solar gain. $(S^d + S^n)/2$

The effective temperature concept, based on the above principles, is now discussed.

4.3.1 Effective Temperature:

Qualitatively, the effective temperature is that outdoor dry bulb temperature that would produce the same heat transfer through the building envelope as the superposition of conductive, convective, radiative heat transfer and internal free heat actually occurring (ref. 23). It describes the outdoor temperature increase equivalent to the internal gains. This can be written as:

$$T_{eff}^d = t_o^d + \frac{[2(1-B)S + F^d - dR^d]}{UA + DCQ}$$

$$T_{eff}^n = t_o^n + \frac{[2BS + F^n - dR^n]}{UA + DCQ}$$

where:

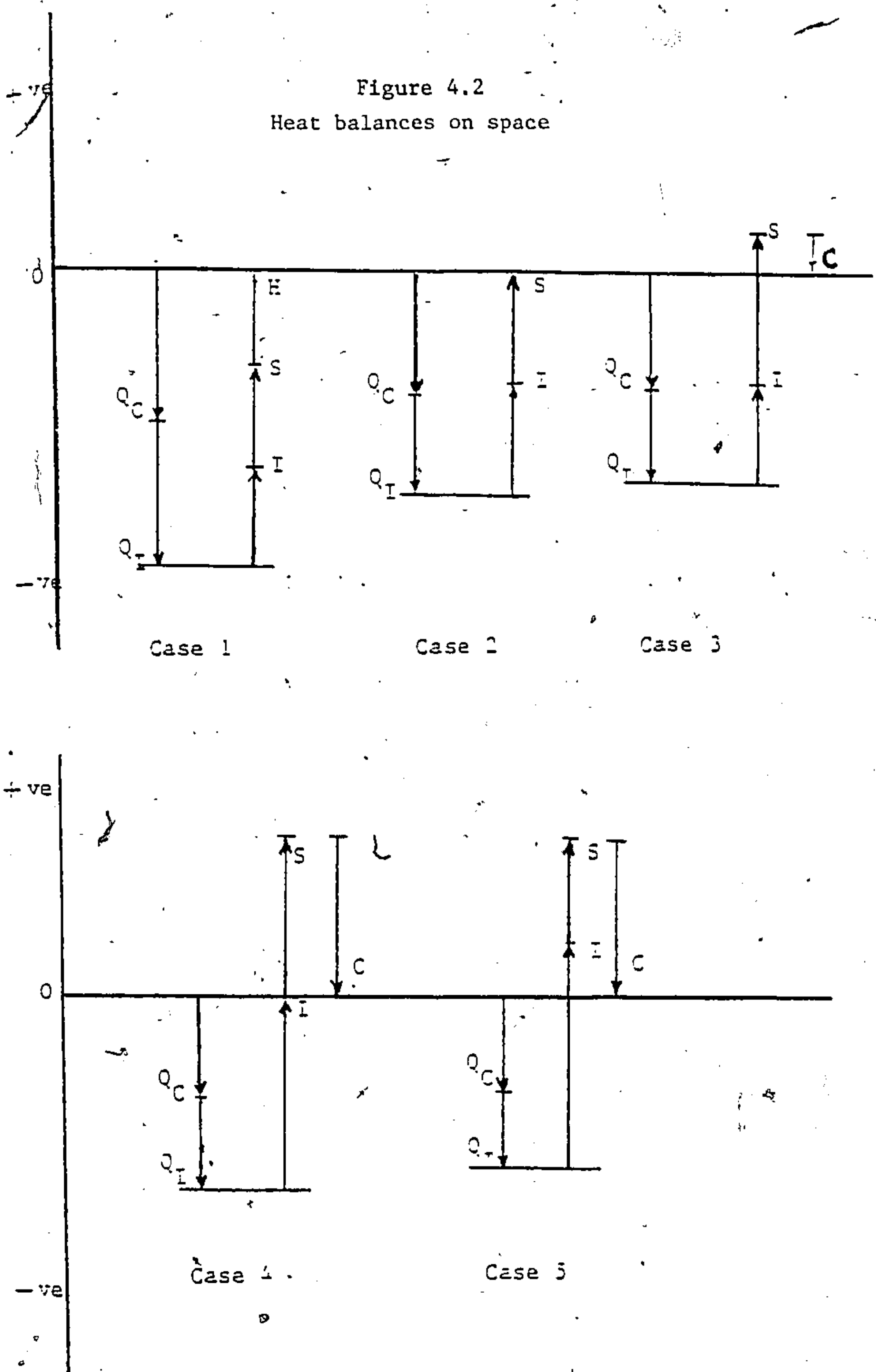
T_{eff}^{d} is the day effective temperature (deg C)

T_{eff}^{n} is the night effective temperature (degC)

The heating load as calculated by CIRA (eqn. 4.1) is based on the assumption that 100% of the solar and internal gains are useful in reducing the heating load i.e. all the solar and internal gains "stay" inside the house, thereby ignoring occupant comfort. This assumption is fairly valid for cold months when transmission losses are high. However in seasonal transition months, such as April/May, the solar and internal gains alone may more than offset transmission losses. This would result in an increase in space temperature.

This is best explained with reference to figure 4.2.(ref. 12)
The vertical axis denotes heat losses/gains.
Case 1 is a typical case for a colder month (for example, December,January) when heat must be supplied to maintain the required space temperature. In this case all of the solar and internal gains are useful in reducing the heating load. This is a case of 100% utilization of free heat.
In Case 2, no space heating is necessary since the gains have just offset the transmission losses. In this case the space temperature lies within the thermostat deadband.
Cases 3 through 5 illustrate the situations when solar and internal gains exceed the transmission losses and hence the excess heat must be removed to prevent the space temperature from rising above an acceptable limit. This situation becomes worse in tight, well

Figure 4.2
Heat balances on space



insulated houses with high solar and internal gains. DOE simulation has shown (ref. 12) to predict inside space temperatures of 110 F in the abscence of procedures to calculate utilization factors. Simulation of the passive solar ranch house (Ottawa) using the DOE 2.1A program by Patwardhan (ref.12) has shown that the solar gain utilizaton factor can be as low as 43% depending on the tightness and insulation level of the house. A comparison of utilization factors as deduced from DOE 2.1A for the Ottawa house are shown in Tables 4.1 and 4.2. Table 4.1 shows the utilization factors for a house of light construction with moderate levels of insulation, tightness and Solar and Internal gains (Case 1).

Table 4.2 shows the utilization factors for a well insulated tight house with high solar and internal gains (Case2).

The above discussion is to emphasize the fact that all of the solar and internal gains do not contribute to reducing the heating load. It is therefore necessary to make the distinction between available solar and internal gains and 'Useful' free heat. Therefore equation 4.1 must be rewritten as:

$$H = (Q_c + Q_i) - (N_s S_g + N_i F)$$

where:

N_s is the solar utilization factor, $N_s S_g$ being portion of solar gains useful in reducing the heating load

N_i is the internal gain utilization factor, $N_i F$ being the portion of internal gains useful in reducing the heating load.

CIRA uses utilization factors of unity throughout the heating season, thereby leading to significant underprediction in heating load when compared with DOE 2.1 (ref.12). A comparison of heating load prediction between the two programs for the Ottawa house(s) can be

Table 4.1
Comparison of Utilization Factors
Between CIRA and DOE 2.1A for Case 1

MONTH	CIRA	DOE 2.1A
JAN	1.000	1.000
FEB	1.000	0.982
MAR	1.000	0.898
APR	1.000	0.659
MAY	1.000	0.341
OCT	1.000	0.489
NOV	1.000	0.853
DEC	1.000	0.983

Table 4.2
Comparison of Utilization Factors
Between CIRA and DOE 2.1A for Case 2

MONTH	CIRA	DOE 2.1A
JAN	1.000	0.829
FEB	1.000	0.752
MAR	1.000	0.628
APR	1.000	0.416
MAY	1.000	0.159
OCT	1.000	0.219
NOV	1.000	0.523
DEC	1.000	0.798

Table 4.3
Comparison of Heating Loads between
CIRA and DOE 2.1A for Case 1

MONTH	CIRA (GJ)	DOE 2.1A (GJ)	Variation CIRA/DOE %
JAN	13.61	14.61	-6.84
FEB	9.91	11.00	-9.91
MAR	7.07	7.65	-7.58
APR	3.17	3.96	-19.95
MAY	1.27	1.66	-23.49
OCT	1.48	2.26	-34.42
NOV	4.66	4.89	-4.80
DEC	11.81	12.81	-3.59
TOTAL	53.15	58.27	-8.79

Table 4.3
Comparison of Heating Loads between
CIRA and DOE 2.1A for Case 2

MONTH	CIRA (GJ)	DOE 2.1A (GJ)	Variation CIRA/DOE %
JAN	4.33	5.06	-14.49
FEB	2.88	3.65	-21.05
MAR	1.79	2.36	-24.43
APR	0.72	1.13	-36.17
MAY	0.00	0.38	-100.00
OCT	0.00	0.55	-100.00
NOV	0.96	1.40	-31.58
DEC	3.75	4.40	-14.79
TOTAL	14.43	18.94	-23.81

found in Tables 4.3 (Case 1) and 4.4 (Case 2). It can be seen that the agreement between the programs worsens when the insulation levels and tightness increase.

Therefore the modified expressions for calculating the effective temperature are:

$$T_{eff}^{d} = t_o^{d} + \frac{[2\,(1-B)S\,N_s + N_i\,F^{d} - dR^{d}]}{UA + DCQ}$$

$$T_{eff}^{n} = t_o^{n} + \frac{[2BS\,N_s + N_i\,F^{n} - dR^{n}]}{UA + DCQ}$$

The **EGY_UTIL** routine determines the utilization factors from empirical correlations developed by Barakat and Sander (refs. 15 and 16). These factors were derived from hourly heat balances on space for 11 Canadian locations. Factors for Light, Medium and Heavy construction with allowable indoor temperature rise of 0, 2.75C, 5.5C (dictated by occupant preference) can be determined by using the following equation and the parameters as given in Table 4.5.

The curve fit equations for solar and internal gain utilization factor are of the form:

$$N_s = \frac{a + b\,GLR}{1 + c\,GLR + d\,GLR^2}$$

where: N_s is the Solar Utilization factor.

Similar correlation have been developed for the Internal gain utilization factor, N_i:

for IGLR < 0.7

$$N_i = 1.0$$

Table 4.5

Coefficients for the Barakat and Sander correlation for calculating Solar Utilization factors.

Constant Temperature				
Mass Unit	a	b	c	d
Light	1	6.498	5.505	12.38
Medium	1	5.751	5.038	7.724
Heavy	1	2.891	2.571	2.711

Temperature Rise 2.75 C				
	a	b	c	d
Light	1.156	-.3479	1.117	-.4776
Medium	1	4.838	4.533	3.632
Heavy	1	.2792	.2450	.4230

Temperature Rise 5.5C				
	a	b	c	d
Light	1.112	-.2334	.8660	.2611
Medium	1.010	.4038	.5574	.4394
Heavy	.9863	.0774	.0535	.3437

for $0.7 \leq IGLR \leq 5.0$

$$N_i = \frac{P_1 + P_2 (IGLR)^{P_3}}{1 + P_2 (IGLR)^{P_3+1}}$$

for IGLR > 5.0

$$N_i = 1.0/IGLR.$$

where;

N_i is the monthly internal gain utilization factor.

a, b, c, d are constants depending on the mass level of the house and indoor temperature rise. (Table 4.5)

GLR is the gain load ratio.

IGLR is the Internal Gain Loss ratio.

The gain load ratio is a normalized parameter given by :

$$GLR = \frac{S}{L_t + L_a + L_b - F}$$

The internal gain loss ratio (IGLR) is given by:

$$IGLR = \frac{F}{L_t + L_a + L_b}$$

S is the average monthly solar gain from subroutine **EGY_SOLGAIN.** (GJ)

L_t is the monthly total heat loss above grade (GJ)

L_a is the monthly loss due to infiltration. (GJ)

L_b is the monthly basement heat loss. (GJ)

F is the monthly average internal gain.

The sum of L_t and L_a can be computed by multiplying the Building load coefficient (from **EGY _ INFOTP**) with the indoor-outdoor temperature difference.

Table 4.6

Correlation Constants for Monthly Data Points

(Internal Gain Utilization Factor Calculation)

Profile	Temp. Swings	Mass Level	P_1	P_2	P_3	r.m.s
House and Constant	All	All	0.675	2.3558	2.342	0.029

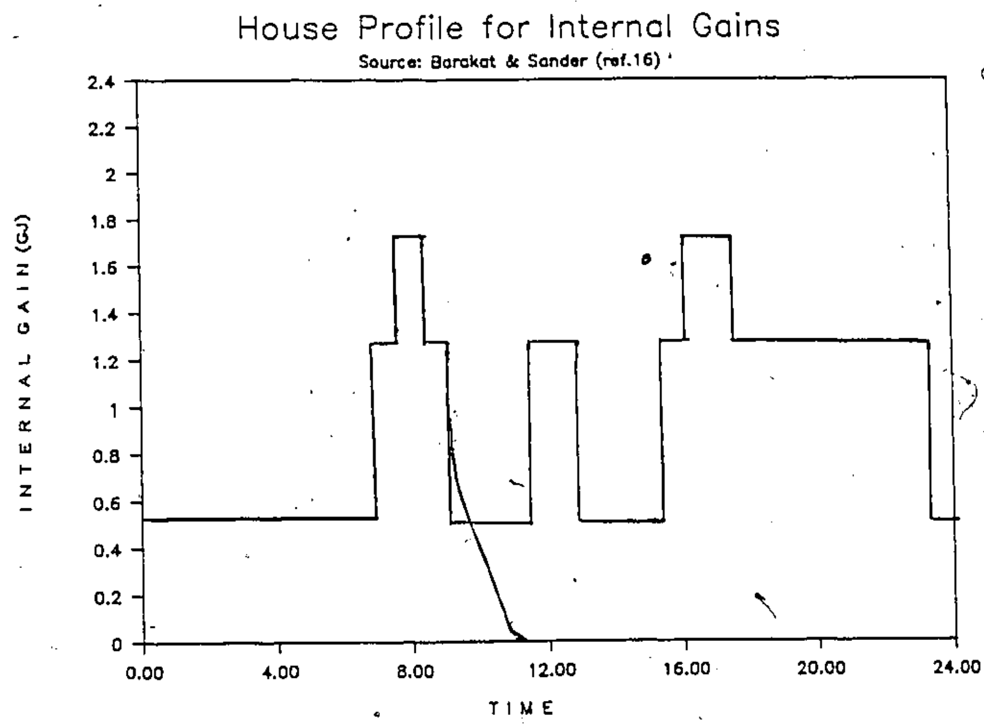
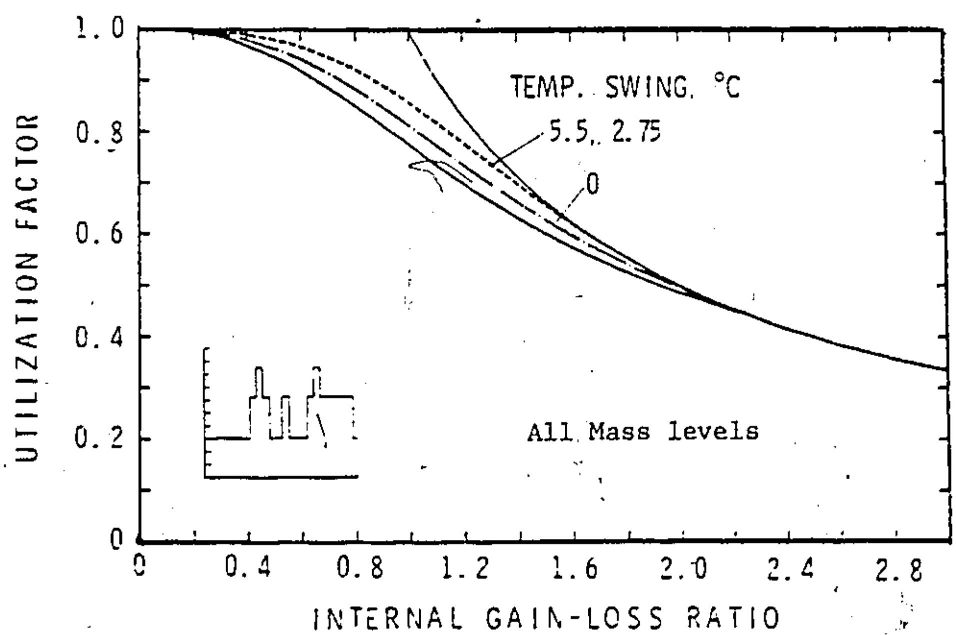


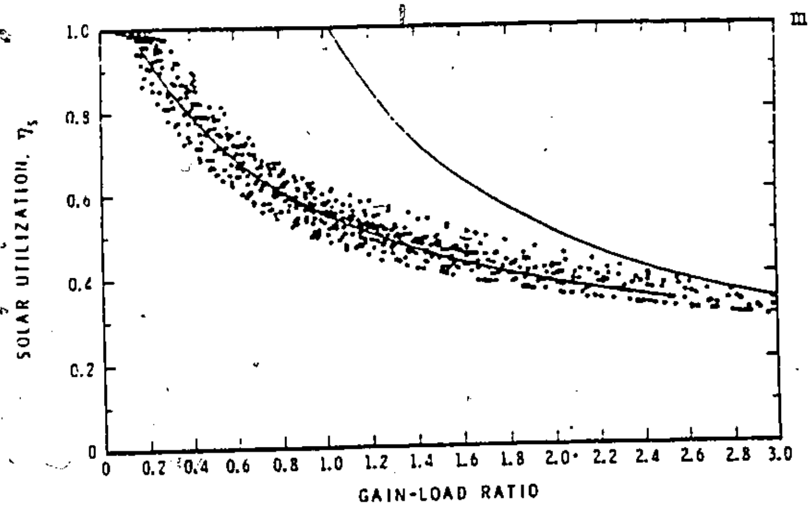
Figure 4.3

House profile for internal gains

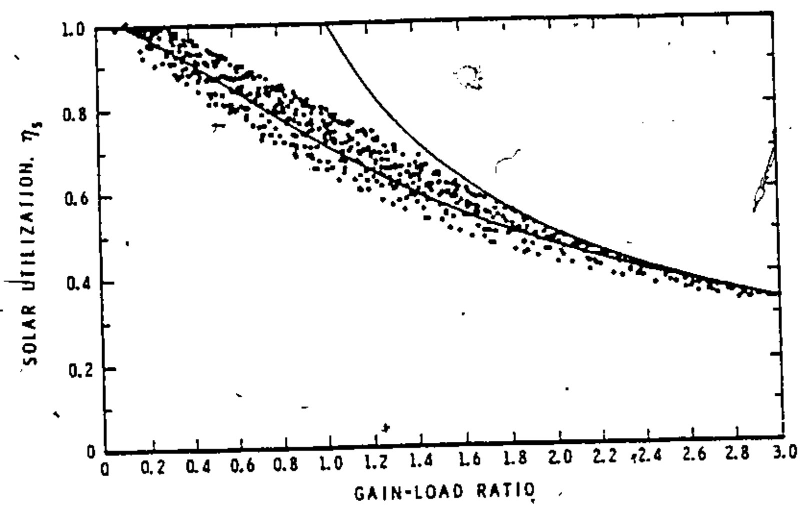


Internal Gain Utilization factor Vs IGLR.

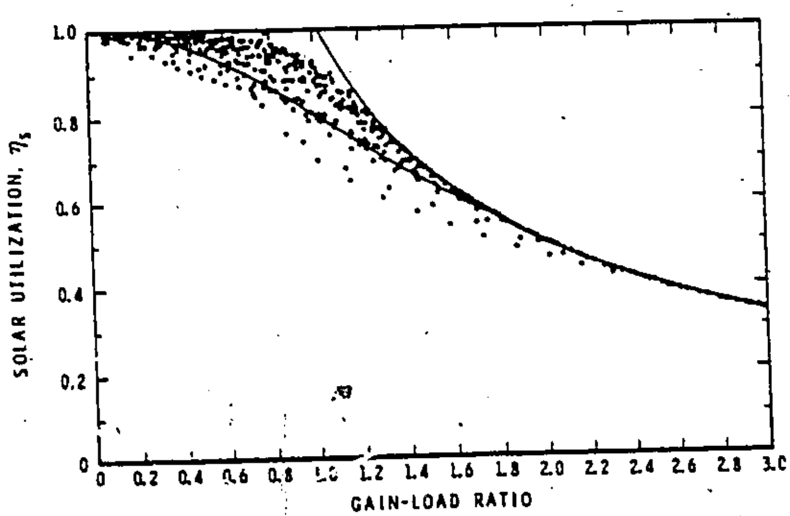
Figure 4.4



(a) LIGHT CONSTRUCTION (MGR = 1)



(b) MEDIUM CONSTRUCTION (MGR = 2.6)



(c) HEAVY CONSTRUCTION (MGR = 7.2)

Solar gain utilization factor Vs. GLR

Figure 4.5

Table 4.6 gives the values for the correlation constants (P_1, P_2 and P_3) for determining the internal gain utilization factor. These correlations constants are valid for a house with a constant internal gain profile (fig.4.3) as assumed in RBEAP. Figures 4.4 and 4.5 (temperature rise =0 deg. C) show typical variation of solar and internal gain utilization factors with GLR and IGLR for different Mass levels. It can be seen that the data points have a fair amount of scatter. However the r.m.s error of prediction using these correlations is .029 or less. (refs. 15 and 16).

4.4 VARIABLE LIST AND MODIFICATIONS:

The variables used in the energy calculation program are listed in Appendix H. The FORTRAN source code is 1767 lines. The calling program for the Energy calculation program is COMP.FOR. The executable file can be produced by compiling the CEGY.FOR file and typing in @Comp at the DCL command level.

4.5 CLOSURE:

A discussion of the Energy Calculation program has been given. The function of the subroutines and a detailed description of the Engineering changes over CIRA has been discussed. The effect(s) of these changes in load predictions made by RBEAP are discussed in detail in Chapter 6. The next Chapter deals with a description of the plotting program.

CHAPTER 5

PLOTTING PROGRAM

5.1 INTRODUCTION:

The variables calculated in CEGY.FOR, which are stored in the HOUSE.LOD file, are used by the plotting routines to display the final ouput of the program. An example HOUSE.LOD file for the passive solar ranch house (Case 2) is given in Appendix G-1. Two VAX/VMS system services which are utilized are the Screen-Management procedures (as explained in Chapter. 2) and the RGL (Regis Graphics Object code library) subroutines (ref. 33).

This Chapter is divided into three sections:

a) An explanation of the keyboard functions which are used during the plotting session.

b) A brief discussion of the subroutines used during the plotting program.

c) A discussion of the HOUSE.LOD file

5.2 KEYBOARD USE:

The plotting program made extensive use of RGL routines and was decidedly superior to the one used in the CIRA program. The results produced by the program are displayed in the form of tabular data. This is the begining of the interactive plotting session. In the present version of the program, 19 variables are displayed in three screens as shown in figures 5.1, 5.2 and 5.3

The following keys (VT-240 Terminal) are active during the plotting session.

Help - Display help screen for appropriate section

Return - Gets the user out of the program and returns to command level i.e. the $ prompt.
@RBEAP should be typed to restart the program.

Do - Display bar-graph of currently highlighted item.

Find - Display full name of currently highlighted item. (fig.5.4)

Insert here - Move any column not currently displayed to the highlighted position. This key allows the user to construct a custom screen. This is useful for printouts where certain information is desired in the same table.
To use:

1. Place highlight on column you wish to replace using the left and right arrow keys.

Graph Data

	1 Dload GJ	2 Nload GJ	3 DayOn %	4 NitOn %	5 SpEgy GJ	6 infil ac/hr	7 T gas therm	8 Telec kWh	
Jan:	5.2	6.2	43.9	52.3	11.3	0.68	0	4221	:Jan
Feb:	4.0	5.4	37.3	50.5	9.3	0.69	0	3564	:Feb
Mar:	2.4	4.3	20.4	36.4	6.7	0.55	0	2932	:Mar
Apr:	1.0	2.3	9.2	20.2	3.3	0.48	0	1969	:Apr
May:	0.0	0.0	0.0	0.0	0.0	0.45	0	1074	:May
Jun:	-0.4	-0.1	0.0	0.0	0.0	0.30	0	1039	:Jun
Jul:	-0.6	-0.3	0.0	0.0	0.0	0.34	0	1074	:Jul
Aug:	-0.5	-0.2	0.0	0.0	0.0	0.33	0	1074	:Aug
Sep:	-0.1	-0.0	0.0	0.0	0.0	0.38	0	1039	:Sep
Oct:	0.8	1.7	6.4	14.4	2.5	0.44	0	1755	:Oct
Nov:	2.2	3.2	19.1	28.4	5.4	0.49	0	2542	:Nov
Dec:	4.2	5.0	35.4	42.9	9.2	0.58	0	3632	:Dec
SUM:	18.2	27.5	171.7	245.1	47.8	5.70	0	25912	:SUM
MEAN:	1.5	2.3	14.3	20.4	4.0	0.48	0	2159	:MEAN

Figure 5.1

Output variables

Graph Data

	9 DewPt deg C	10 Sgain GJ	11 Rloss GJ	12 VBDDy C-day	13 Spce$ $	14 Gas $ $	15 Elec$ $	16 Teffd degC	
Jan:	-6.2	0.8	0.48	622	141.6	0.0	190	3.1	:Jan
Feb:	-5.8	1.2	0.44	500	116.7	0.0	160	6.5	:Feb
Mar:	-1.0	1.8	0.48	355	83.6	0.0	132	14.3	:Mar
Apr:	4.7	1.9	0.45	150	41.8	0.0	89	22.0	:Apr
May:	9.6	3.4	0.44	-51	0.0	0.0	48	28.2	:May
Jun:	14.1	3.6	0.39	-199	0.0	0.0	47	38.8	:Jun
Jul:	17.0	3.7	0.37	-245	0.0	0.0	48	41.2	:Jul
Aug:	15.4	3.1	0.39	-177	0.0	0.0	48	36.9	:Aug
Sep:	12.5	2.4	0.40	-50	0.0	0.0	47	28.2	:Sep
Oct:	6.7	1.3	0.46	124	30.7	0.0	79	22.4	:Oct
Nov:	2.4	0.8	0.45	315	67.6	0.0	114	13.5	:Nov
Dec:	-2.6	0.7	0.47	534	115.1	0.0	163	5.9	:Dec
SUM:	66.7	24.7	5.21	1876	597.2	0.0	1166	261.1	:SUM
MEAN:	5.6	2.1	0.43	156	49.8	0.0	97	21.8	:MEAN

Figure 5.2

Output variables

Graph Data

	17	18	19	1	2	3	4	5	
	Teffn	BLoss	SolUF	Dload	Nload	DayOn	NitOn	SpEgy	
	degC	GJ	%	GJ	GJ	%	%	GJ	
Jan:	-1.0	1.8	94.8	5.2	6.2	43.9	52.3	11.3	:Jan
Feb:	-0.0	1.6	91.3	4.0	5.4	37.3	50.5	9.3	:Feb
Mar:	5.3	1.7	84.0	2.4	4.3	20.4	36.4	6.7	:Mar
Apr:	13.0	1.3	70.0	1.0	2.3	9.2	20.2	3.3	:Apr
May:	14.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	:May
Jun:	18.6	0.0	0.0	-0.4	-0.1	0.0	0.0	0.0	:Jun
Jul:	21.3	0.0	0.0	-0.6	-0.3	0.0	0.0	0.0	:Jul
Aug:	20.2	0.0	0.0	-0.5	-0.2	0.0	0.0	0.0	:Aug
Sep:	16.2	0.0	0.0	-0.1	-0.0	0.0	0.0	0.0	:Sep
Oct:	14.8	0.8	72.4	0.8	1.7	6.4	14.4	2.5	:Oct
Nov:	8.0	1.2	90.1	2.2	3.2	19.1	28.4	5.4	:Nov
Dec:	1.9	1.5	95.0	4.2	5.0	35.4	42.9	9.2	:Dec
SUM:	133.1	10.0	597.6	18.2	27.5	171.7	245.1	47.8	:SUM
MEAN:	11.1	0.8	49.8	1.5	2.3	14.3	20.4	4.0	:MEAN

Figure 5.3

Output variables

Graph Data

	17	18	19	1	2	3	4	5	
	Teffn	BLoss	SolUF	Dload	Nload	DayOn	NitOn	SpEgy	
	degC	GJ	%	GJ	GJ	%	%	GJ	
Jan:	-1.0	1.8	94.8	5.2	6.2	43.9	52.3	11.3	:Jan
Feb:	-0.0	1.6	91.3	4.0	5.4	37.3	50.5	9.3	:Feb
Mar:	5.3	1.7	84.0	2.4	4.3	20.4	36.4	6.7	:Mar
Apr:	13.0	1.3	70.0	1.0	2.3	9.2	20.2	3.3	:Apr
May:	14.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	:May
Jun:	18.6	0.0	0.0	-0.4	-0.1	0.0	0.0	0.0	:Jun
Jul:	21.3	0.0	0.0	-0.6	-0.3	0.0	0.0	0.0	:Jul
Aug:	20.2	0.0	0.0	-0.5	-0.2	0.0	0.0	0.0	:Aug
Sep:	16.2	0.0	0.0	-0.1	-0.0	0.0	0.0	0.0	:Sep
Oct:	14.8	0.8	72.4	0.8	1.7	6.4	14.4	2.5	:Oct
Nov:	8.0	1.2	90.1	2.2	3.2	19.1	28.4	5.4	:Nov
Dec:	1.9							9.2	:Dec
SUM:	133.1							47.8	:SUM
MEAN:	11.1							4.0	:MEAN

Long Name

Effective Temperature(night)

Figure 5.4

'Graph Data' screen when 'Find' key is pressed

2. Press INSERT HERE key. A display (fig. 5.5) will appear with the names of the columns which are not already displayed on the screen.

3. Using the UP and DOWN arrow keys, place highlight on the name of the column you want to insert. If no insertion is required, select Exit.

4. Press RETURN. The displays will disappear and the column will be inserted.

Select - Displays complete list of names of data items. (figs. 5.7 and 5.8)

Prev. Screen - Displays the previous eight columns (if they exist) and/or scroll to the last items.

Next Screen - Displays the next eight columns (if they exist) and/or scroll to the first items.

Arrow keys - Moves highlight left/right or up/down as appropriate

F17 - Snapshot. Saves a copy of the screen to a file called **DATA_TABLE.PRI;n** for later printing. (n is an integer one higher than the last copy of **DATA_TABLE.PRI**)

```
                                Graph Data
           17     INSERT COLUMN                    Possible Answers
          Teffn                                  Exit
          degC   Select column to INSERT          6. Infiltration
                                                  7. Overall gas use
  Jan:    -1.0                                    8. Overall elec use
  Feb:    -0.0    1.6    91.3     4.0     5.      9. Indoor Dew Point
  Mar:     5.3    1.7    84.0     2.4     4.     10. Solar gain
  Apr:    13.0    1.3    70.0     1.0     2.     11. Sky radiation loss
  May:    14.8    0.0     0.0     0.0     0.     12. Var. Base Degree Days
  Jun:    18.6    0.0     0.0    -0.4    -0.     13. Space cond. cost
  Jul:    21.3    0.0     0.0    -0.6    -0.     14. Overall gas cost
  Aug:    20.2    0.0     0.0    -0.5    -0.     15. Overall elec cost
  Sep:    16.2    0.0     0.0    -0.1    -0.     16. Effective Temperature(day)
  Oct:    14.8    0.8    72.4     0.8     1.
  Nov:     8.0    1.2    90.1     2.2     3.2   19.1    28.4     5.4  :Nov
  Dec:     1.9    1.5    95.0     4.2     5.0   35.4    42.9     9.2  :Dec

  SUM:   133.1   10.0   597.6    18.2    27.5  171.7   245.1    47.8  :SUM
 MEAN:    11.1    0.8    49.8     1.5     2.3   14.3    20.4     4.0  :MEAN
                                Keyboard Use
UP or DOWN arrows to change selection, RETURN to choose, ctrl D for default
```

Figure 5.5

'Graph Data' screen when 'Insert here' key is pressed

```
                                Graph Data
           17     18     19      1       2       3      4       5
      +--------- Enter Formula ---------------------+n  NitOn   SpEgy
      |                                             |    %      GJ
      |     Enter formula and press RETURN          |
  J   |      Press HELP for instructions            |9   52.3    11.3  :Jan
  F   |  _                                          |3   50.5     9.3  :Feb
  M   |                                             |4   36.4     6.7  :Mar
  A   +---------------------------------------------+2   20.2     3.3  :Apr
  May:    14.8    0.0     0.0     0.0     0.0     0.0     0.0     0.0  :May
  Jun:    18.6    0.0     0.0    -0.4    -0.1     0.0     0.0     0.0  :Jun
  Jul:    21.3    0.0     0.0    -0.6    -0.3     0.0     0.0     0.0  :Jul
  Aug:    20.2    0.0     0.0    -0.5    -0.2     0.0     0.0     0.0  :Aug
  Sep:    16.2    0.0     0.0    -0.1    -0.0     0.0     0.0     0.0  :Sep
  Oct:    14.8    0.8    72.4     0.8     1.7     6.4    14.4     2.5  :Oct
  Nov:     8.0    1.2    90.1     2.2     3.2    19.1    28.4     5.4  :Nov
  Dec:     1.9    1.5    95.0     4.2     5.0    35.4    42.9     9.2  :Dec

  SUM:   133.1   10.0   597.6    18.2    27.5   171.7   245.1    47.8  :SUM
 MEAN:    11.1    0.8    49.8     1.5     2.3    14.3    20.4     4.0  :MEAN
```

Figure 5.6

'Graph Data' screen when numeric keypad 'Enter' is pressed

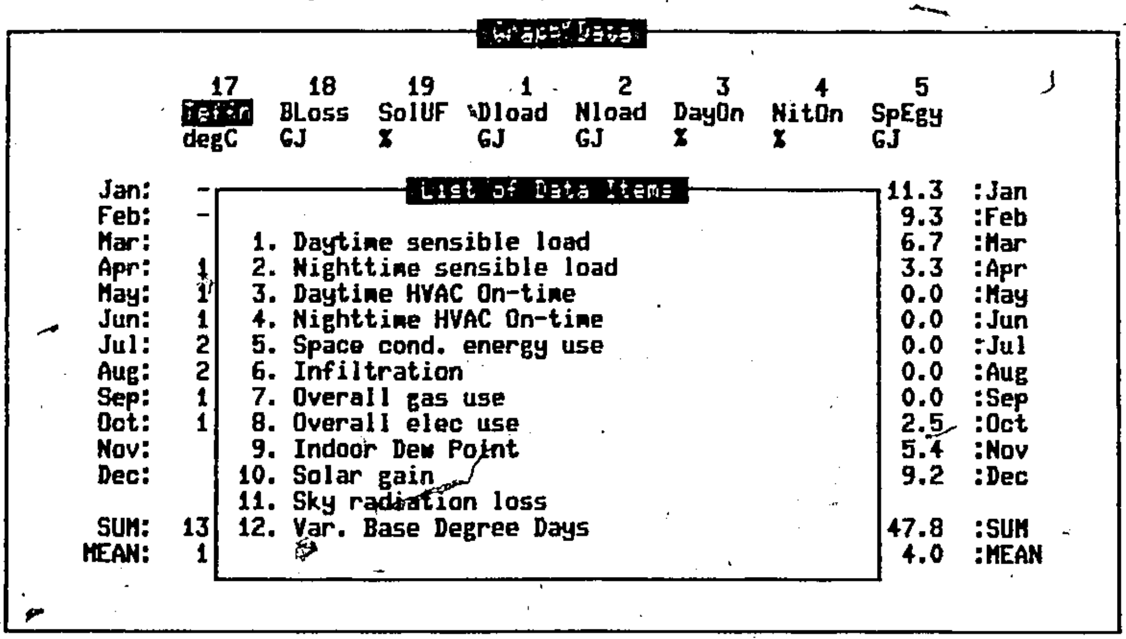


Figure 5.7

'Graph Data' screen when 'Select' key is pressed

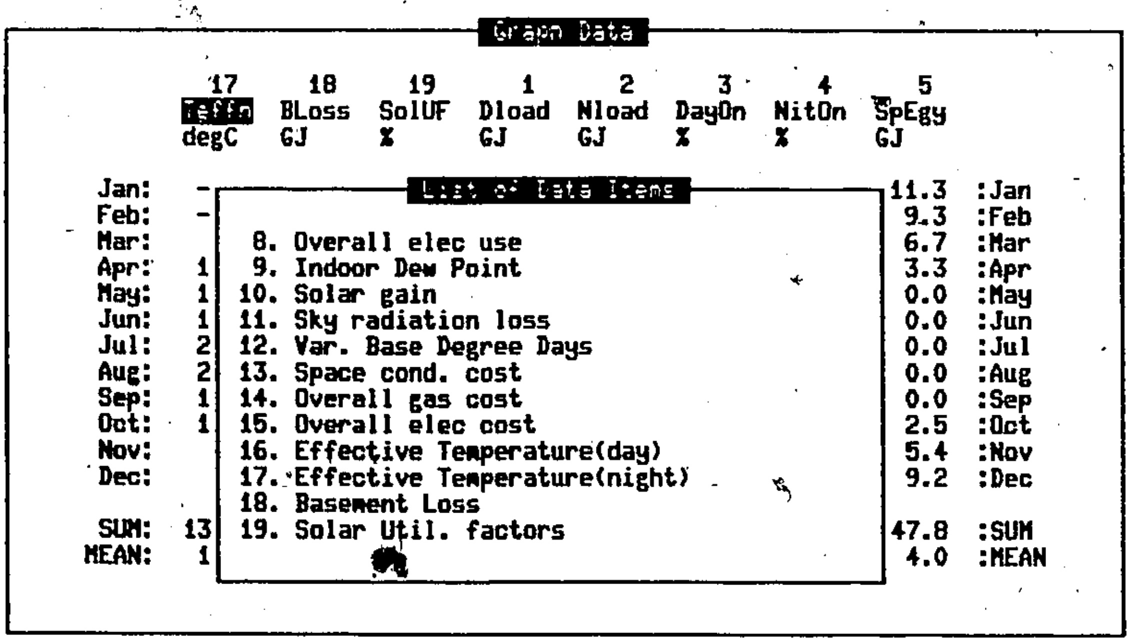


Figure 5.8

'Graph Data' screen when 'Select' key is pressed

PFn - Display multiple bar graphs of data items where n is the number of data items to be graphed. For example PF1 displays one data item on a single graph (fig. 5.9), PF2 displays two data items (fig. 5.10), PF3 displays 3 data items (fig. 5.11) and PF4 displays 4 data items. (fig. 5.12)

To use:

Press PF1 to PF4 depending on the number of graphed. Using the UP and DOWN arrow keys, select items to be graphed, one at a time. Press RETURN after each selection. The display will disappear and reappear for each subsequent item to be graphed.

'.' - Numeric pad decimal. Changes the type of highlight you keep pressing '.', the highlight will shut off allowing for photographs of the screen. Pressing '.' again restores the cursor. All functions work as normal whether or not the cursor is visible.

'0' - Numeric pad zero - Change the column headings to blank, small letters, capital letters, small Roman numerals, capital Roman numerals and back to Arabic. Only the Arabic are specific to the data item, the others are specific to the column position. This is handy for both printouts and photographs.

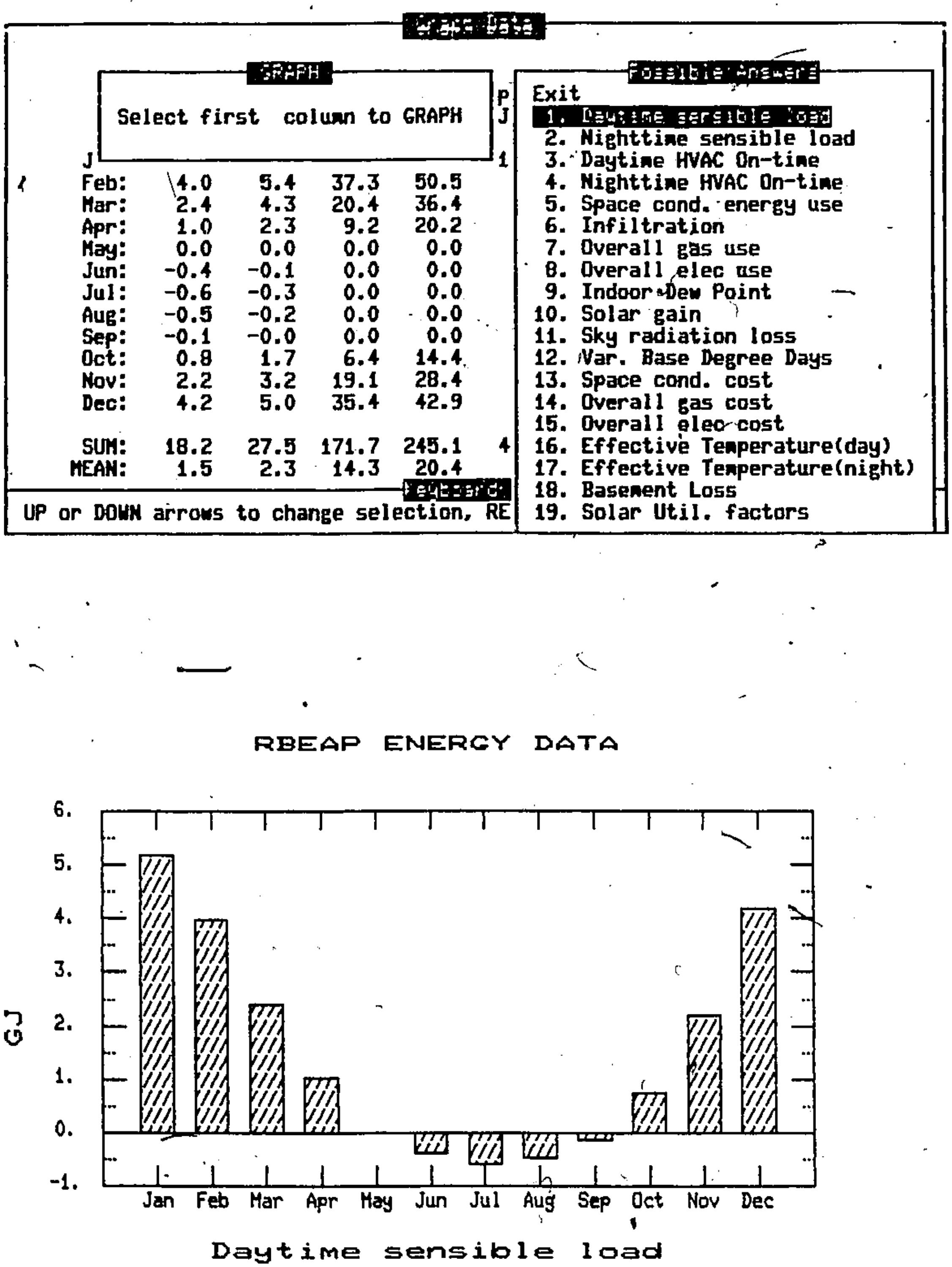


Figure 5.9

One output variable graph display

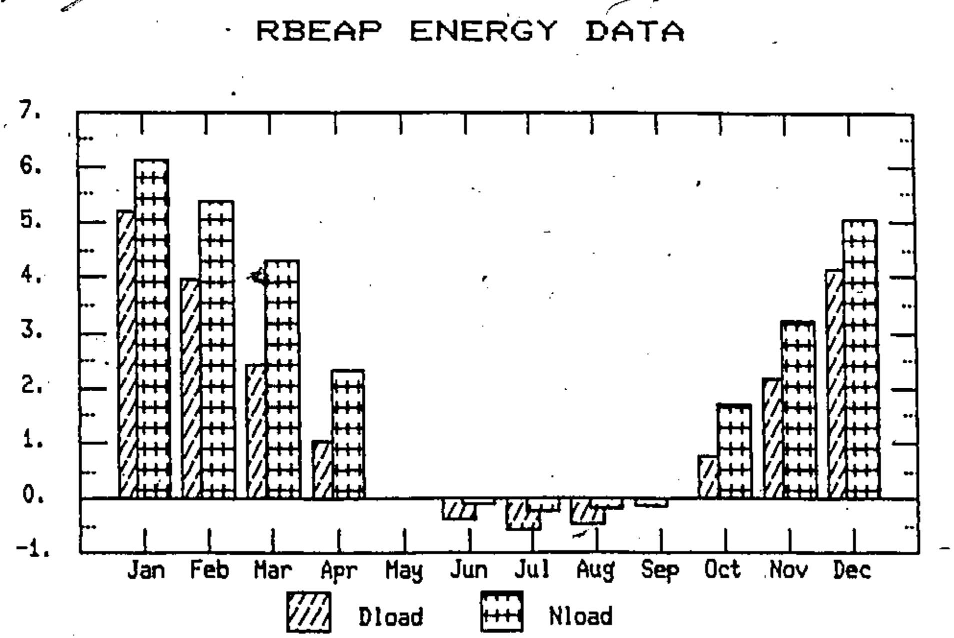


Figure 5.10

Two variable graph display

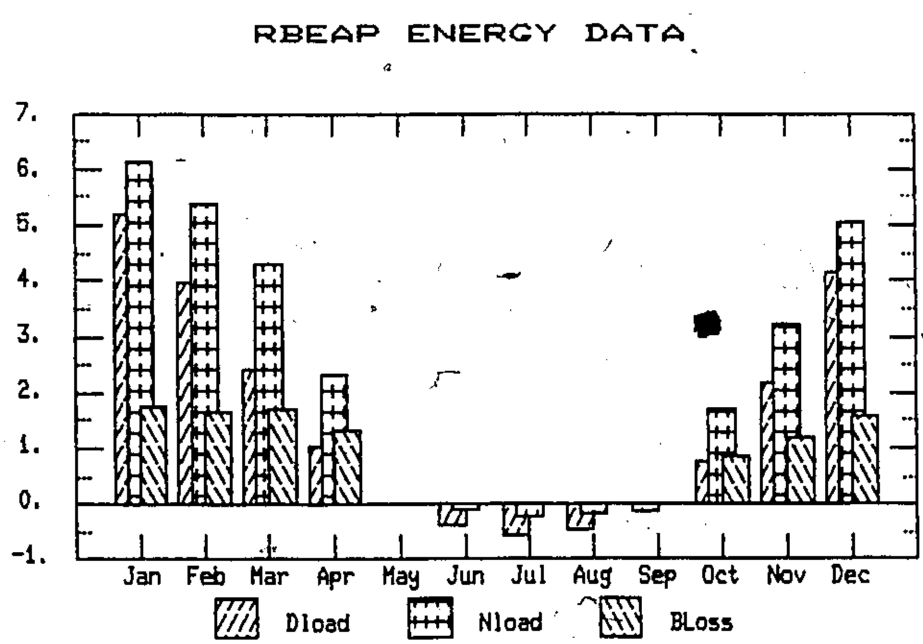


Figure 5.11

Three variable graph display

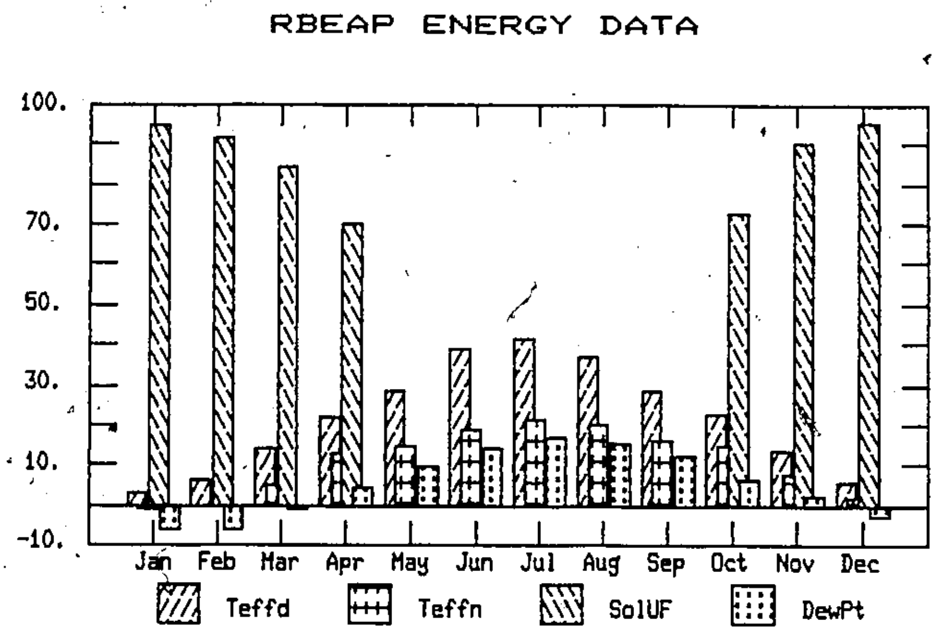


Figure 5.12

Four variable graph display

ENTER - Numeric pad 'ENTER'. By pressing this key the stack calculator (similar to a HP calculator) is enabled allowing the user to calculate between columns (see fig. 5.6). For example the user might want to compute the product of Solar gain and solar utilization factors and put the information in a new column called 'UseSol'. If Solar gain is displayed in column n and Utilization factors in column m, then the new column can be created by typing [n]![m]*, when asked to type in the formula.

The program will also request the long and short name of the new column to be created. For a demonstration of the stack calculator, the user is required to type 'DE' when asked to provide a formula. When DE is typed a display with the label 'Stack Calculator Demo' (fig. 5.13) and you will be asked to provide the formula.(eg. 3!5/). The screen will now show the stacks X,Y,Z,T (fig.5.14 and 5.15). By pressing the space bar, the values of the entries (3 and 5 in this case) will appear in the stacks. At the end of the operation the answer is returned (fig.5.16). The construction of a formula and the operators used are the same as those described in Chapter 2. The 'Help' facility (figs. 5.17, 5.18, 5.19 and 5.20) may also be utilized.

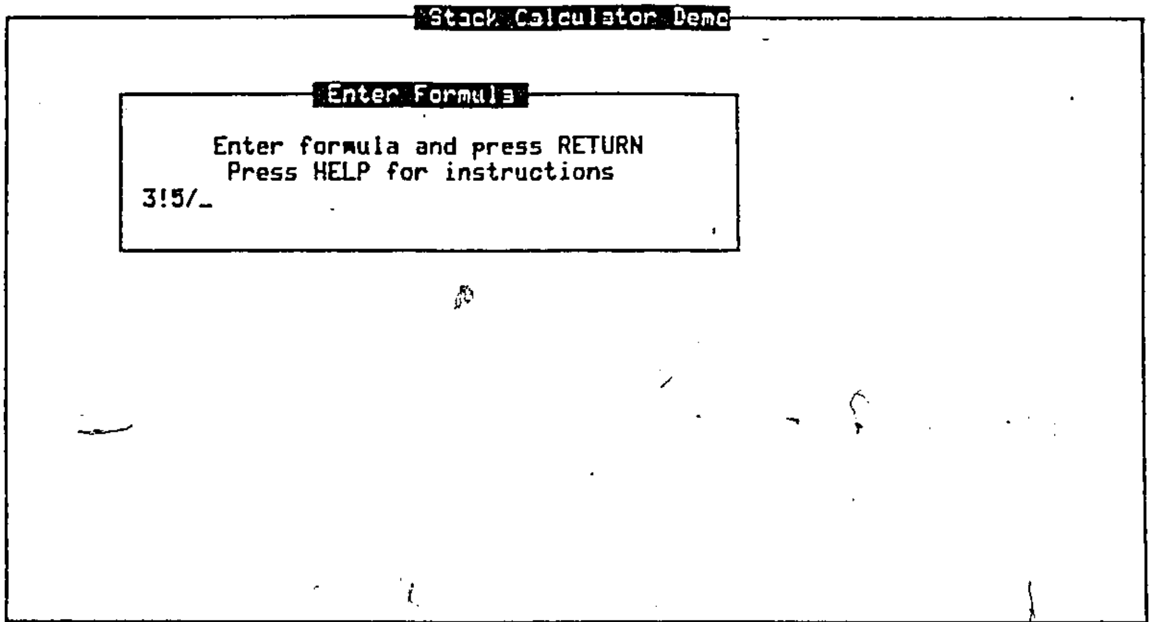


Figure 5.13

Figures 5.13 - 5.16 show the screens for the stack calculator example.

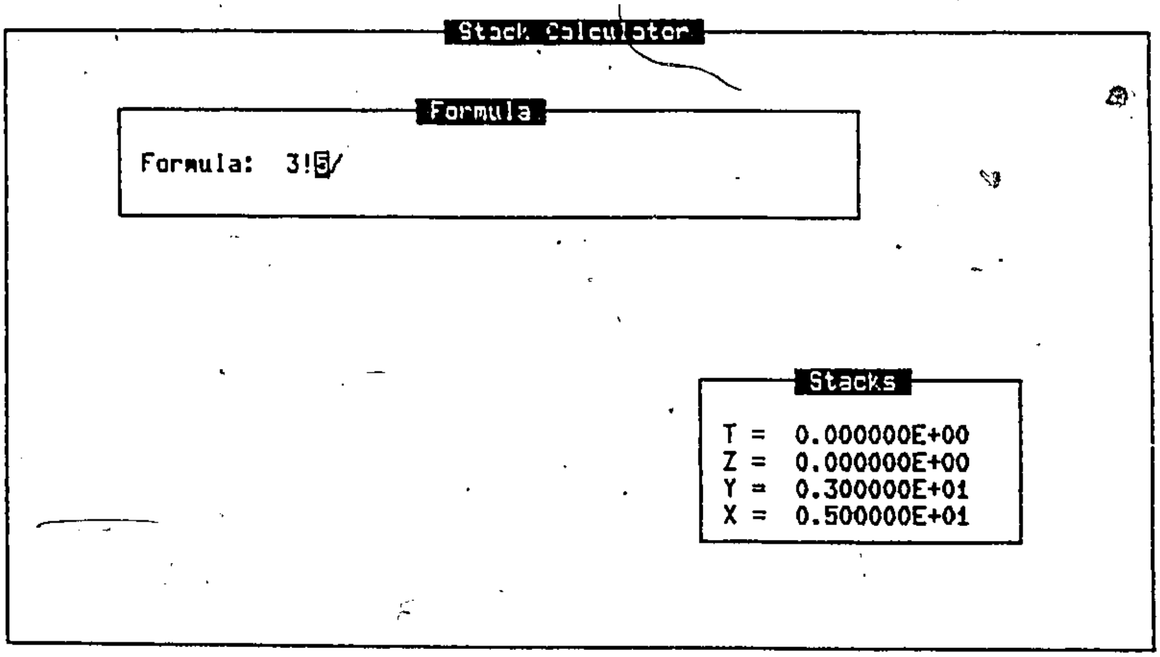


Figure 5.14

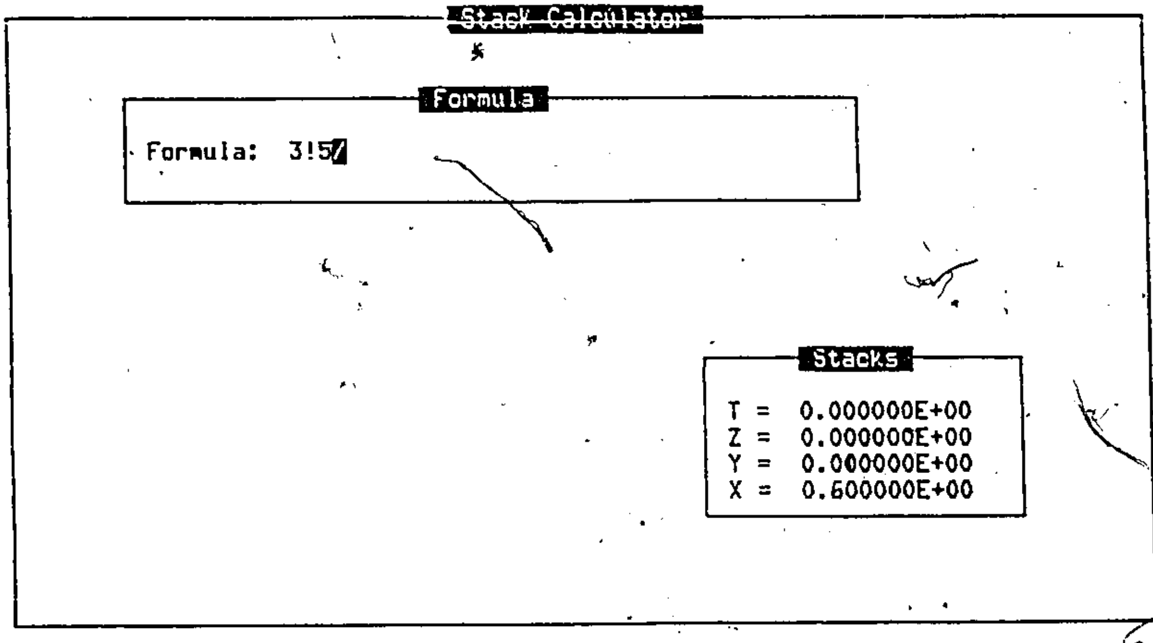


Figure 5.15

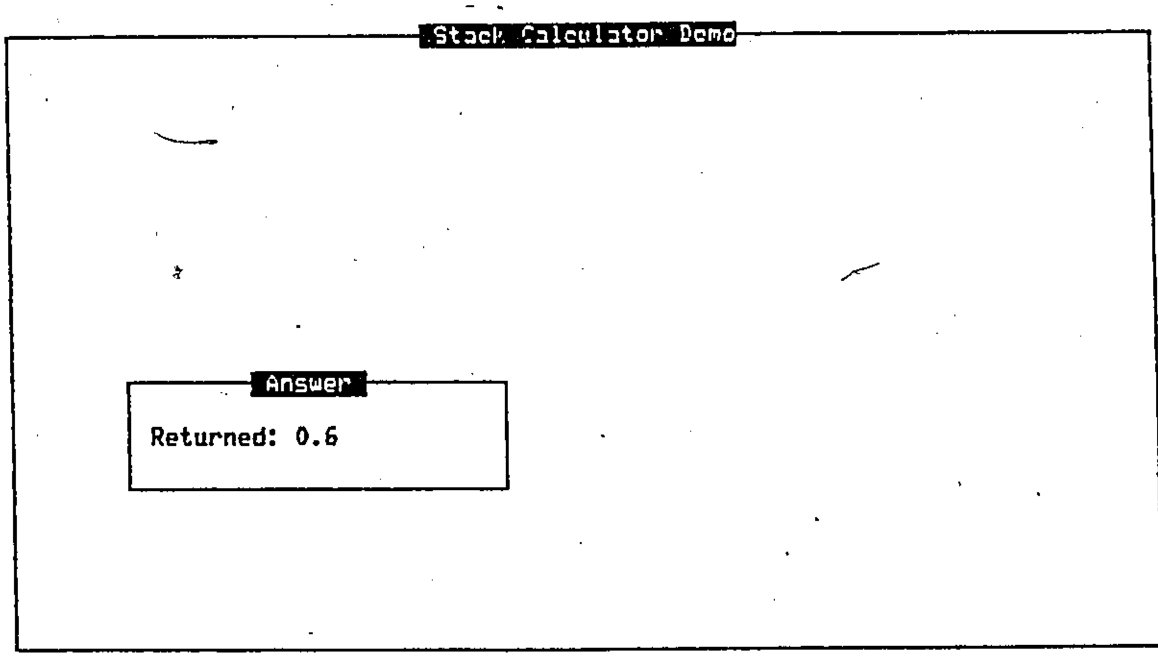


Figure 5.16

Help Information

Enter the formula for the column you wish to create.

This is done in the style of an HP calcuator.

Character	Function
[n]	Column numbers must be enclsed in square brackets
C	Clear Stack
!	Enter
+ -	Addition, Subtraction
* /	Multiplication, Division
@	Change Sign

Press any key to continue

Figure 5.17

Figures 5.17 - 5.20 show the screens for 'Help' during the plotting session.

Help Information

Character	Function
^	Y to the X power
L	Natural Log (base e)
X	Exponential Function (e^x)
I	Invert
~	Swich X and Y
=	X equals Y
#	X not equals Y
>	X Greater than Y

Press any key to continue

Figure 5.18

Help Information

Character	Function
<	X less than Y
)	X greater than or equals Y
(	X less than or equals Y

Demonstration: To run a demonstration of the stack calculator type 'DE' when asked to provide formula. When DE is typed a display with the label 'Stack Calculator demo' appears and you will be asked to provide a formula (eg 3!5/. The screen will now show the stacks X,Y,Z,T. By pressing the space bar the values of your entries (3 and 5 in this case) will appear in the stacks as the operation proceeds.

Press any key to continue

Figure 5.19

Help Information

At the end of the operation,the answer is returned.

Logical Operators: True places -1 in the X register
False places 0 in the X register

Example: [2]![3]/ This divides column 3 by column 2.
2!3/ This divides 2 by 3.

Note: Formulas can be up to 40 characters long.

Constants must be positive (use @ to change sign). They can be real or integer unless in scientific form, in which case they must include decimal point.
Eg. 2.34567E-3

Press any key to continue

Figure 5.20

5.3 SUBROUTINE DESCRIPTION:

The subroutine call sequence for the plotting program, GRAPH HOUSE.FOR is shown in figure 5.21. A brief description of the subroutines follows.

Read House Lod:

This routine reads the HOUSE.LOD file. It calls FORMAT DATA which uses the format code read by READ HOUSE LOD to reformat the HOUSE.LOD variables for graphical display.

Hi Lo:

This routine uses the information read from the HOUSE.LOD file to determine the y-axis range and also the number of divisions and subdivisions to be displayed on the graph.

Fmt:

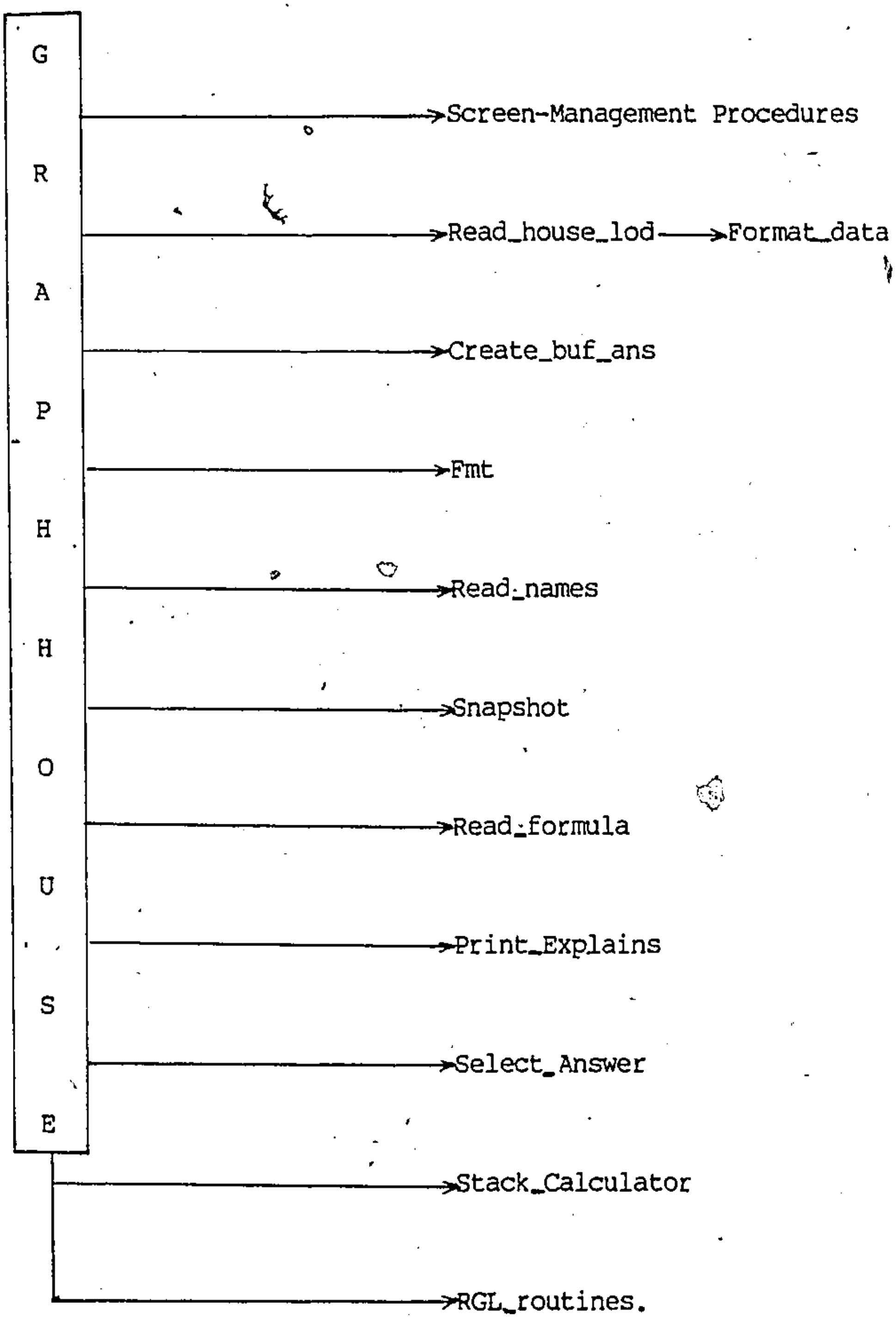
The inputs to this routine are the format code (as read from the HOUSE.LOD file) and the measurement to be formatted. The output is the formatted measurement. The format code is the format statement used in CIRA (BASIC) for the particular variable.

Read Names:

This routine reads the long name, short name and units of any new column to be created by the user and then displays the necessary information in 'Graph Data'.

Figure 5.21

Call Sequence for Plotting Program, GRAPH HOUSE.FOR



Create_buf_ans:

This routine creates a working character buffer to be used during the plotting program. This also includes possible answer lists to be displayed in 'Graph Data'.

Snapshot:

This routine saves the current graph data screen to the file called data table.pri;n for later printing.

The functions of the **PRINT_EXPLAINS, SELECT_ANSWER** and **STACK___CALCULATOR** subroutines have been described earlier in chapter.2. A detailed description and use of the RGL routines is given in reference 33. The call sequence for the RGL routines is shown in figure 5.22.

5.4 THE HOUSE.LOD FILE:

This file is a sequential data file containing the results of the program as calculated in CEGY.FOR. A sample HOUSE.LOD file is listed in Appendix G-1. Some representative portions of the House.Lod file are listed in Tables 5.1 and 5.2.

A discussion of the data structure of this file follows. Table 5.1 lists the first 44 records of the sequential HOUSE.LOD data file. The first record contains the descriptive title for the contents of the HOUSE.LOD file. This title will also appear as the Header for all

Figure 5.22

Call Sequence for RGL routines.

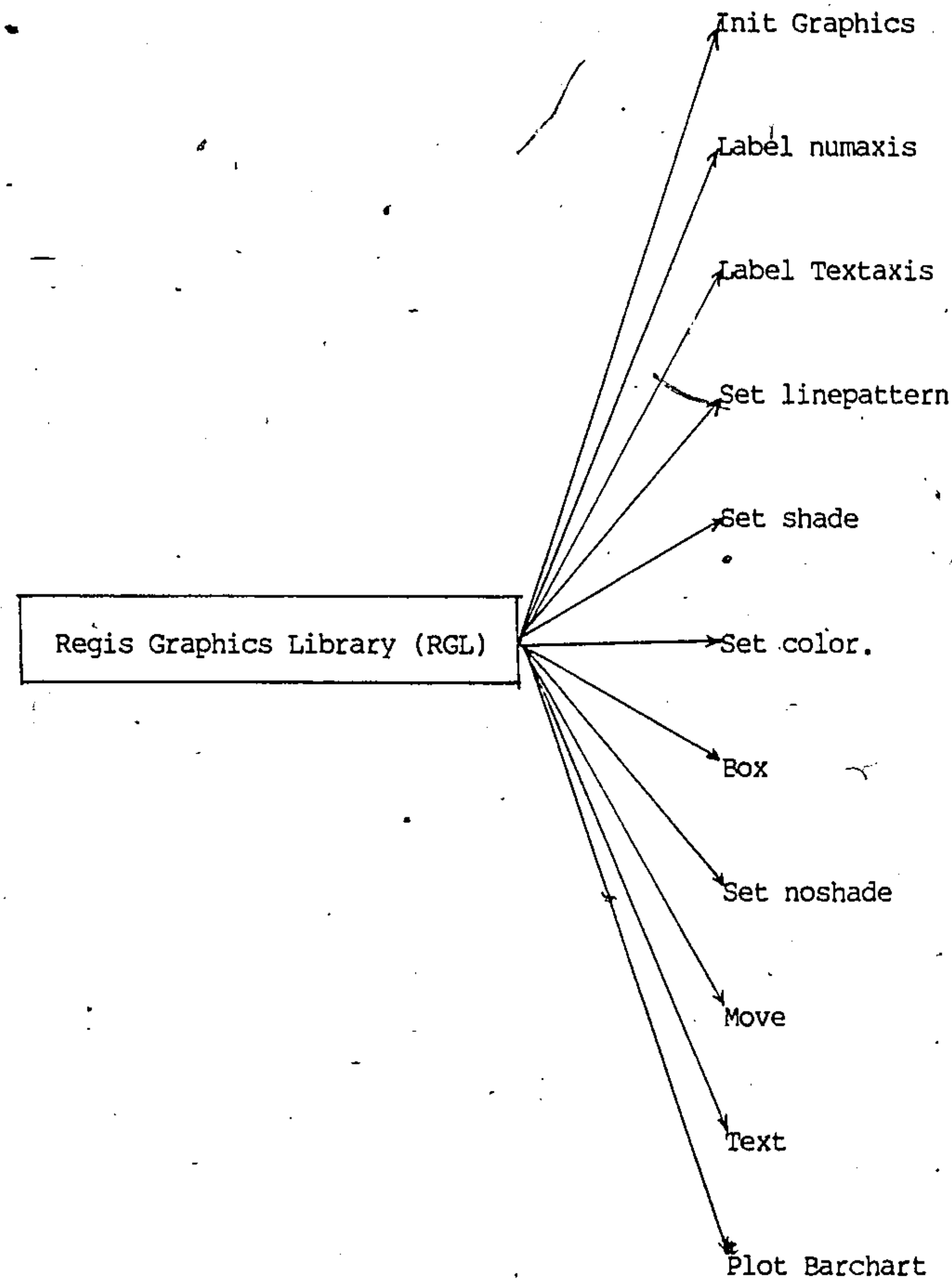


Table 5.1

Example Listing of a portion of the HOUSE.LOD file

```
RBEAP energy data
21

1$Occupants' Name
LIFE

1$House name
Case 2

1#House Area (sqm)
109

1#House Volume (cum)
266

1$city
OTTAWA

1#Latitude (deg)
45

1#Altitude (meters)
125

1#Azimuth (deg)
0

1#Solar Storage Factor (unitless)
0.22

1#Therml time constant (hr)
13.7953

1#Free Heat (W)
670.442

1#Moisture (Kg.day)
1.9835

3# Building Load Coefficient (W/C): yearly/heating/cooling
80.4722
87.9405
73.0039
```

Table 5.2

Example Listing of a portion of the HOUSE.LOD file

Content of Record	Description
Available Solar Gain	Long Name
AvSol	Short Name
GJ	Units to appear in Tabular display
###.#	Format Code from BASIC
.000002532	Conversion from Btu/day to GJ
122061 117787 123818 89093.5 67233.4 76527.7 63625.9 82736.1 83229.8 106525 80573.1 101427	Calculated values from Subroutine Egy Solgain

graphs drawn during the course of the plotting program. Record number 2 (1$ Occupants' Name) is the value assigned to the character variable occupant name. The prefix 1$ indicates that this variable has only one value associated with it and it is of character type. Similar descriptions apply for the other information listed in Table 5.1. For example '3# Building Load Coefficient' indicated that this variable has three values associated with it (and hence of Dimension 3) and is of numeric type. The begining of the HOUSE.LOD file contains information on variables whose associated values are less than 12. The next part of the file contains information on the variables associated with monthly values as listed in Table 5.2.

A description of the records for monthly variables follows:

The first record contains the Long Name of the variable. This is the name that will appear when the 'FIND' key on the VT-240 terminal is pressed. The second record contains information on the Short Name of the variable. This is the name that will appear as the Label in 'Graph Data'. The third record contains the unit conversion factor with which the HOUSE.LOD value has to be multiplied for display in 'Graph Data'. In this case the conversion of the Avaialble Solar Gain is from Btu/Day (HOUSE.LOD units) to GJ (units for Tabular display). The remaining records are the 12 program calculated values for the 12 months of the year.

The purpose of the above discussion is to aid future workers or users who would like to modify the Tabular data . The above data structure must be strictly adhered to. The other output file from the plotting program is the Related Data.pri;n file which can be found in Appendix G-2.

5.5 CLOSURE:

A description of the plotting program used in RBEAP has been completed. The FORTRAN source code is approximately 1972 lines. The next chapter deals with a description of the results obtained by using the RBEAP program.

CHAPTER 6

RESULTS AND VALIDATION

6.1 INTRODUCTION:

This Chapter discusses the validation of RBEAP with regard to the DOE 2.1A program. This validation was carried out in four steps:

1) The first step was to check the accuracy of the unmodified FORTRAN, i.e. RBEAP containing the original CIRA algorithms without solar and internal gain utilization factors or the Mitalas basement model, with CIRA in order to confirm that both programs produced identical results with identical inputs. In this step a number of runs were made of the FORTRAN version and the resulting HOUSE.DAT, HOUSE.STD and HOUSE.LOD files were compared, item by item, with the corresponding files which were obtained by running identical inputs through the original CIRA program on a Radio Shack Model II microcomputer. In each case, the resulting data files were found to be identical to the sixth significant figure for each item of data with occasional exceptions. All exceptional cases differed by one or two in the final digit as a result of the different precision used in arithmetic operations used in the respective computers and languages. At this stage it was concluded that all subroutines in unmodified FORTRAN version were yielding identical results in comparison with the original CIRA program. Subsequent runs using RBEAP as discussed below include the previously described modifications to the original CIRA program.

2) A Passive Solar Ranch house in Ottawa was chosen to test the effects of incorporating Utilization factor routines and Modified floor thermal resistance routine on the Heating Load prediction.
3) A house in Detroit with a full basement was chosen to test the combined effect of incorporating the basement model due to G.P.Mitalas as well as Utilization factor routines on the Heating Load prediction.
4) A multiprogram comparison between RBEAP, NBSLD and BLAST was carried out for two cities, Minneapolis and San Francisco. The test house in this case was the Hastings Ranch house.

This Chapter also gives information on the program statistics pertaining to Memory requirements and run-time statistics.

6.2 RESULTS FOR THE PASSIVE SOLAR RANCH HOUSE:

6.2.1 House Description:

Figure 6.1 shows the views of a Passive Solar Ranch house which was modelled as being located in Ottawa. The house is of slab-on-grade construction. This house has been modelled earlier in CIRA by Patwardhan (ref.12) and DOE 2.1A by Colborne et. al. A Light construction was chosen with the thermostat setting at 70 deg F and insulation and tightness levels were allowed to vary. The two cases that were considered in this report were:

	R_{wall}	$R_{ceiling}$	Glazing	Avg.Ach
Case 1	12	20	Double	0.6
Case 2	30	50	Triple	0.3

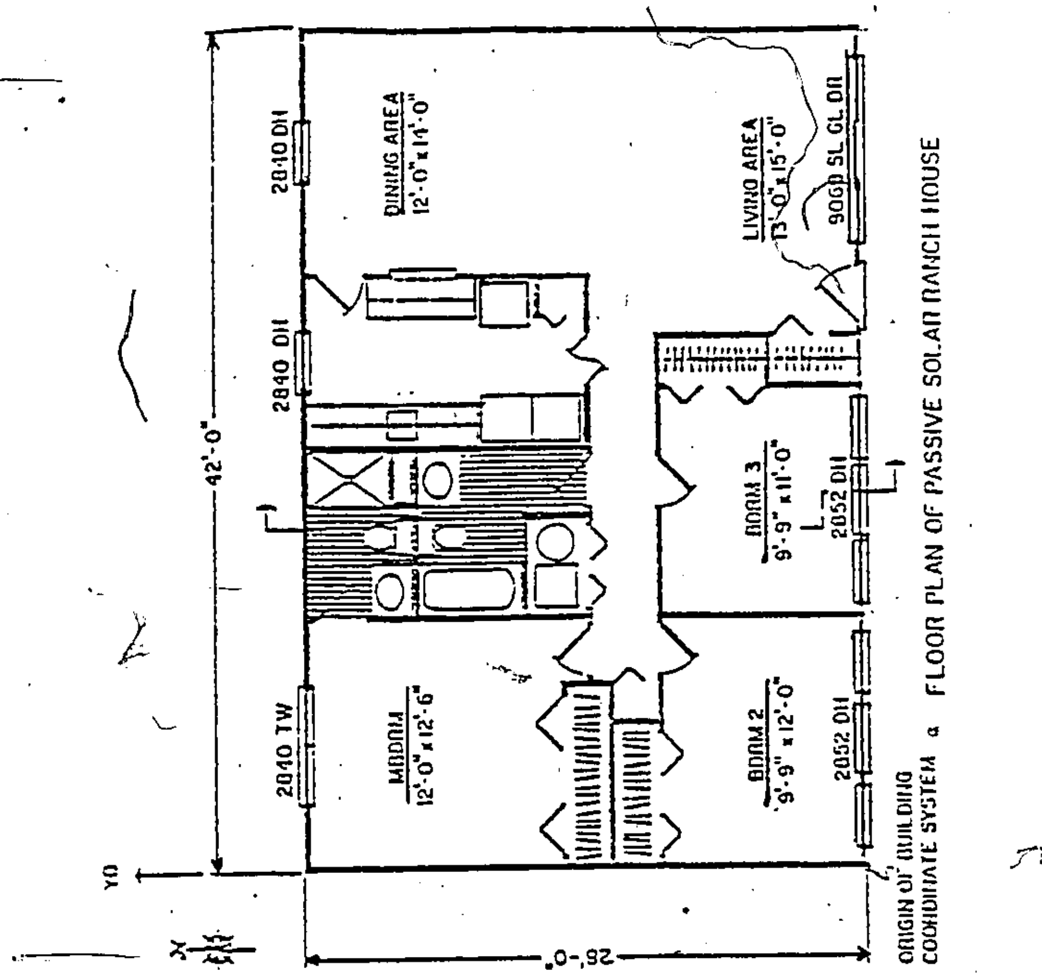
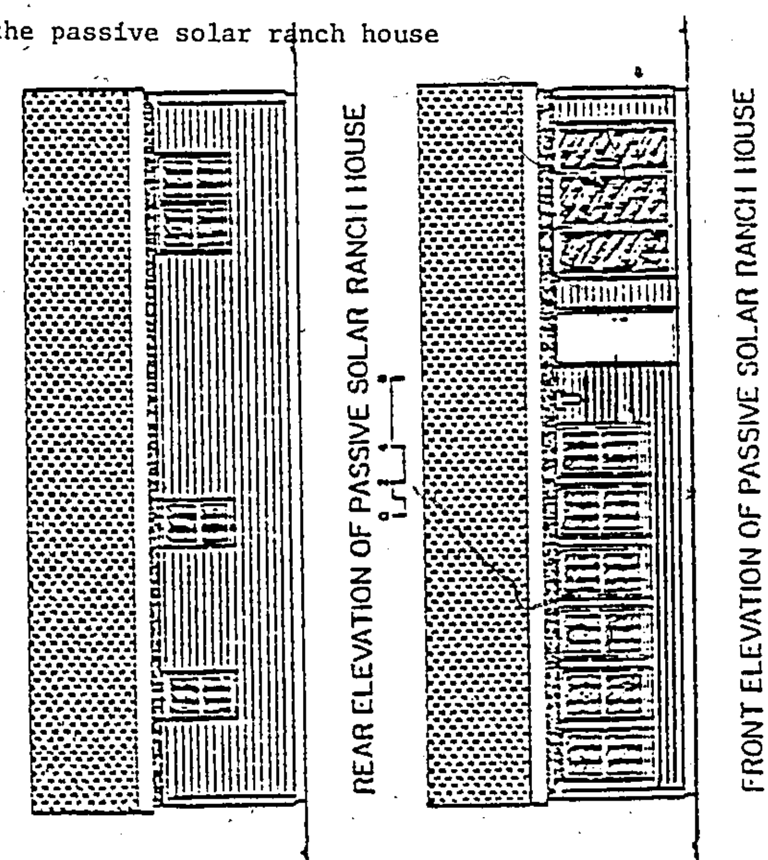


Figure 6.1
Views of the passive solar ranch house



The input listings for the house as modelled in CIRA are given in Appendix J-1 (Case 1) and Appendix J-3 (Case 2). The input listings for the house as modelled in RBEAP are given in Appendix J-2 (Case 1) and J-4 (Case 2).

6.2.2 Free Heat Analysis:

It was noticed from the CIRA modelling of Case 1 and Case 2 by Patwardhan (ref. 12) that the amount of available free heat (defined as the sum of solar and internal gains) considered by the programs, CIRA and DOE 2.1A, was not the same. It was therefore decided, for the purpose of an accurate determination of the effect of utilization factors, to remodel the house such that the amount of available free heats considered by the programs was almost the same. Exact correspondence could not be obtained because of limitations inherent in the CIRA program; namely the difficulty in inputing free heats by directly making modifications in the BASIC source code. The figures 6.2 through 6.9 show the comparison between available and useful solar gains and free heats for Case 1 and Case 2. It can be seen that an attempt has been made, given the limitations of the CIRA program, to make the available free heats for the programs almost equal. This thermodynamic condition of equal available free heats, once established, would not be altered by either changes in house construction or indoor temperature swings. A comparison of Solar utilization factors between CIRA, RBEAP and DOE 2.1A can be found in figures 6.10 and 6.11. The utilization factors as used in the CIRA program are taken to be unity throughout the heating season. It can be seen that the utilization factors as predicted by DOE 2.1A are higher in the colder months of winter but are lower in the 'swing' months. It has been pointed out earlier (Chapter 4) that the Sander & Barakat correlation used in RBEAP is a line of best fit through points of scatter. Morover the utilizaton factors as deduced from the DOE 2.1A program are based on loads calculated on an hourly basis. It can, therefore, be concluded that in general, the Barakat & Sander correlation can be used with a fair degree of confidence in monthly energy analysis programs. This confidence is reflected in the use of this correlation in another monthly energy analysis program, HOTCAN (ref. 17). The comparison results between RBEAP and DOE 2.1A show that this correlation works quite well as far as influencing the final heating load calculation is concerned. Numeric values for Graphs 6.2 through 6.11 can be found in Appendix K-1. The next section deals with a multiprogram comparison of heat load predictions between CIRA, RBEAP and DOE 2.1A.

6.2.3 Comparison of Heating Loads between CIRA, RBEAP and DOE 2.1A:

The following situations were examined for this multiprogram comparison. The Passive Solar Ranch house was with slab-on-grade was again taken as the test house and the construction level were allowed to vary from light to medium. The thermostat setting however was not allowed to vary and was maintained at 70/70 deg F. This was due to the inability of the CIRA program to model swings in indoor

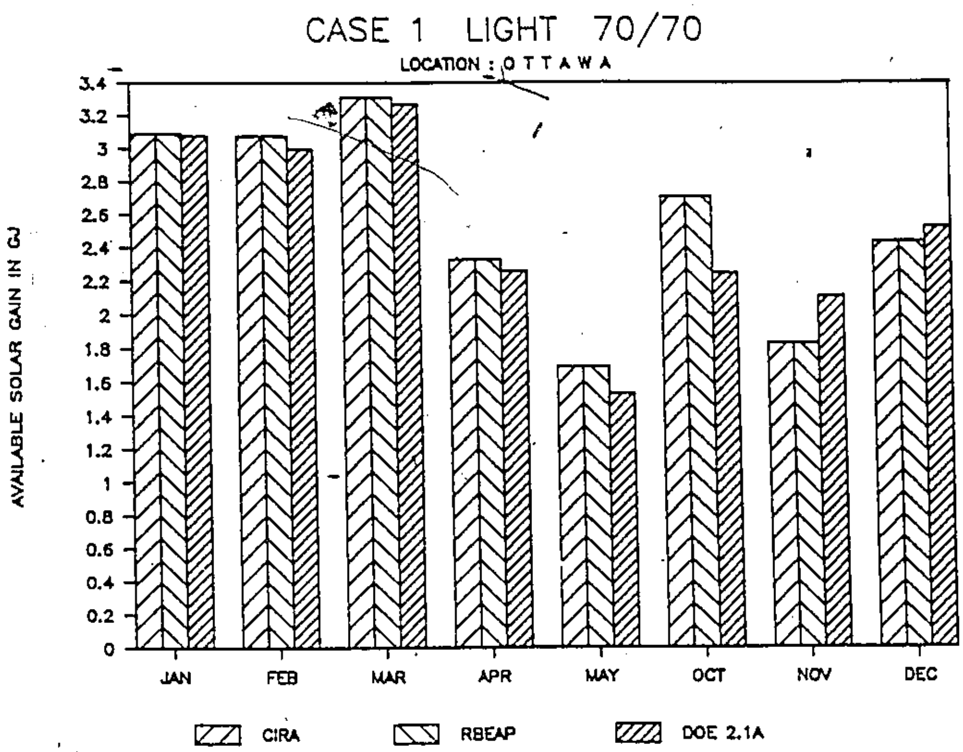


Figure 6.2
Comparison of available solar gain

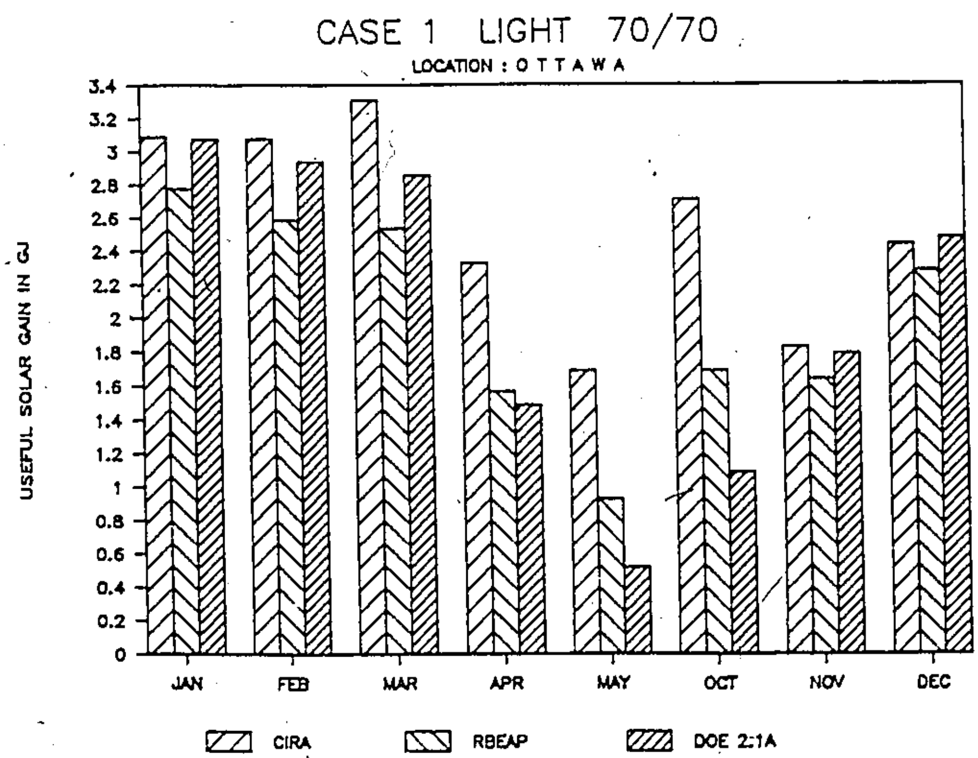


Figure 6.3
Comparison of useful solar gains

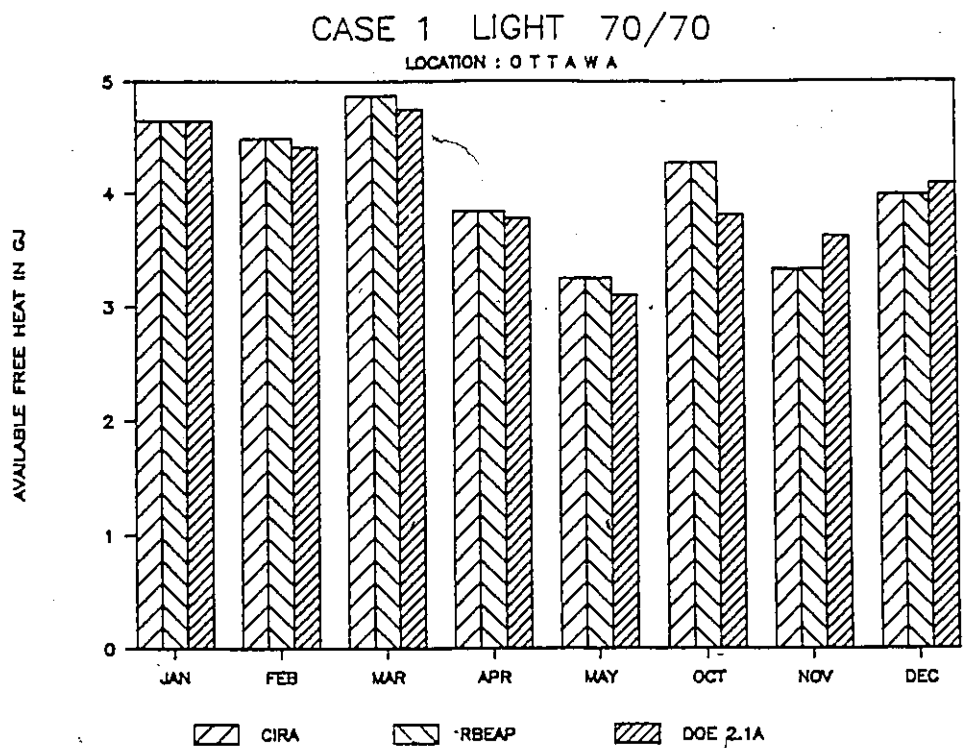


Figure 6.4
Comparison of available free heat

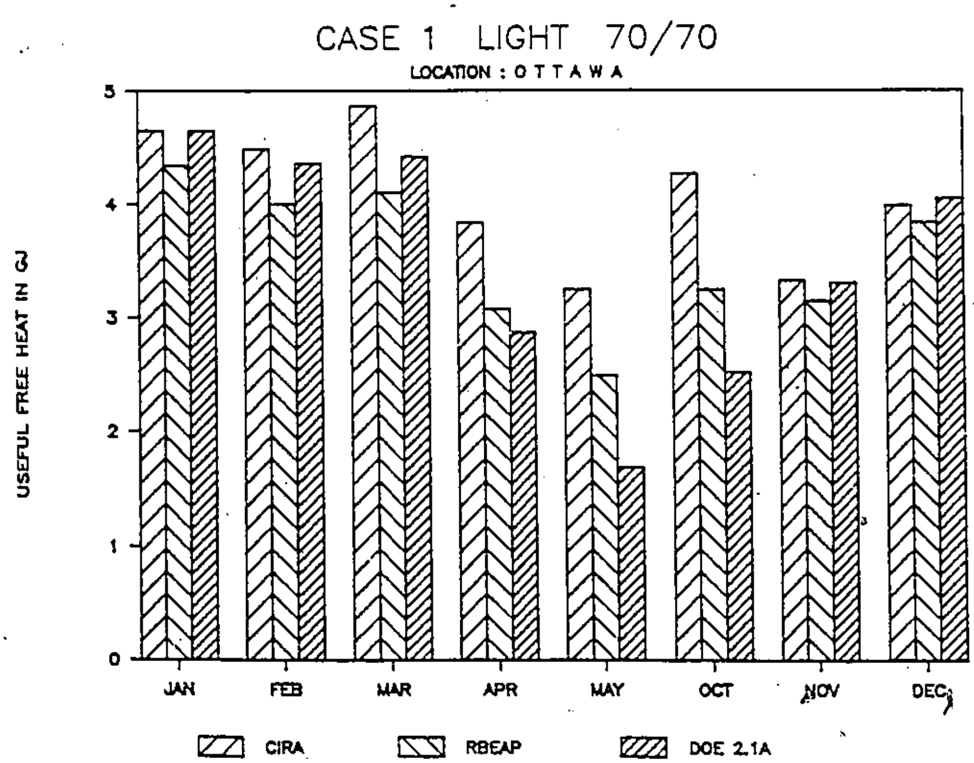


Figure 6.5
Comparison of useful free heat

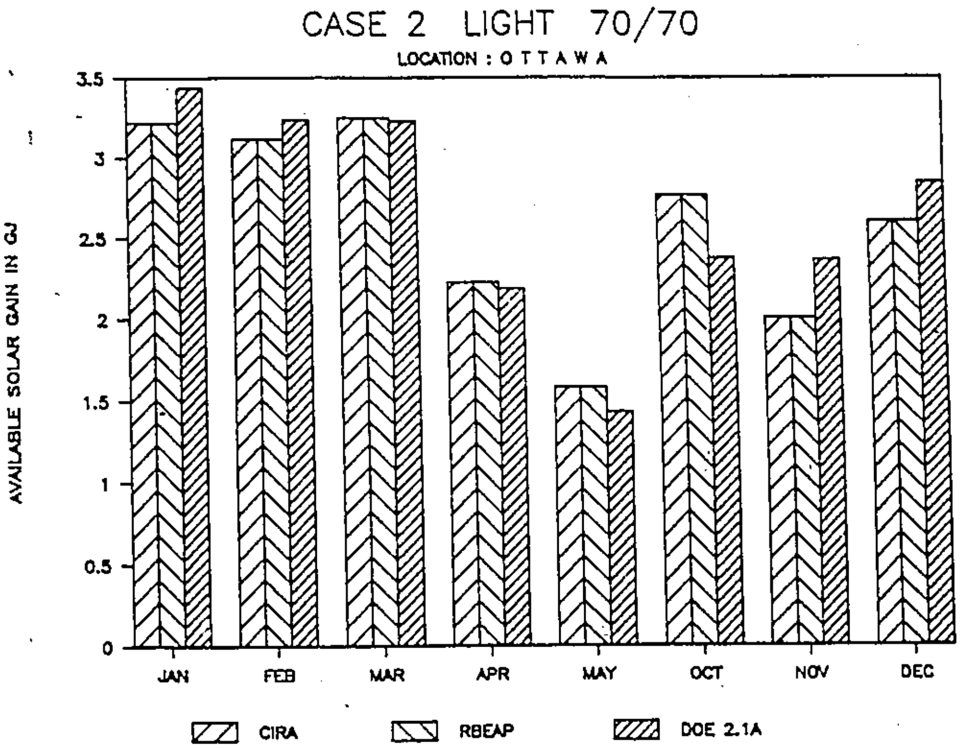


Figure 6.6
Comparison of available solar gain

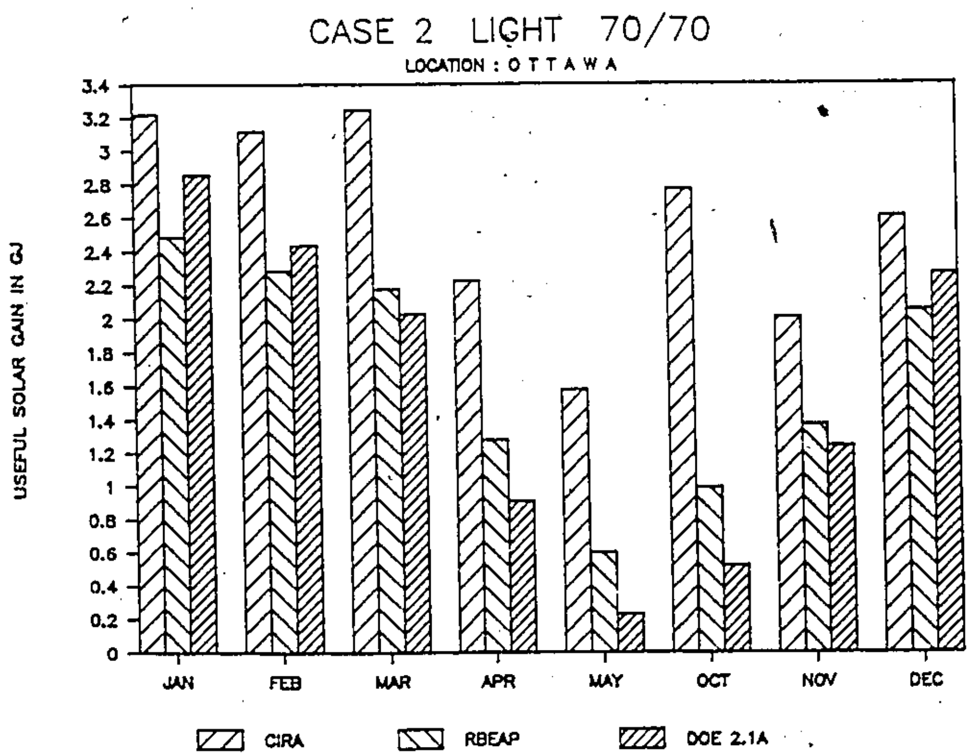


Figure 6.7
Comparison of useful solar gain

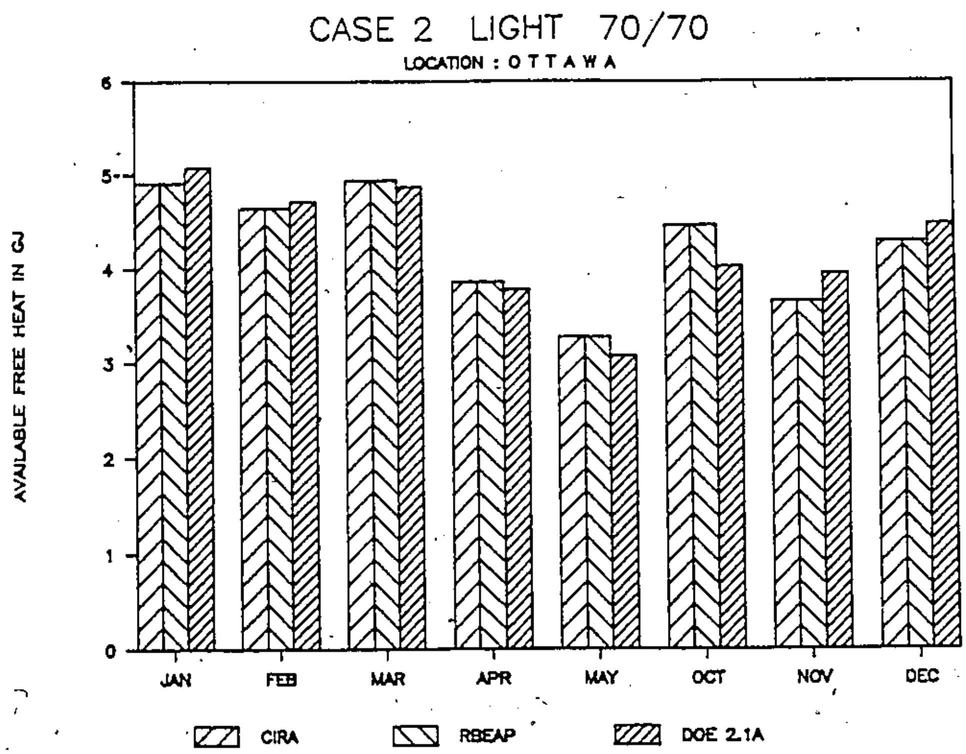


Figure 6.8
Comparison of available free heat

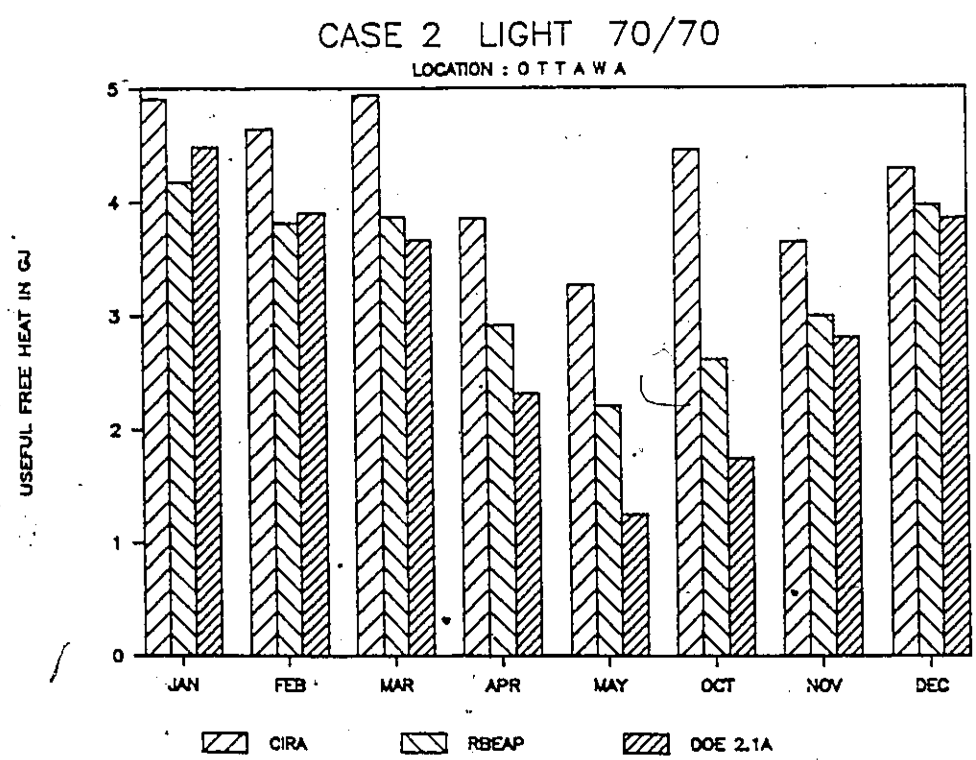


Figure 6.9
Comparison of useful free heat

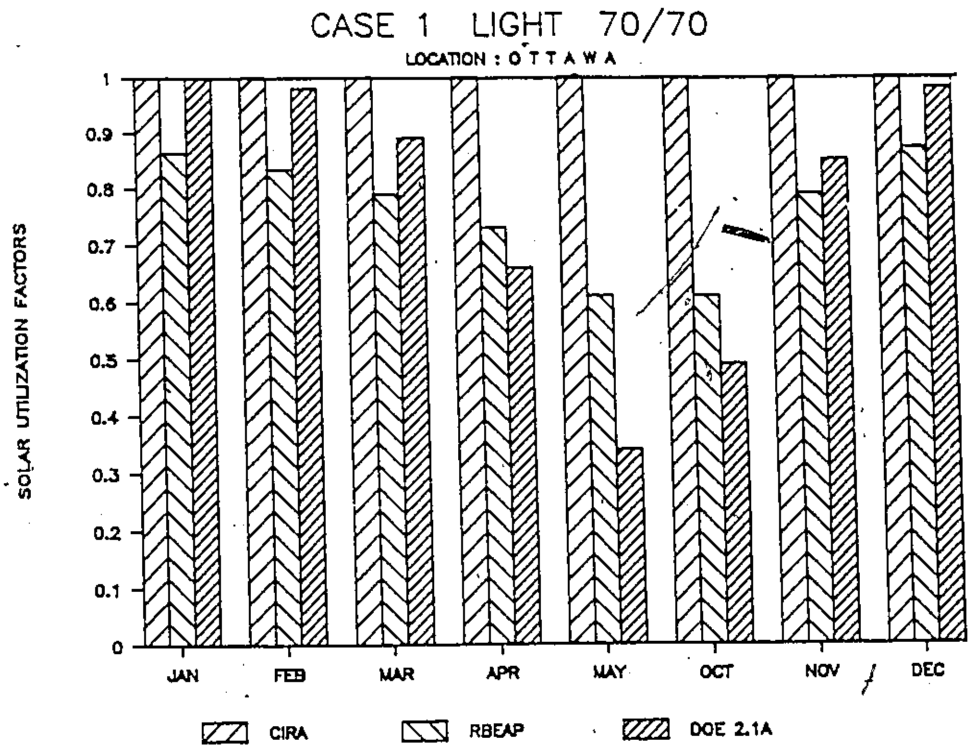


Figure 6.10
Comparison of utilization (solar) factors

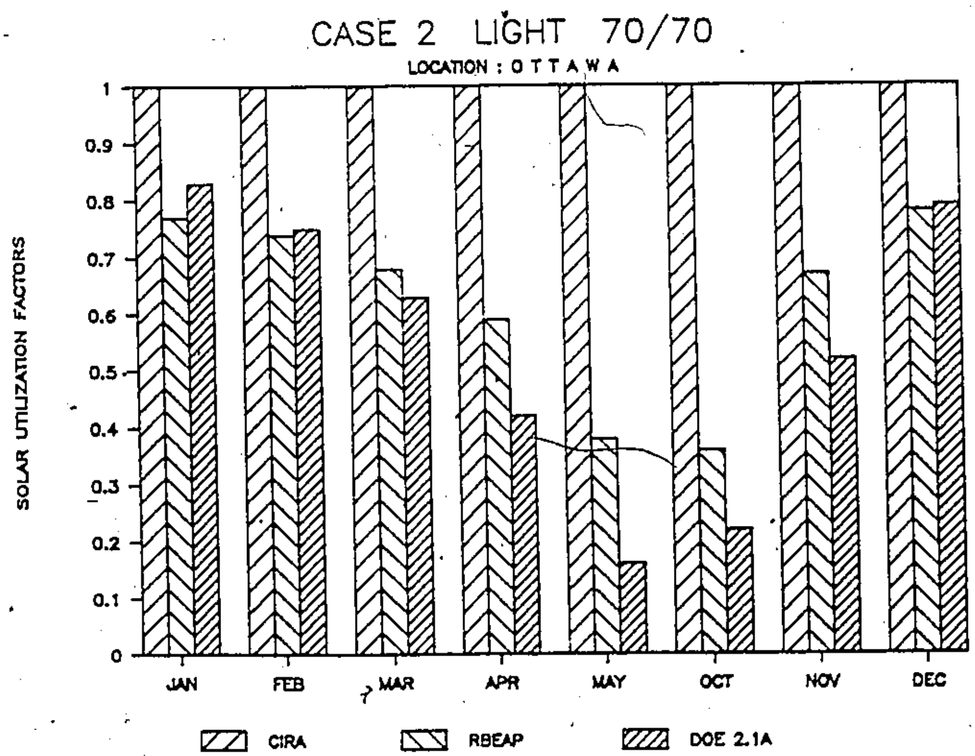


Figure 6.11
Comparison of solar utilization factors

temperature. The results are shown graphically in figures 6.12 through 6.17 and the numeric values corresponding to these graphs can be found in Appendix K-2. It can be seen that the agreement between RBEAP is quite good. Indeed, during each month of the respective heating seasons shown in the figures, the RBEAP prediction of heating load is closer to the DOE 2.1A prediction than is the original CIRA prediction, except for May in figure 6.17. Generally the improvement is quite noticeable in the swing months of April/May/October. It can also be seen that for Case 2, RBEAP has generally indicated heating months for May and October, as did DOE 2.1A, whereas CIRA has predicted them to be cooling months. This was due to the modified indicator calculation procedure involving utilization factors (see chapter 2. Subroutine EXT_INDIC).

In general, it has been found that the worst deviation on a monthly basis was 15% and on a seasonal basis the worst deviation was 7%. The agreement has been found to weaken slightly as 'Heavier' houses are modelled. It can be seen that for Case 2, Heavy, 70/70 both CIRA and RBEAP predict May as a cooling month. It must be pointed out that the indicator calculation in RBEAP is not perfect. In general, if heating loads for a month are anticipated to be very small, the indicator, despite the effect of utilization factors, will switch the month to a cooling month. Nevertheless the improvement over CIRA is quite evident.

The effects of indoor temperature swings on the utilization factors and hence, on the heating load prediction, are examined in the next section.

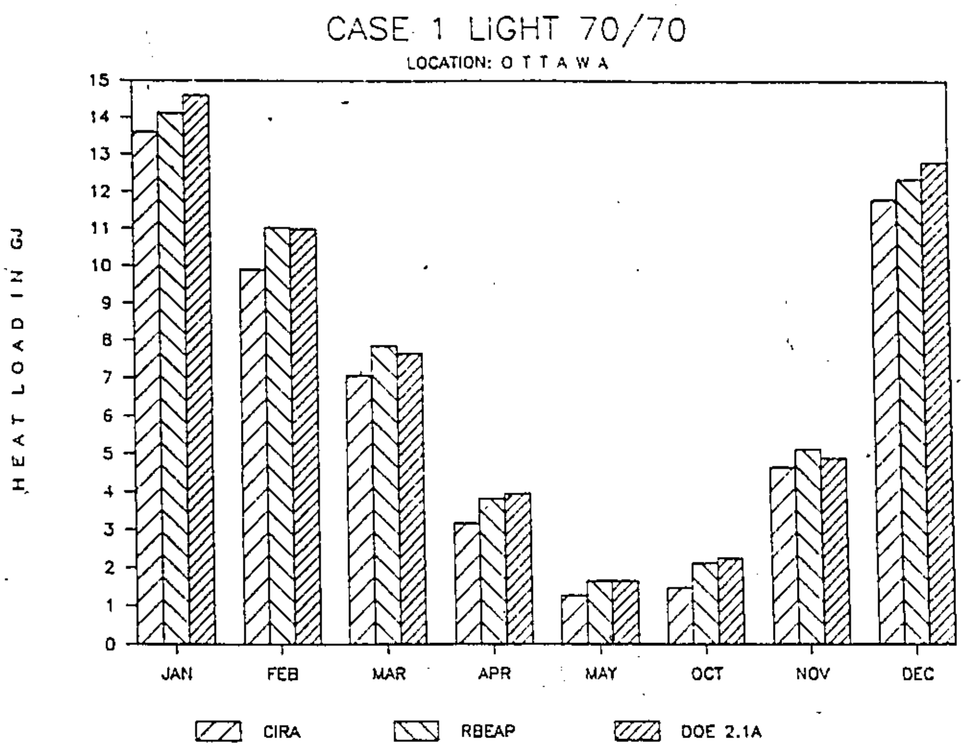


Figure 6.12

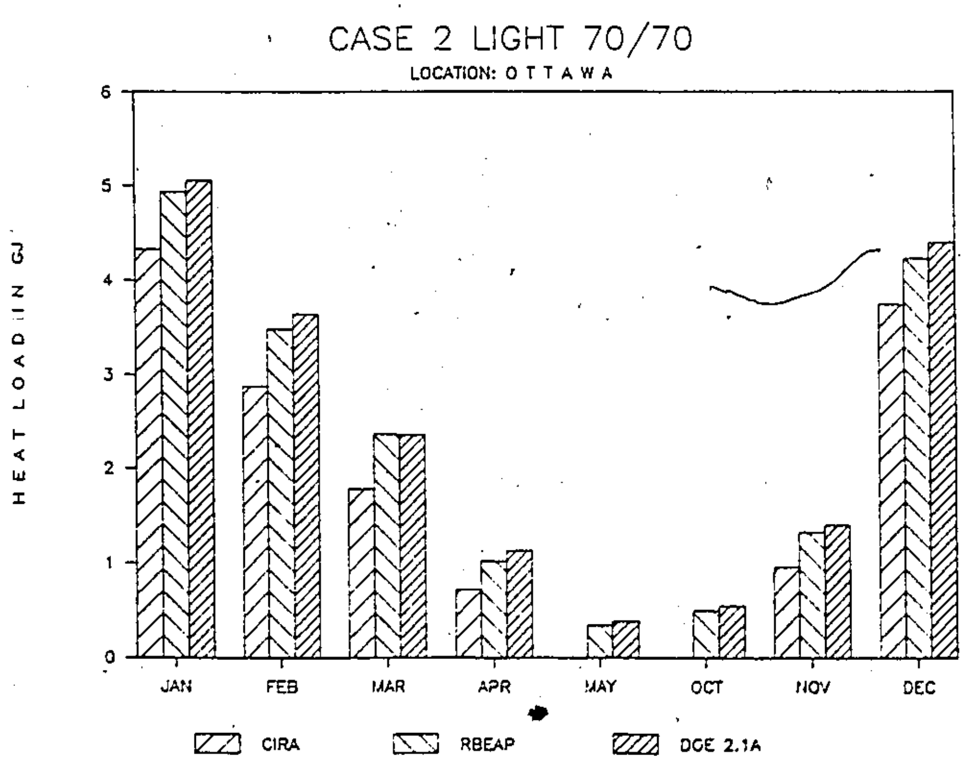


Figure 6.13

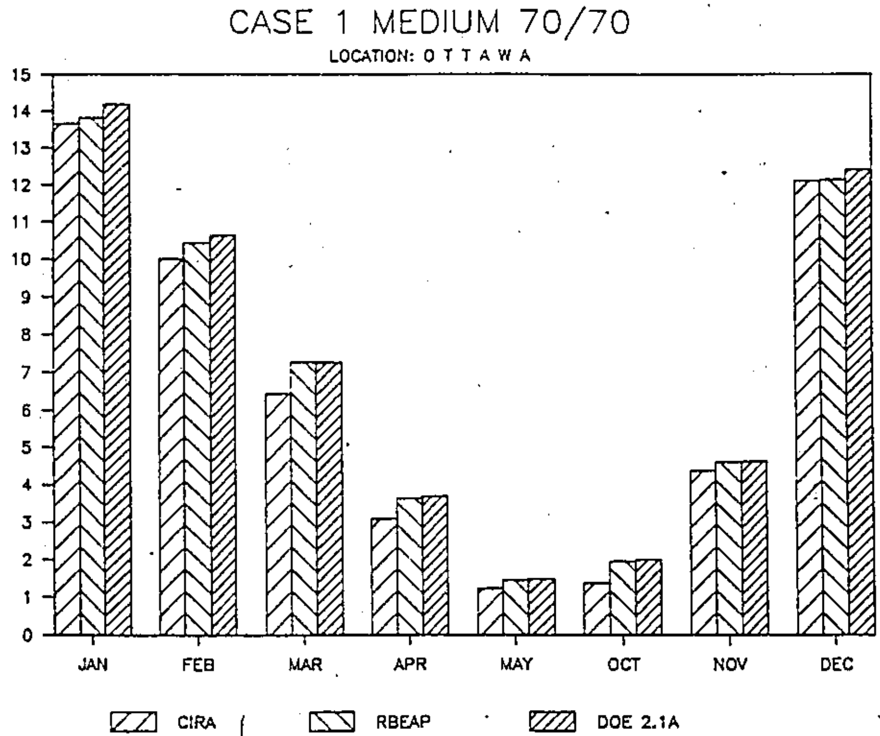


Figure 6.14

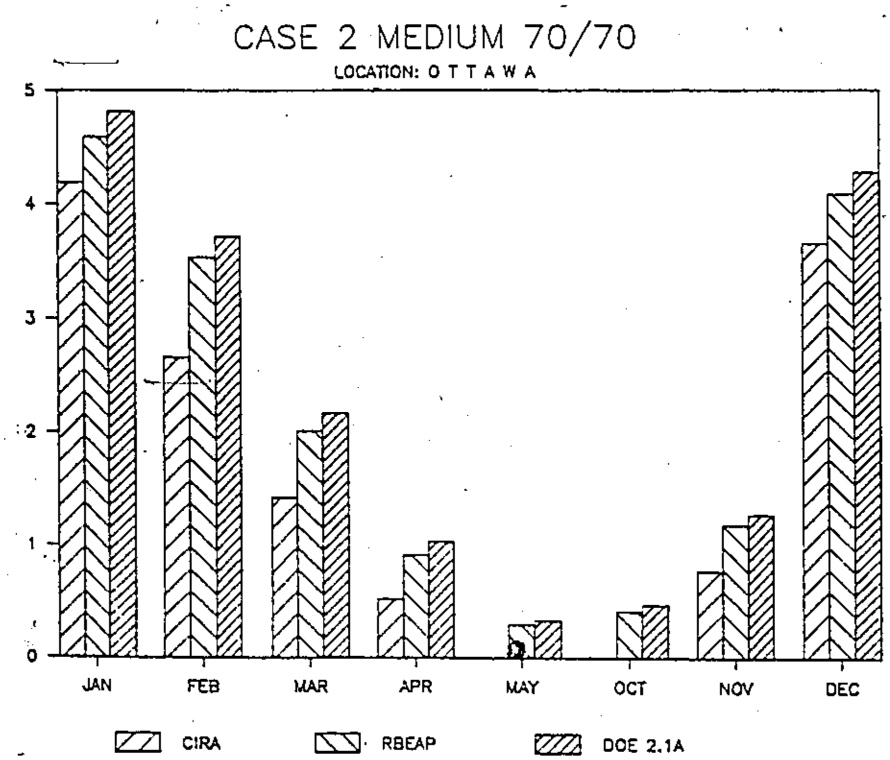


Figure 6.15

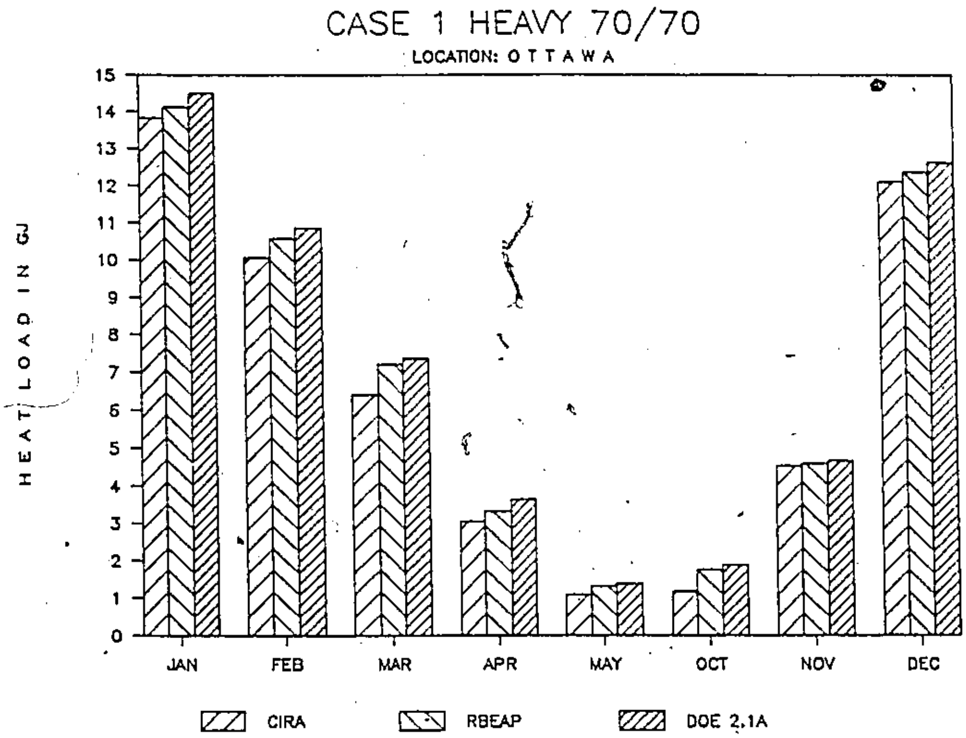


Figure 6.16

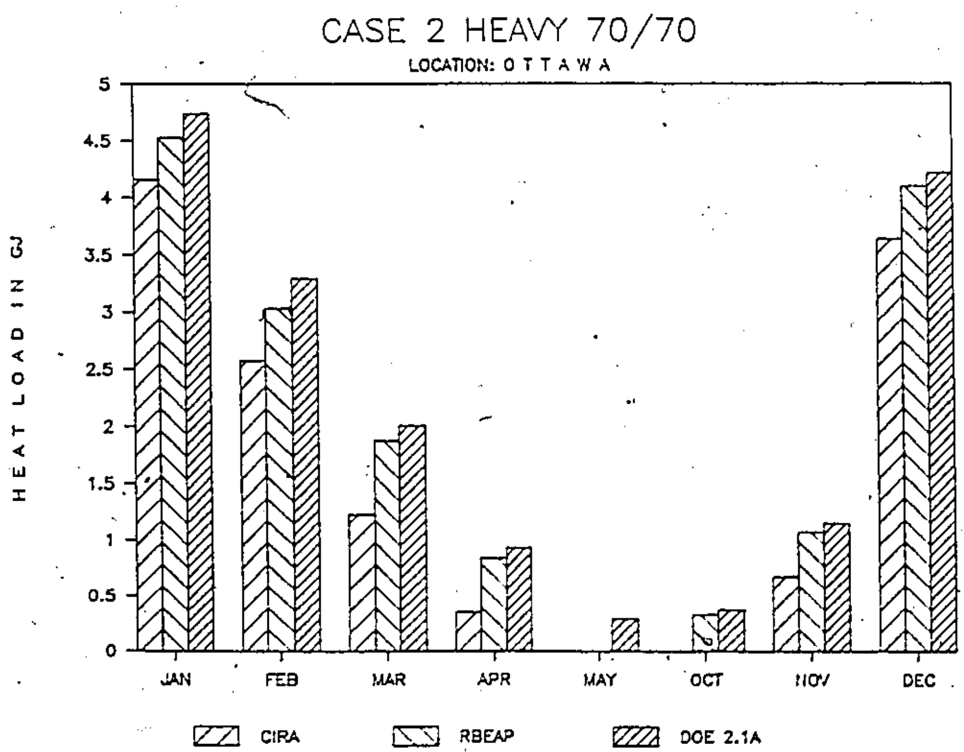


Figure 6.17

6.2.4 Comparison of the effects of indoor temperature swings on Heating loads as predicted by RBEAP and DOE 2.1A.

In this section the effect of indoor temperature swing on the heating load prediction is examined. The temperature swings influence the heat load prediction because the coefficients to be used for determining the solar utilization factors from the Barakat & Sander correlation are dependent on them. Consequently, the useful solar gain and hence the heat loads are affected. The CIRA program was not chosen for this comparative study because of its inability to model or accept indoor temperature swings. The following situations were examined.

CASE 1

CONSTRUCTION	TEMPERATURE RANGE (deg. F)	
Light	70/75	70/80
Medium	70/75	70/80
Heavy	70/75	70/80

CASE 2

CONSTRUCTION	TEMPERATURE RANGE (deg. F)	
Light	70/75	70/80
Medium	70/75	70/80
Heavy	70/75	70/80

The results are shown in figures 6.18 through 6.29. Numeric values for these graphs are given in Appendix K-3. It can be seen that the agreement is quite good. However the indicator has switched RBEAP to

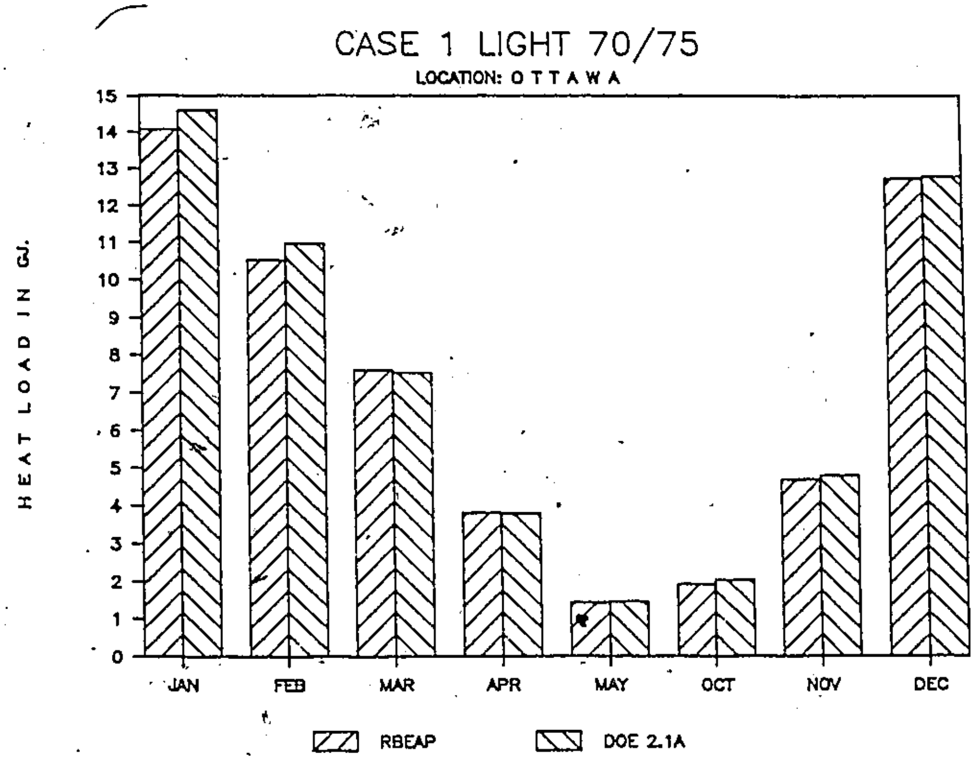


Figure 6.18

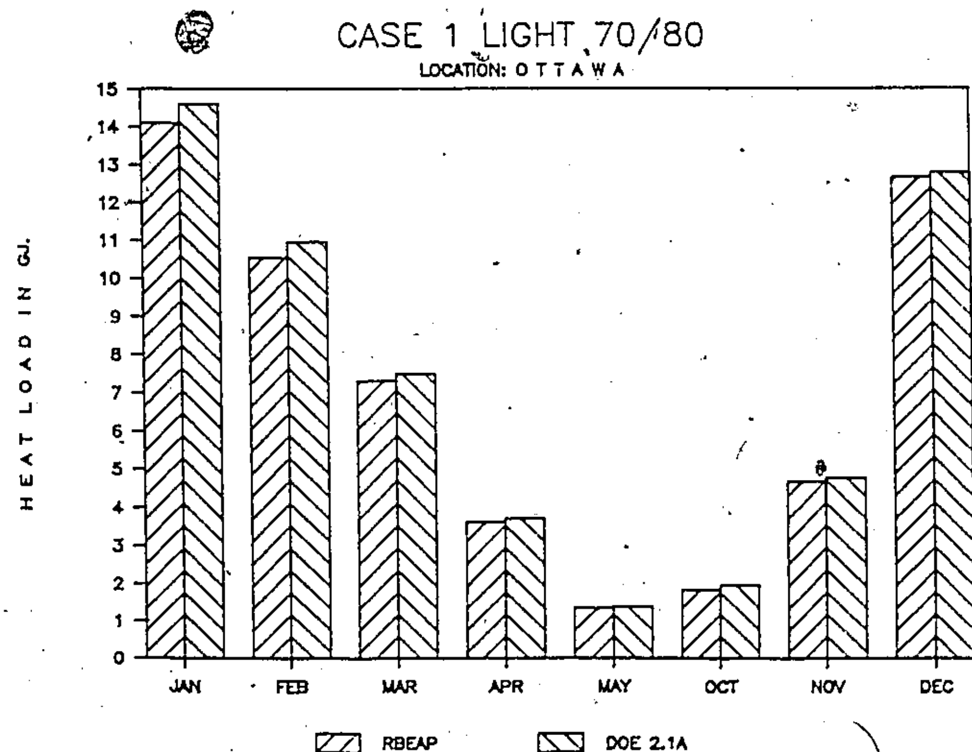


Figure 6.19

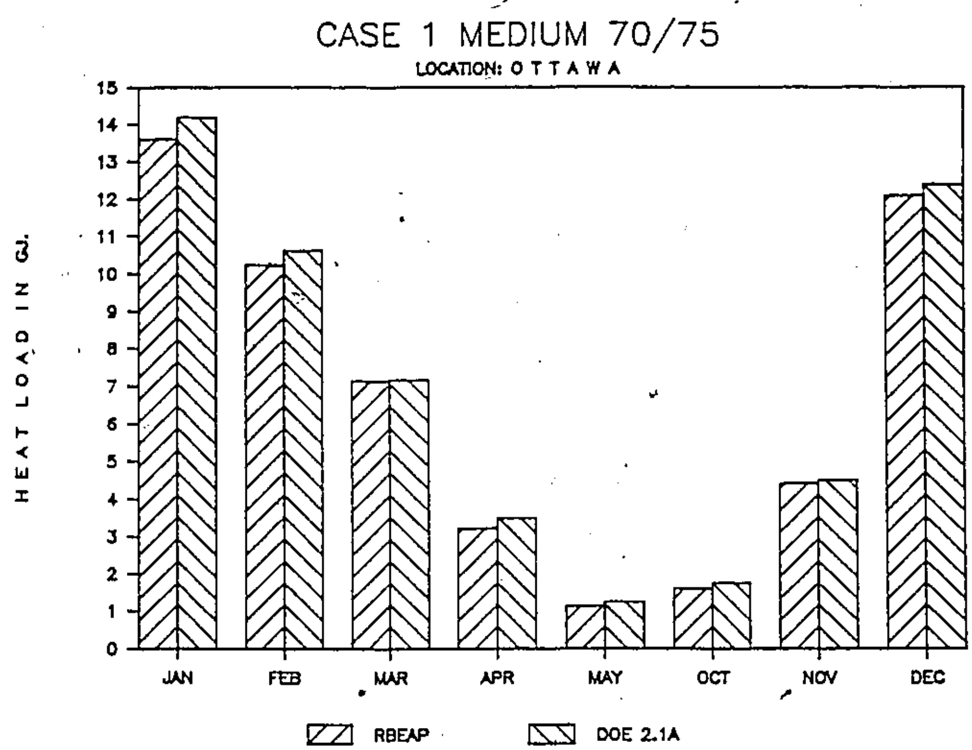


Figure 6.20

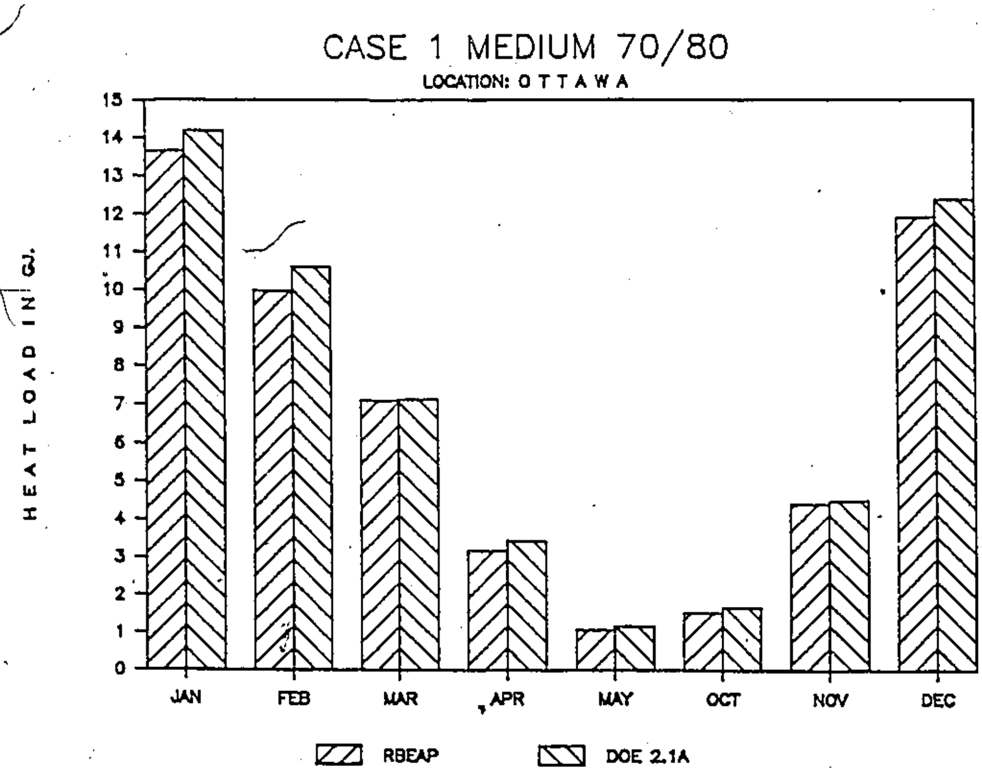


Figure 6.21

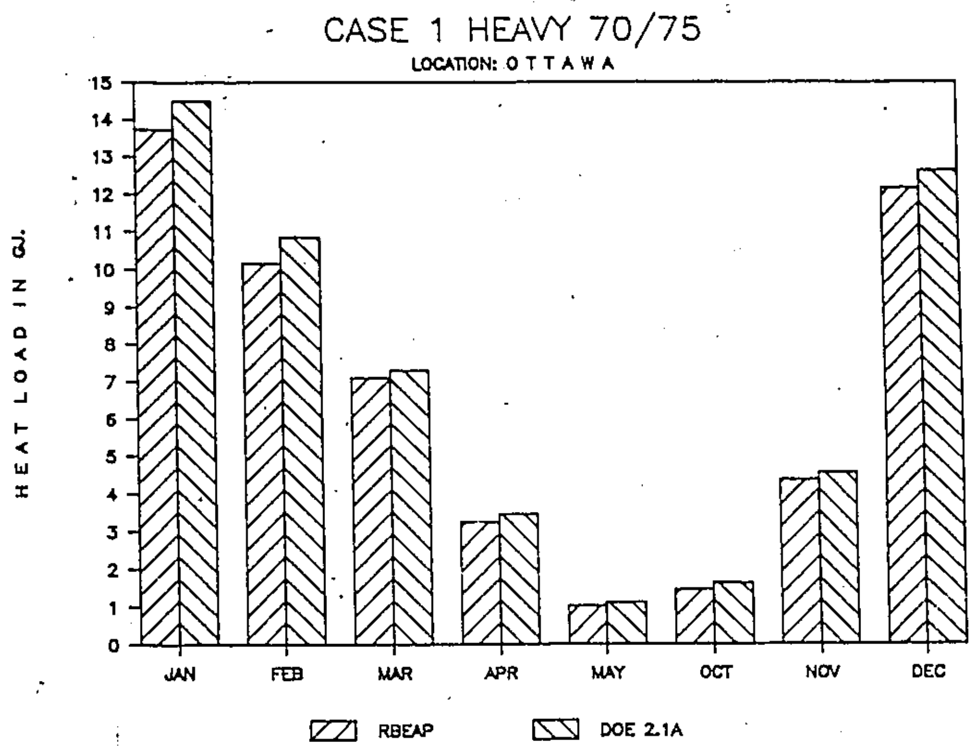


Figure 6.22

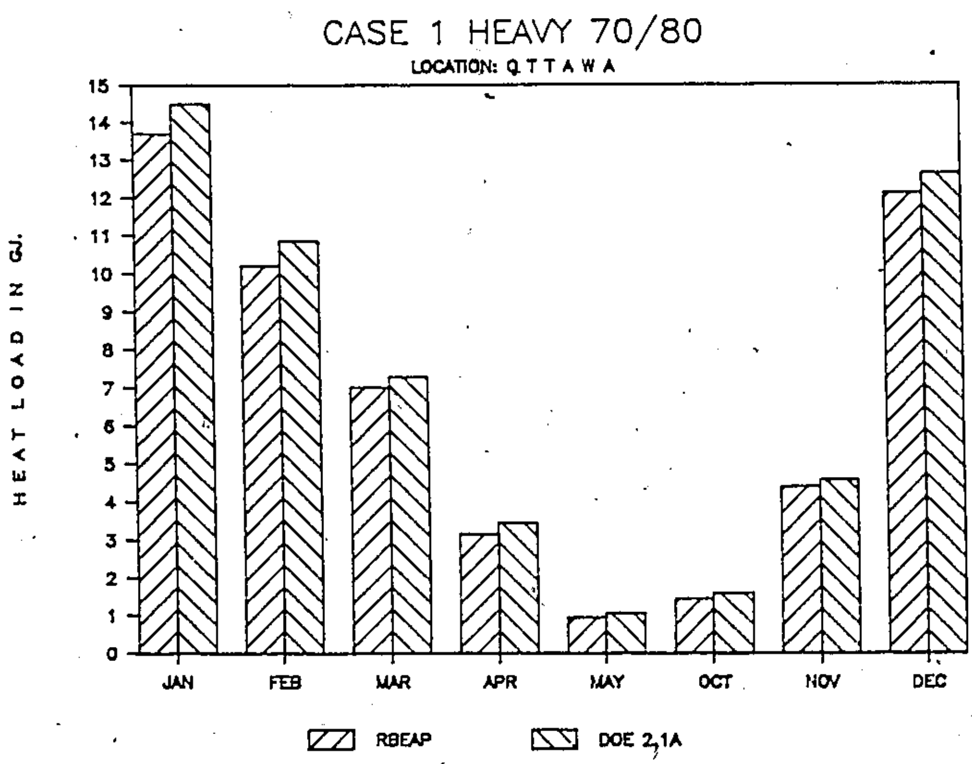


Figure 6.23

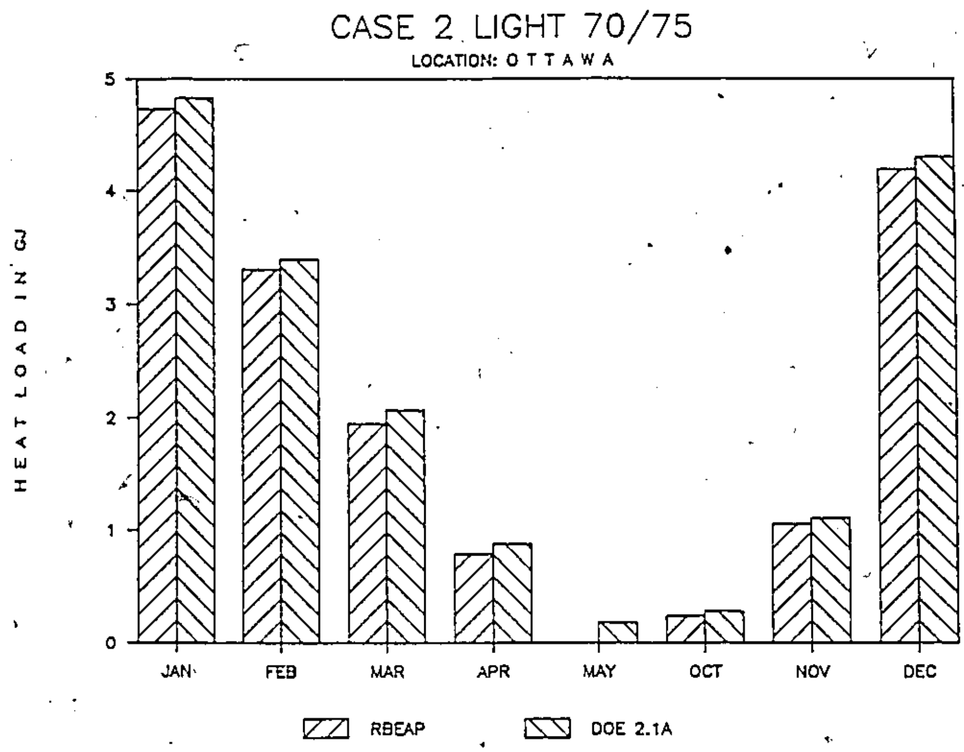


Figure 6.24

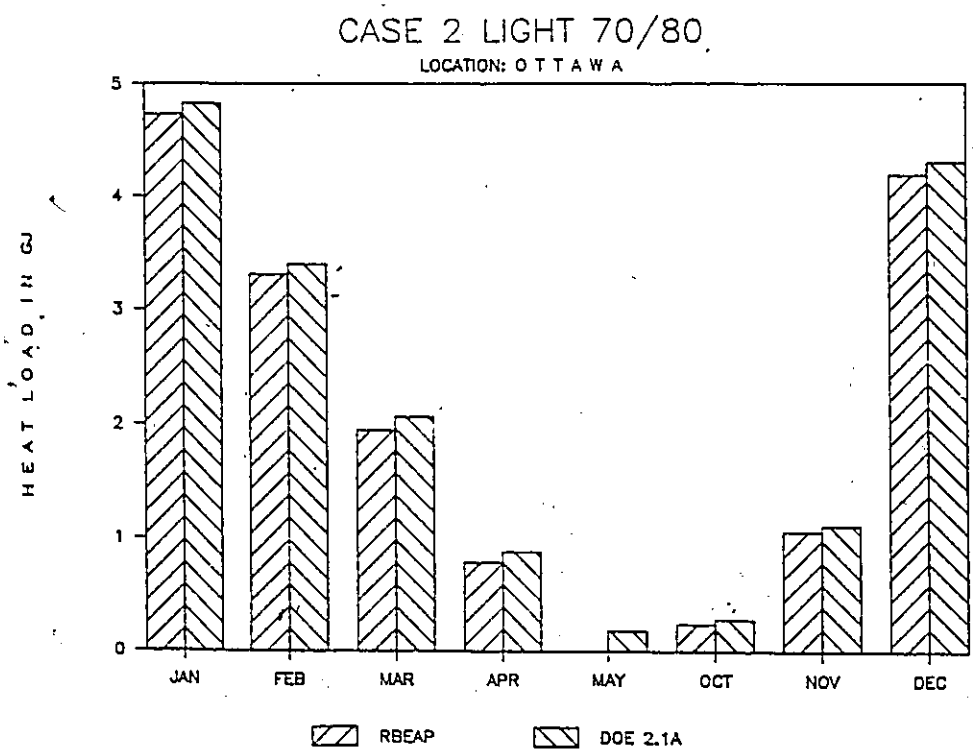


Figure 6.25

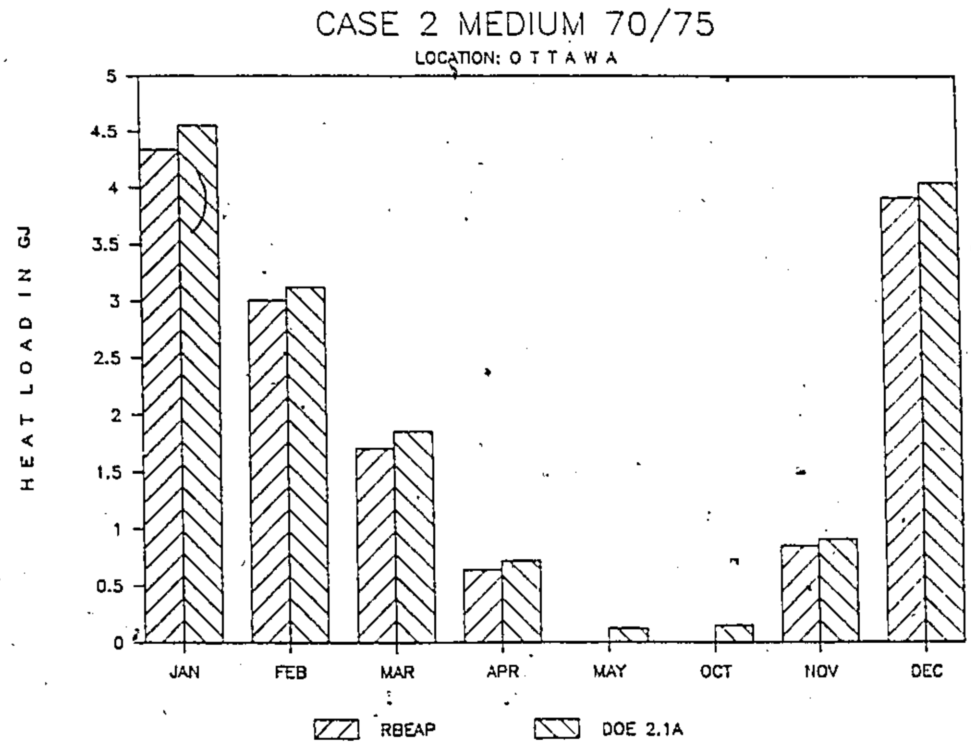


Figure 6.26

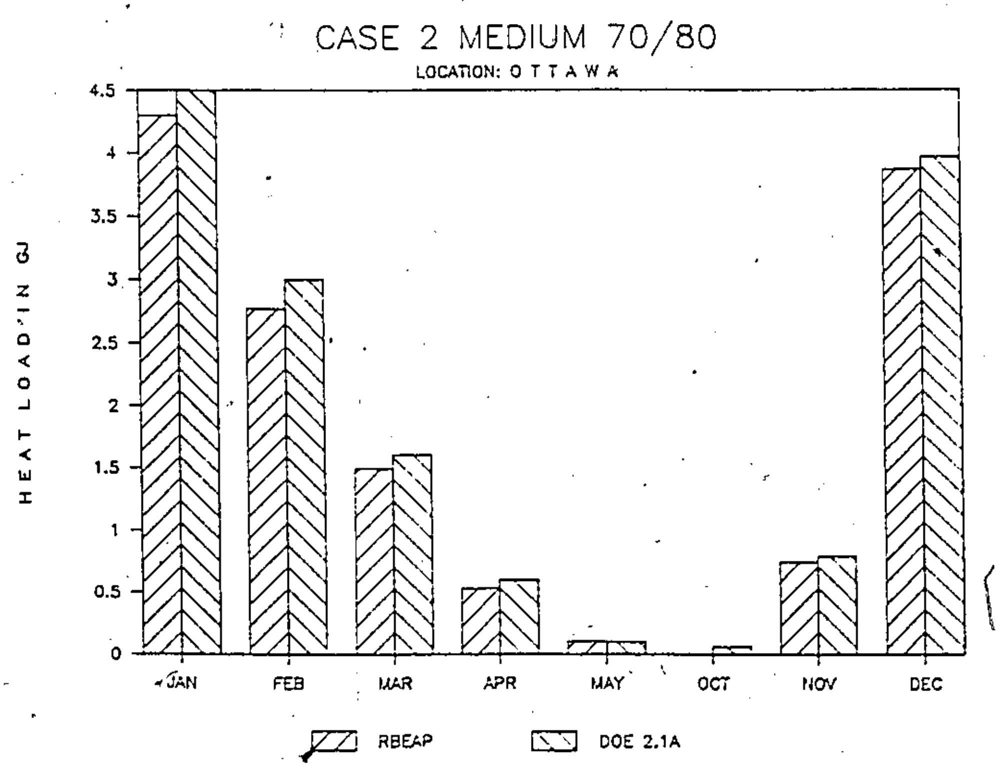


Figure 6.27

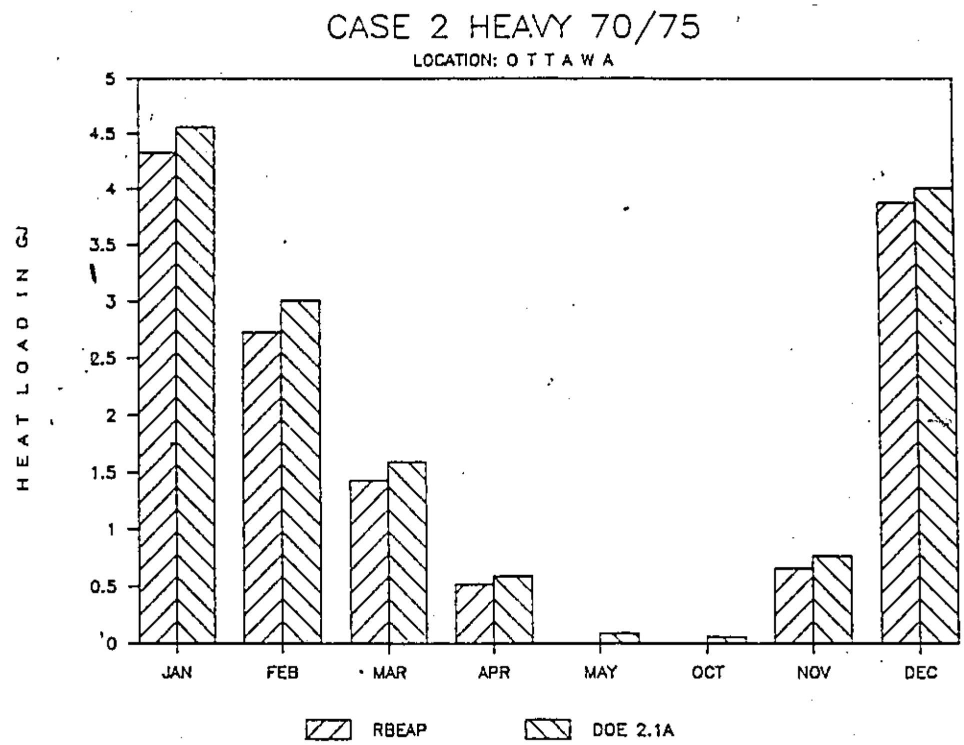


Figure 6.28

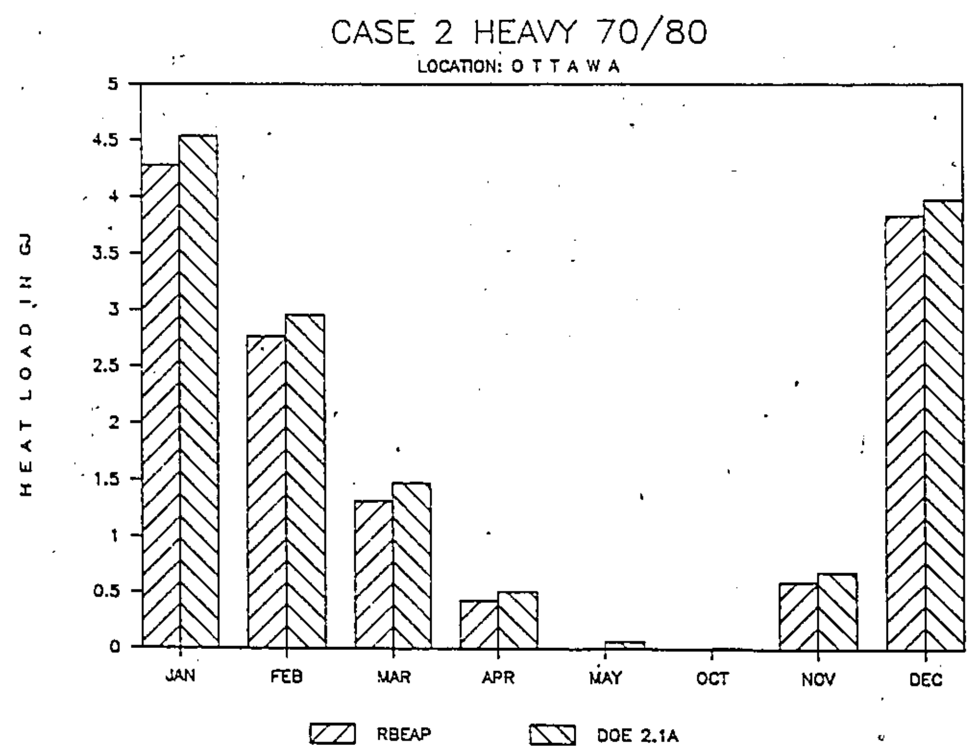


Figure 6.29

a cooling month in quite a few instances. This switching effect has been to found occur more often in tighter, well insulated houses, with large indoor temperature swings and low anticipated heating load. It may be pointed out that the program algorithm itself is not defective but is subject to the quirks of the Barakat and Sander correlation. However the improvement over the CIRA program is significant especially when it is considered that CIRA is unable to model indoor temperature swings. Another fact that may be mentioned here is that air temperatures are still being used to calculate heat loss from slab-on-grade floors. The agreement between RBEAP and DOE 2.1A shows that this is not a significant source of error.

The next section deals with the effect of incorporating the Mitalas basement model in RBEAP.

6.3 <u>RESULTS FOR THE 'VILLAGES OF RIVERSIDE' HOUSE</u>:

The 'Villages of Riverside' house was used for the comparative study. A schematic of this house is given in figure 6.30. A sectional view of the basement of Villages of Riverside house is shown in figure 6.31. The input listings for this house as modelled in CIRA [by Patwardhan (ref.12)] and RBEAP (by the author) are given in Appendix L-1 and L-2 respectively. The comparative study is divided into two sections:

i) The 'Villages of Riverside' house was modelled on a version of RBEAP with the Mitalas basement model but without solar and internal gain utilization factor routines.

ii) The same house was modelled on a version of RBEAP which had both

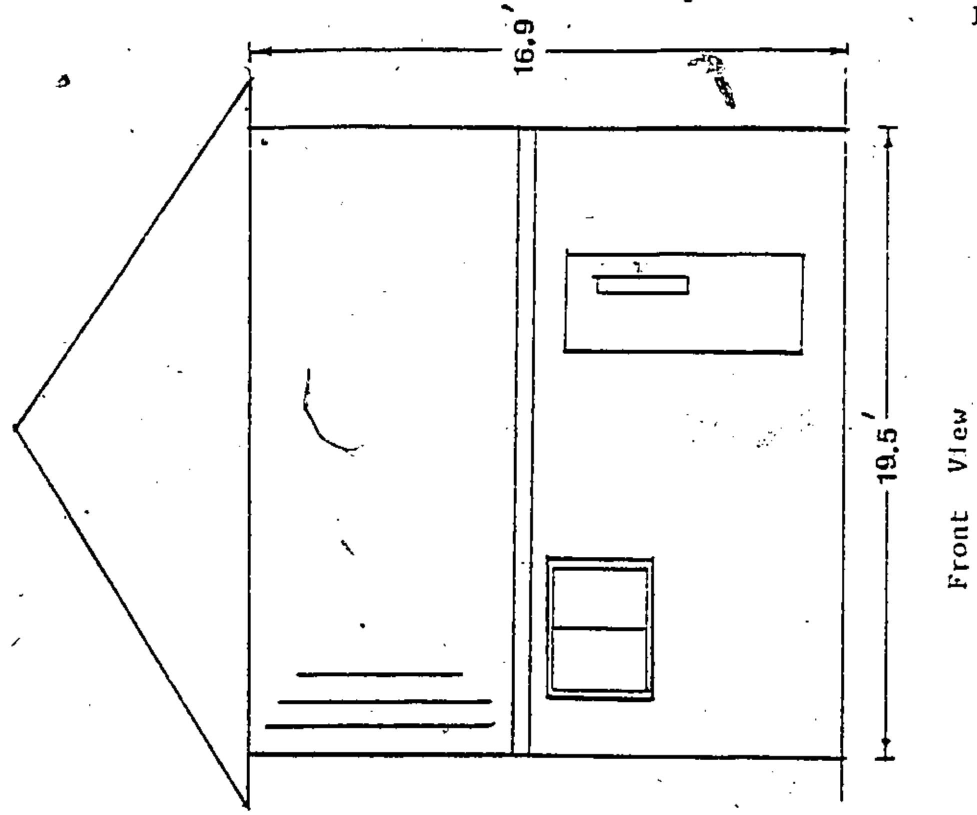
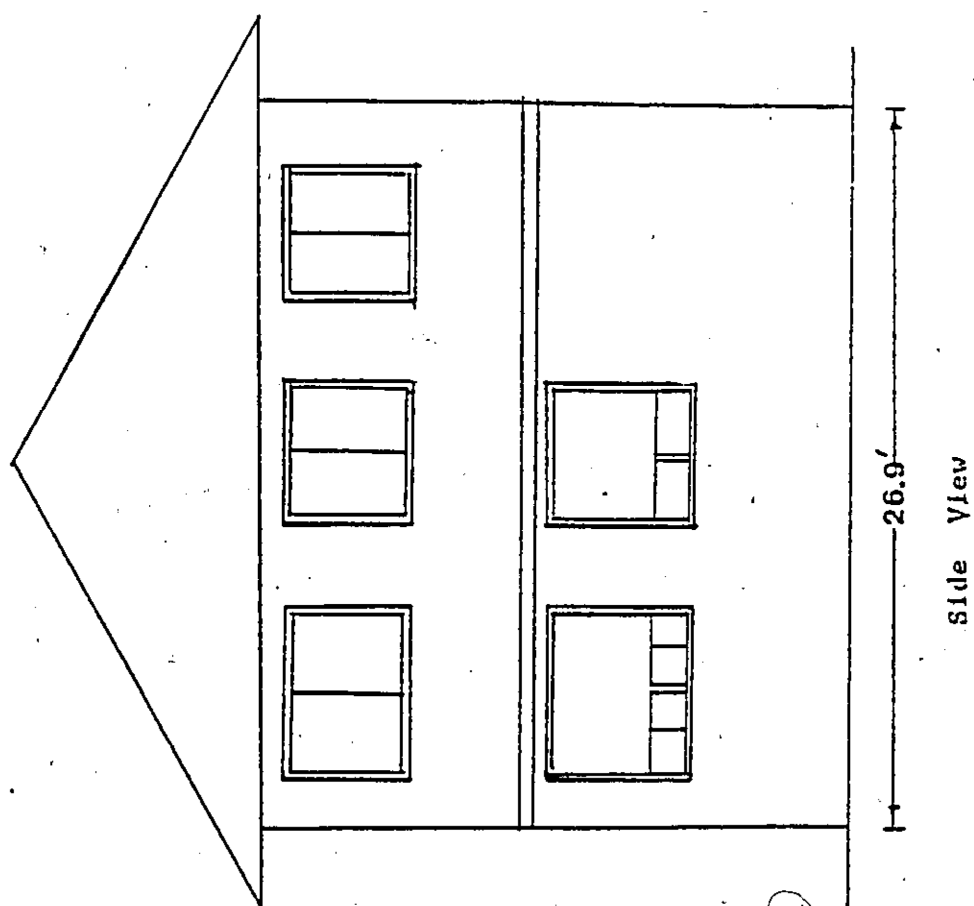


Figure 6.30
Side and front view of the 'Villages of Riverside' house.



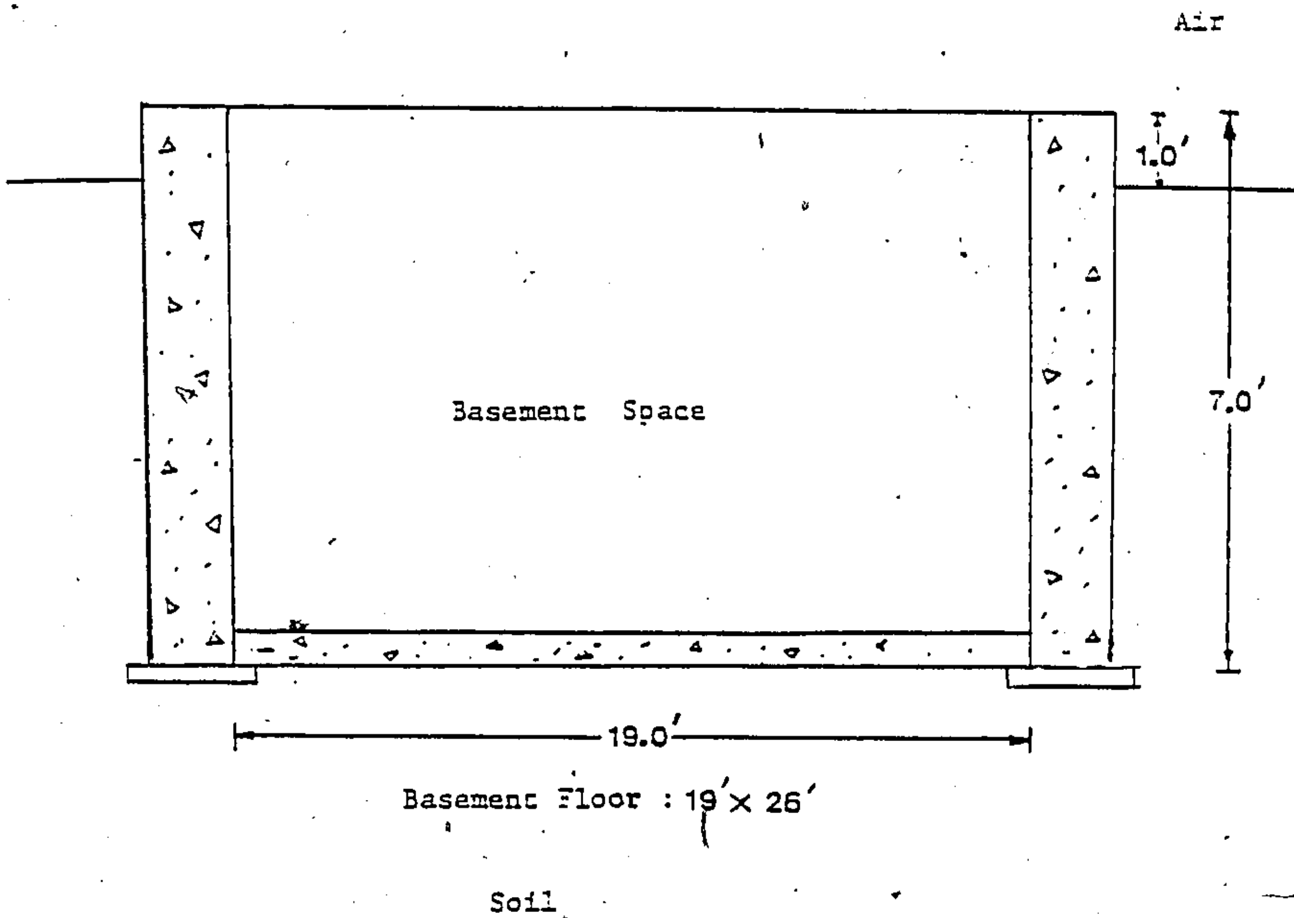


Figure 6.31
Sectional view of the basement of the 'Villages of Riverside' house.

the Mitalas model as well as utilization factor routines.

6.3.1 Comparison of Heating loads between CIRA, RBEAP and DOE 2.1A using RBEAP with the Mitalas basement model only.

Two situations were considered for this comparative study. In the first case the basement was assumed to be uninsulated. In the second case the basement walls were insulated to an R-value of 11 sq.ft/Btuh. The results are shown graphically in figures 6.32 and 6.33. Figures 6.34 and 6.35 give the basement heat loss for the uninsulated and insulated cases. Numeric values for these graphs can be found in Appendix M. It can be seen that the results as predicted by RBEAP for both cases are quite good even in the absence of utilization factors. This indicates that the basement heat loss as predicted by the Mitalas model in RBEAP is contributing to an overall improvement in both monthly and heating season prediction. It can be seen in figures 6.34 and 6.35 that the peak basement heat loss is occurring in the month following the month of lowest average outdoor temperature, i.e. the time lag introduced by the soil is being accounted for in RBEAP. The peak basement heat loss was found to be in the month of February in both cases. The agreement between RBEAP and DOE 2.1A increases in the swing months because the Mitalas basement model has been shown to follow a standard reference program for calculating basement heat loss, HEATING 5, more closely than the CIRA program (ref. 12).

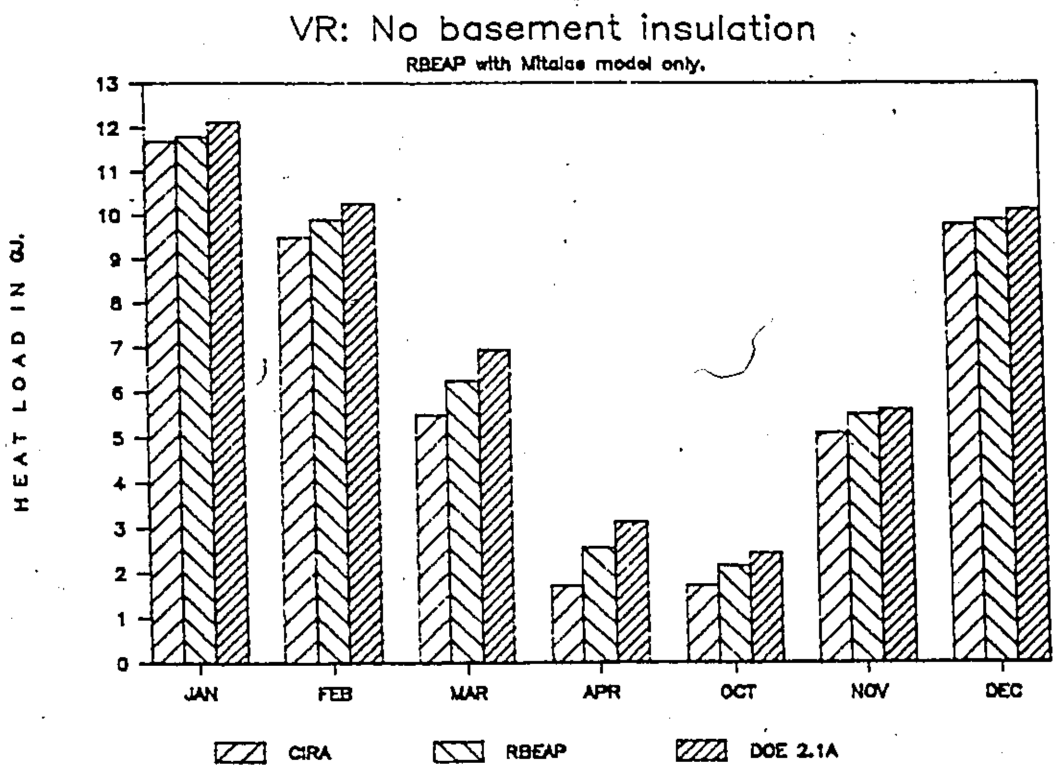


Figure 6.32
Heating load comparison

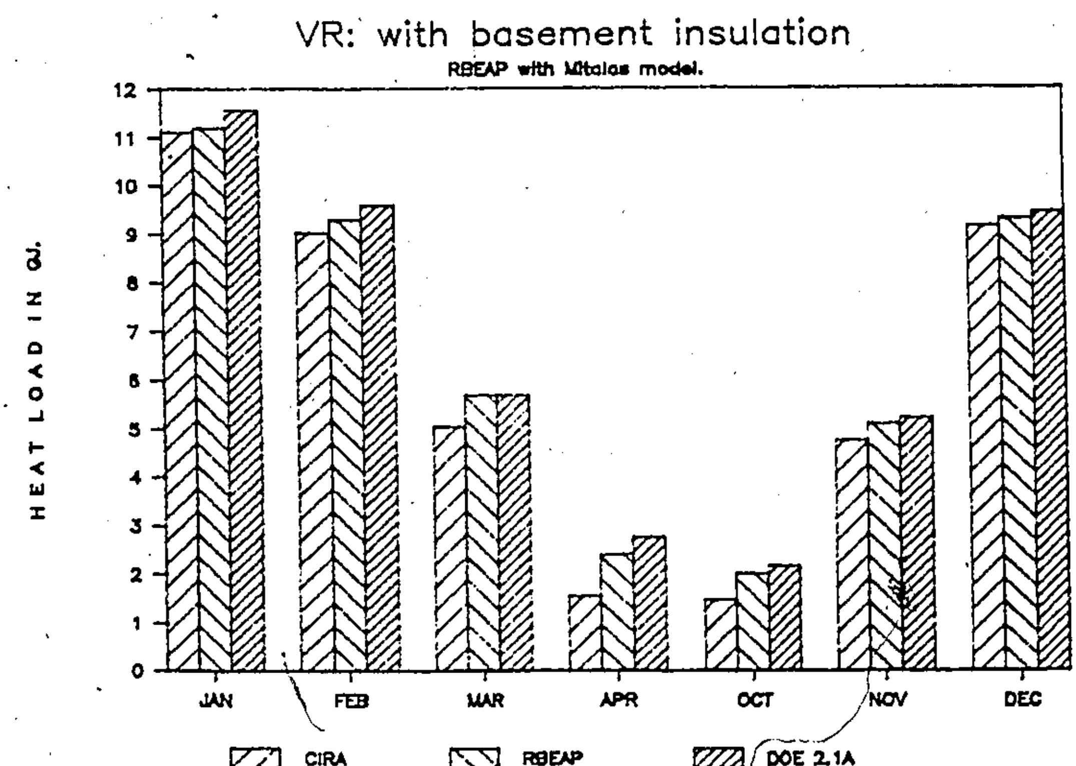


Figure 6.33
Heating load comparison

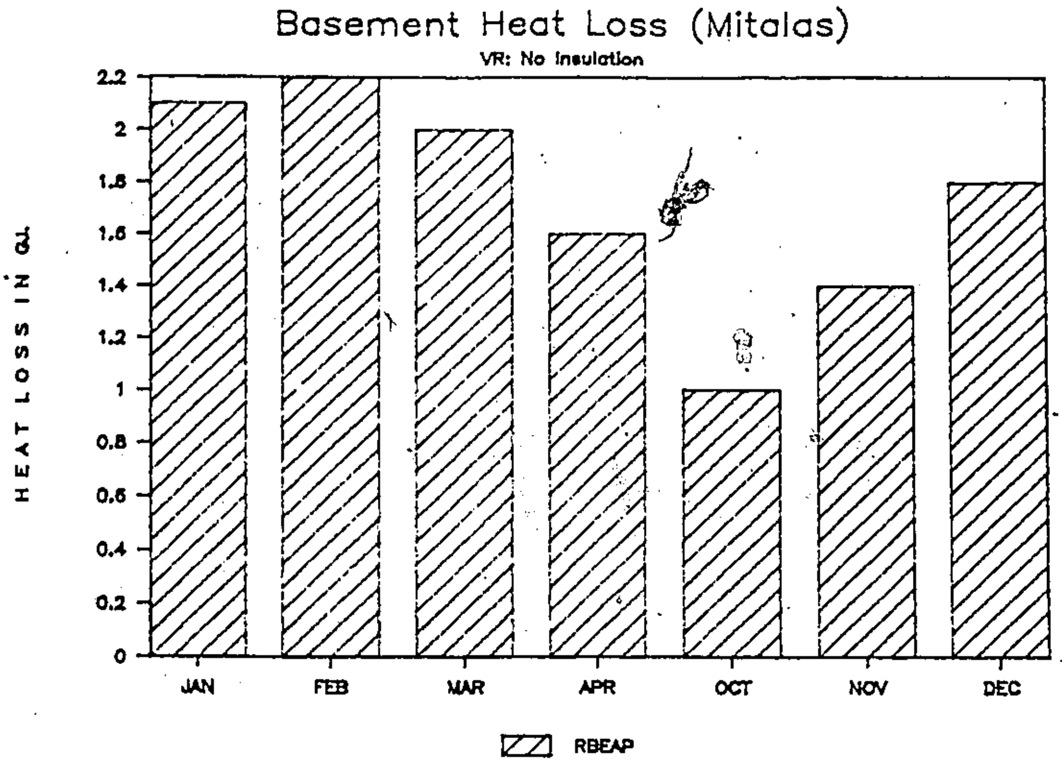


Figure 6.34
Basement heat loss

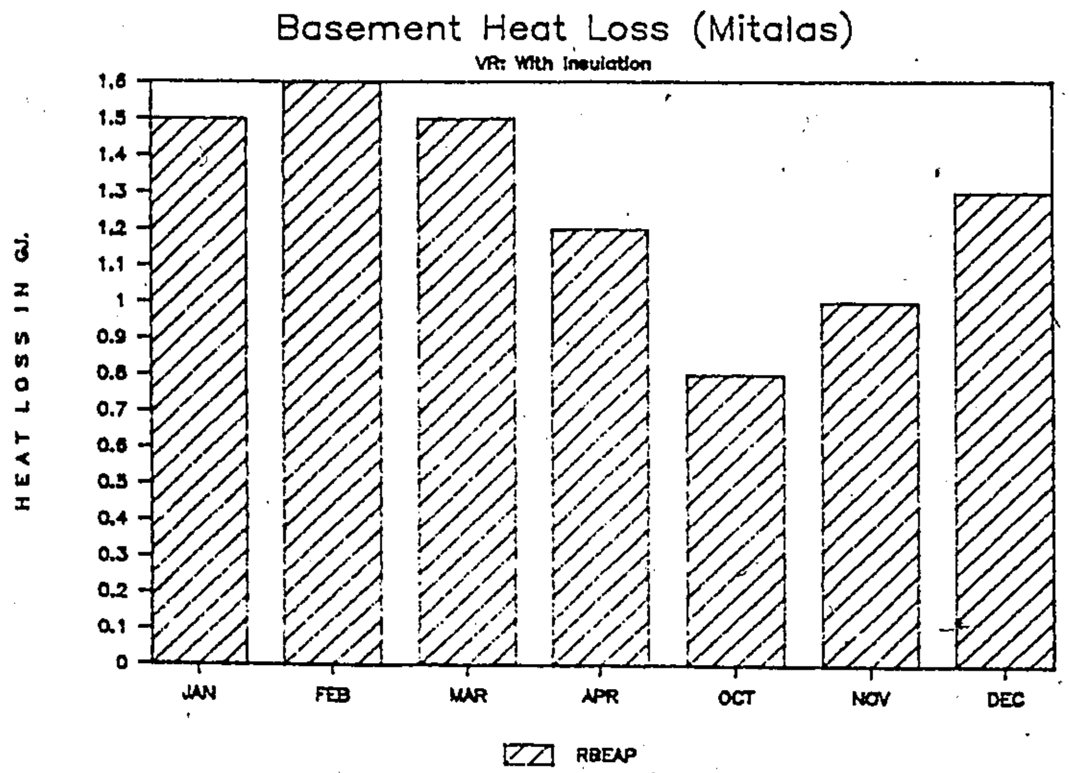


Figure 6.35
Basement heat loss

6.3.2 Comparison of Heating loads between CIRA, RBEAP and DOE 2.1A using RBEAP with the Mitalas model as well as Solar and Internal Gain utilization factors:

The 'Villages of Riverside' house was again considered for this study. The results are shown graphically in figures 6.36 and 6.37. Numeric values for these graphs can be found in Appendix M.

It can be seen that the combined effect of the Mitalas model has further improved the agreement between RBEAP and DOE 2.1A. For example, in the month of April, the variation between RBEAP (version with Mitalas model only) and DOE 2.1A was 18.02%. However, this variation droppped to -0.32% when utilization factors were introduced into the program. Based on the above discussions, it can be concluded that RBEAP program can be used with greater confidence in the modelling residential buildings.

6.4 Results for the Hastings Ranch house:

The Hastings ranch house was used as a test house by Carroll (ref.7) in order to make a multiprogram comparison between DOE , NBSLD and BLAST. The results obtained by him for two cities, Minneapolis and San Francisco were used by the author for his comparative study. The Hastings Ranch house was modelled in RBEAP. Figure 6.38 shows a schematic of the Ranch house.

6.4.1 Comparison of Heating Loads between DOE, RBEAP, NBSLD and BLAST:

Figures 6.39 and 6.40 show the heating load comparison for two cities of vastly differing climate. The RBEAP load predictions are

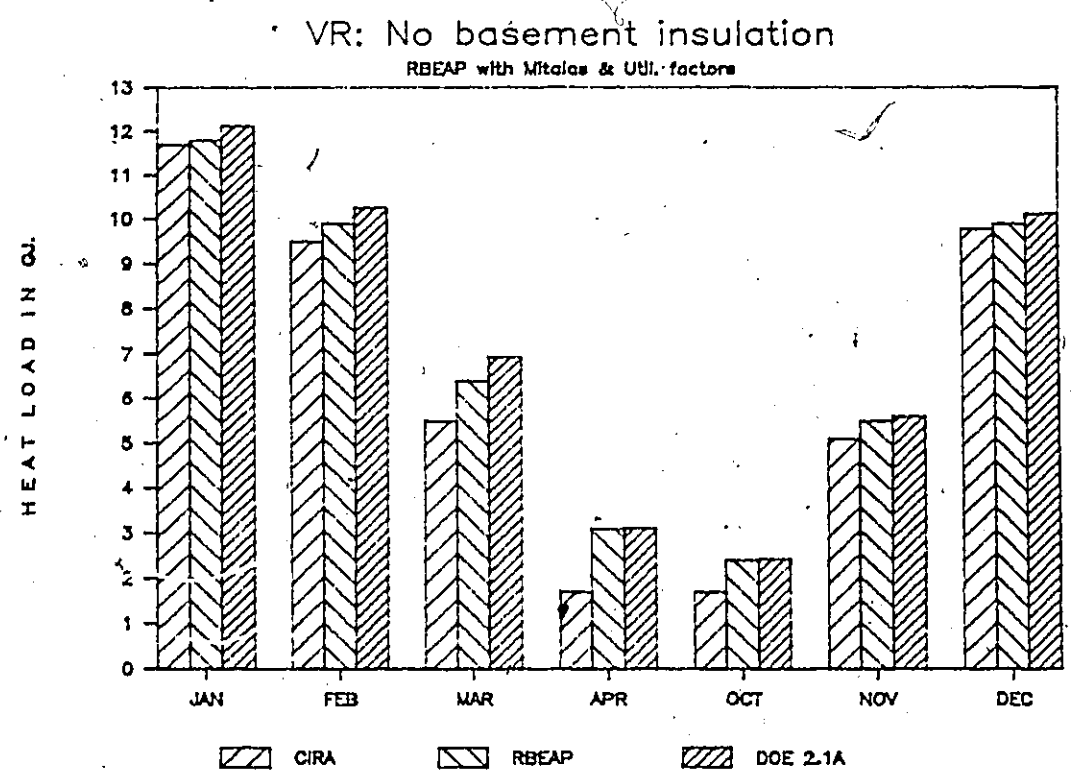


Figure 6.36

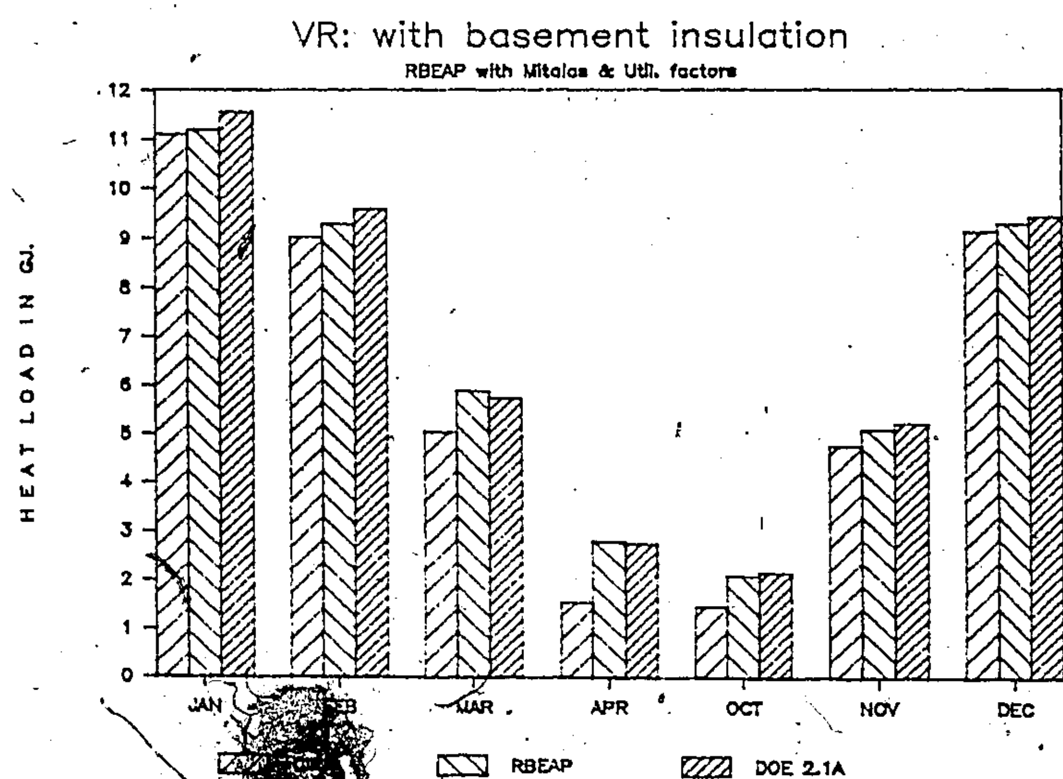


Figure 6.37

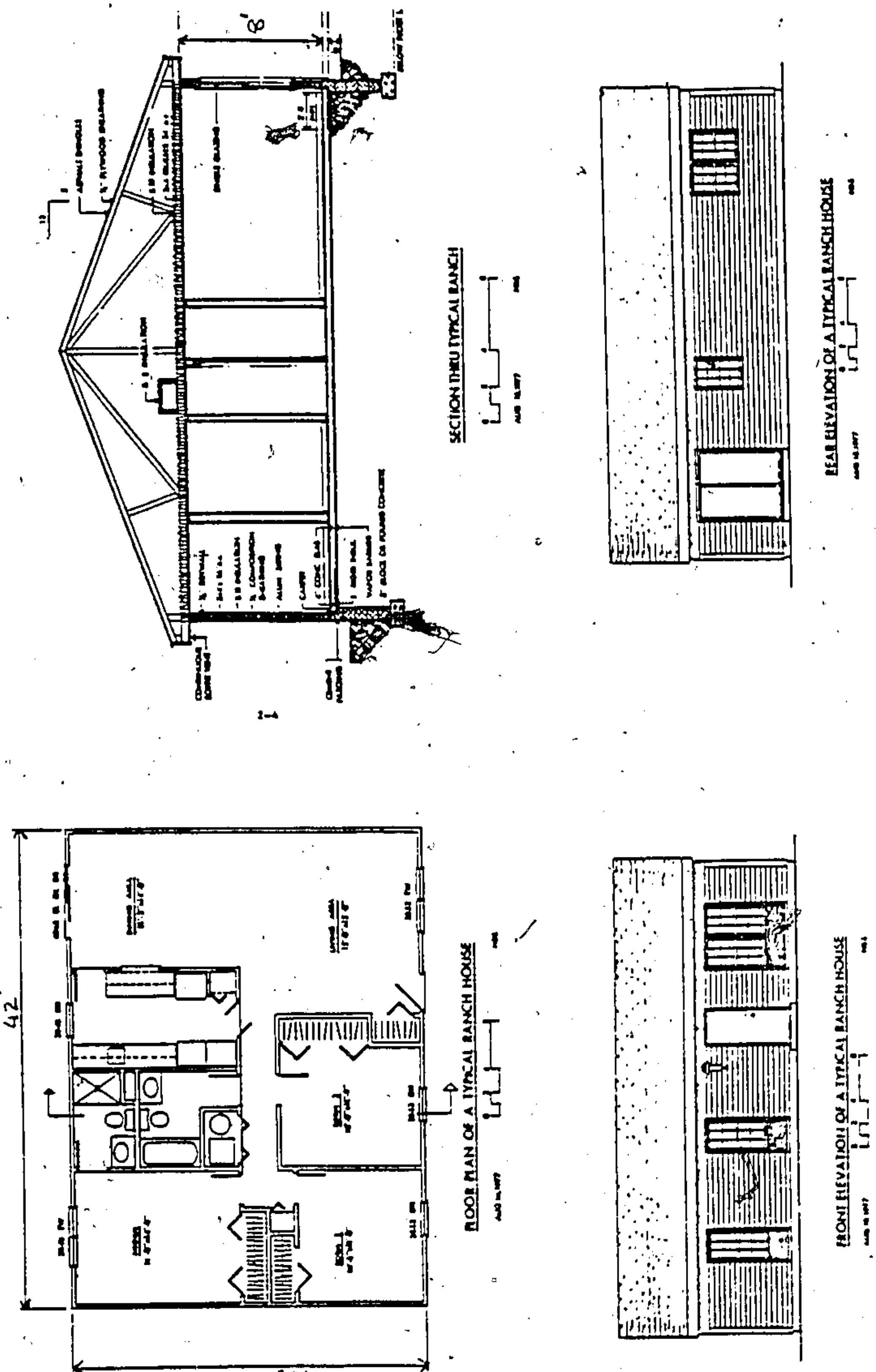


Figure 6.38

Views of the passive solar ranch house.

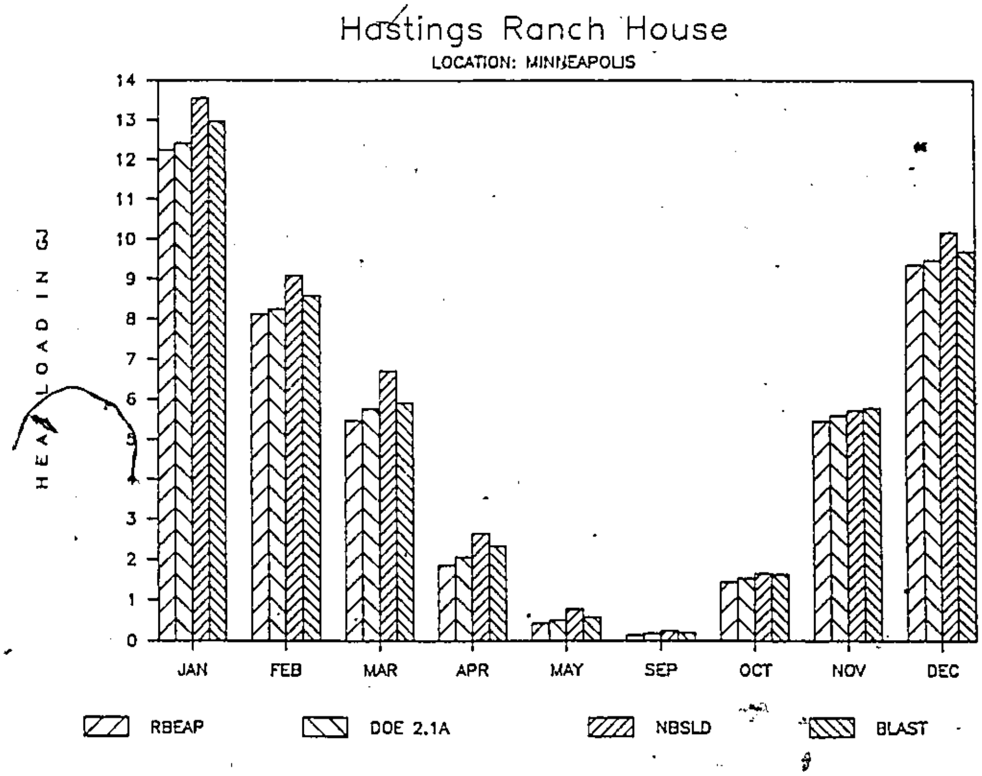


Figure 6.39

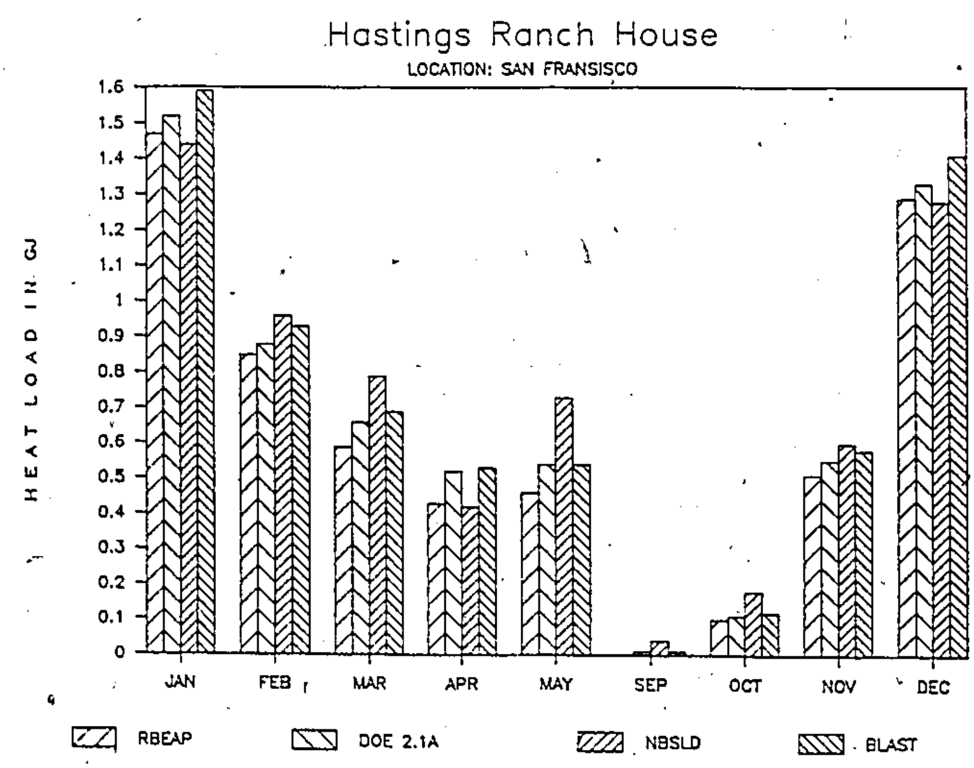


Figure 6.40

followiing the same trend, as established earlier, with regard to the DOE program. Also, the load predictions in comparison with NBSLD and BLAST are in fair agreement.

6.5 <u>**CLOSURE:**</u>

The RBEAP program has been tested and validated against DOE 2.1A, a popular public domain hourly energy analysis program. The results from two other hourly energy analysis programs, NBSLD and BLAST were also used to confirm the accuracy and consistency of RBEAP energy predictions. The results as validated so far indicate that good accuracy has been achieved with considerably simpler algorithms and input requirements. The overall conclusions and recommendations are presented in Chapter 7.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION:

The objective of this work was to develop a FORTRAN language Residential Building Energy Analysis program (RBEAP) based on the CIRA model. The program with the necessary changes in engineering methods was developed and validated against a well established public domain hourly energy analysis program. The following overall conclusions were drawn from these endeavours:

7.2 CONCLUSIONS:

1. The Residential Building Energy Analysis program can be used with greater confidence in modelling and predicting energy usage on a monthly basis. In general, the maximum monthly deviation from DOE 2.1A predicted energy use is of the order of 15%. The maximum deviation on a seasonal basis is 7%.
2. The drawbacks of the CIRA program such as the inabilty to model tight, well insulated houses with high solar and internal gains have been eliminated through the use of solar and internal gain utilization factors. An added benefit is the ability to consider indoor temperature swings.
3. The present basement model in RBEAP can be relied upon to give a realistic and accurate prediction of basement heat loss.
4. The modular nature of the RBEAP program together with the flexibility of the VAX/VMS system can allow for easy alterations of the program .

7.3 LIMITATIONS OF RBEAP:

1. The program is a monthly energy analysis program and treats months as either heating or cooling. Therefore the percentage of cooling in a swing month cannot be determined.
2. The Basement heat loss calculations are available for two sets of soil conductivities only. Although these soil conductivities cover the general range that is to be expected, the program might not be that accurate if the soil surrounding the basement has a conductivity vastly different from the above mentioned sets.
3. Air temperatures are still being used to compute heat loss from slab-on-grade floors. However the error introduced in the overall heating load prediction due to this procedure is not very large as can be seen in the comparison tables for the Passive Solar Ranch house (Figures 6.11 through 6.30 in Chapter 6).

7.4 RECOMMENDATIONS:

The RBEAP program can be used as a basis for development by future workers. Possible changes could include:

1. The reduction of the basic calculation time step to a week or a day. This change should be made keeping in view the fact that the Barakat and Sander correlation for calculating utilization factors (ref. 30) cannot be used for time steps smaller than a month. Also the equations developed by G.P.Mitalas (ref. 14) are valid for calculation of monthly basement heat loss only. Alternate procedures would have to be developed in order to calculate utilization factors and basement heat loss.

2. The basement calculation procedure could also be made sufficiently flexible such that it can calculate shape amplitude and attenuation factors based upon user-input soil conductivities. At present the Mitalas model does not allow for this.
3. A procedure for calculating heat loss from slab-on-grade floors which uses ground temperatures rather than air temperatures could be incorporated.

REFERENCES

1. Diamond, S.C., and Hunn, B.D., "Comparison of DOE-2 Program Simulations To Metered Data For Seven Commercial Buildings", ASHRAE Journal, 1981, Part One.

2. Black, A.W., "A Heretical View of Energy Programs Or is Bigger Really Better", ASHRAE Journal, 1977, Part Two.

3. Garcia, C.A., and Lamb, J.P., " Classification of Computer Programs for HVAC Applications", ASHRAE Journal, 1977, Part Two.

4. Burch, D.M., and Arumi-Noe, F., "DEROB Simulation of the NBS Thermal Mass Test Unit", ASHRAE Journal, 1984, Part 2B.

5. "BLAST Version 2.0, Users Manual", prepared by U.S. Army Construction Engineering Research Laboratory, P.O.Box 4005, Champaign, IL, 61820, June 1979.

6. Thumann, Albert P., "Handbook Of Energy Audits", The Fairmont Press Inc., Atlanta, Georgia, 1979.

7. Carroll, W.L., "Annual Heating and Cooling Requirements and Design Day Performance for a Residential Model in Six Climates: A Comparison of NBSLD, BLAST2 and DOE 2.1", Presented at the ASHRAE/DOE Conference on Thermal Performance of the Exterior Envelopes of Buildings, Orlando,Fla., December 3-5 1979.

8. "ESA (Energy Systems Analysis) Series Users Manual", Prepared by Energy Conservation Buildings program, Public Works Canada, July 1978.

9. Robertz, W., Rogers, R., Nall D., and Greenberg, D., "Comparison of Computer Predicted Thermal Loads with Measured Data from Three

Occupied Townhouses", ASHRAE Journal, 1978, Part One.

10. "Engineering Methods (CIRA 1.0 Reference Manual)", Prepared by Energy Performance of Buildings Group, Lawrence Berkeley Laboratory, University of California, Berkeley, Calif., 1982

11. Colborne, W.G., Hall, J.W., and Wilson, N.W., " A Critical Comparison of Two Building Energy Simulation Programs", SUNFEST '83, 9th Annual Conference of the Solar Energy Society of Canada, August 1-5 1983.

12. Patwardhan, A.G., "A Critical Evaluation of the Computerized Instrumented Residential Audit (CIRA) Program", M.A.Sc Thesis, Department of Mechanical Engineering, University of Windsor, 1984.

13. "EEDO 1.0 Reference Manual", prepared by Burt Hill Kosar Rittlemann Associates, Butler, PA, 1984.

14. Mitalas, G.P., "Calculation of Basement Heat Loss", ASHRAE Journal, 1983, Part 1B.

15. Sander, D.M., and Barakat, S.A., " A Method of Estimating the Utilization of Solar Gains Through Windows", ASHRAE Journal, 1983, Part 1A.

16. Sander, D.M., and Barakat, S.A., " A Method of Estimating the Utilization of Internal Heat Gains", ASHRAE Journal, 1986, Part 1A.

17. Dumont, R.S., Lux, M.E., and Orr, H.W., " HOTCAN: A Computer Program for Estimating the Space Heating Requirements of Residences", DBR Computer Program No. 49, National Research Council of Canada, Ottawa, September 1982.

18. "TRAKLOAD User's Manual", Prepared by Morgan Systems Corporation, 1654 Solano Ave., Berkeley, CA 94707, March 1985.

19. Kusuda, T., Sud, I., and Alereza, T., " Comparison of DOE-2 Generated Residential Design Energy Budgets with those calculated by the Degree Day and Bin Methods", ASHRAE Journal, 1981, Part One.

20. "CARRIER E-20 II User's Manual", Prepared by Carrier Corporation, Syracuse, N.Y., 1981

21. "HEAP - National Energy Analysis Audit Procedure", Carrier Corporation Syracuse, N.Y.

22. " RTL (Run Time Library) Routines - Part II", VAX/VMS System Services Manual, Prepared by Digital Equipment Corporation, P.O. Box CS2008, Nashua, NH, 03061.

23. " CIRA 1.0 Reference Manual", Prepared by Lawrence Berkeley Laboratory, University of California, Berkeley, CA March 1982.

24. Mitalas, G.P., "Basement Heat Loss Studies at DBR/NRC", DBR Paper No. 1045, National Research Council of Canada, September 1982.

25. Balcomb, J.D., Barley, D., McFarland, R.D., Perry, J., Wray, W.O., and Noll, S., " Passive Solar Design Handbook", Volume 2, January 1980, U.S. Department of Energy.

26. Beckman, W.A., Klein, S.A., and Duffie, J.A., " Solar Heating Design by the F-Chart Method", Wiley, New York, 1977.

27a. Brunt, D., "Radiation in the Atmosphere", Quarterly Journal of Radiation, Meteorology Society, 66, 34 (1940)

27b. Berdahl, P., and Fromberg, R., " The Thermal Radiance of Clear Skies", Solar Energy, Volume 29 No.4, Pages 299-314, 1982.

28. ASHRAE Handbook, 1981, Fundamentals, American Society of Heating Refrigerating and Air Conditioning Engineers, Inc., 1791, Tullie Circle NE, Atlanta, GA 30329.

29. Turner, W.D., Elrod, D.C., and Simon-Tov,I.I., "HEATING5: An IBM 360 Heat Conduction Program", Oak Ridge National Laboratory, Oak Ridge, Tennessee, March 1982.

30. Muncey, R.W.R., and Spencer, J.W., "Heat Flow into the Ground under a House", Energy Conservation in Heating Cooling and Ventilating Buildings, Volume 2 (Hemisphere Publishing Corporation 1978).

31. Kusuda, T., " A Variable - Base Degree Day Method for Simplified Residential Building Energy Analysis", NBS, February 1981.

32. Sherman, M.H., and Grimsrud, D.T., " Measurement of Infiltration Using Fan Pressurization and Weather Data", Presented at the First Symposium of the Air Infiltration Centre on Instrumentation and Measurement Techniques, Windsor, U.K., October 6-8, 1980, and LBL Report No. LBL-10852.

33. "RGL (Regis Graphics Library) Routines", User's Manual Prepared by Digital Equipment Corporation, P.O.Box CS2008, Nashua, NH, 03061.

Appendix A

Listing of the modified SUBFLOOR.INF file

as used in RBEAP

```
Subfloor.Inf

$01
Subfloor NAME
\NAME


$02

3
\\
\\
$02
Subfloor TYPE
\TYPE
BCS
B
$03

4
\BBasement\CCrawlspace\SSlab-on-grade\
\B1.0\C0.0\S0.0\
$03
Soil TYPE
\MITSOIL
WR
W
$04\$02=S>#08\

5
\WWell-Drained-Clay\RRocks and wet sand\
\\
$04
Where is the Basement Insulation
\MITINS
IOB
I
#05

6
\IInside\OOutside\BBoth Inside and Outside\
\\
#05
Basement Temperature
deg C\1.8*32+\32-1.8/
\TEMP
5
30
21
#06\$02=S>#16\
```

```
7

#06
Above Grade wall R-value
K-sqm/W\5.6745*\5.6745/
\MITAREA
.1
5.5
3.0
#07

8
#07
Above grade height
m\.3048/\.3048*
\WALLS
0.0
4
1\$02=C>.6\
#08

9
#08
Exposed perimeter
m\.3048/\.3048*
\WALLS
6
300
30
#09

10
Floor Area (joists)
sqm\10.7639*\10.7639/
\AREA
1
500
100
#10\$02=S>#24\

11
#10G
No. of Floor Penetrations
No.\
\LEAKG
0
30
10
#11

12
```

```
#11
Floor Sp. Leakage Area
sqmm/sqm\1076.39/\1076.39*
\LEAKG
0
2600
{450!V10*V09/.2!1076.39*+}
#12

13
#12
No. of Windows
No.\
\LEAKG
0
10
2
#13

14
#13G
No. of wall vents
No.\
\LEAKG
0
20
5
#14

15
#14G
No. of Wall Penetrations
No.\
\LEAKG
0
30
10

16
#15
Wall Specific Leakage area
sqmm/sqm\1076.39/\1076.39*
\LEAKG
0
3250
{600!V13*1000!V12*450!V14!V08*/.5!1076.39*+}
#16

17
#16
Area A2
```

```
sqm\10.7639*\10.7639/
\MITAREA
1
500
10
#17

18
#17
R-value for A2
K-sqm/W\5.6745*\5.6745/
\MITAREA
0.0
10.0
3.0
#18

19
#18
Area A3
sqm/10.7639*\10.7639/
\MITAREA
1
500
10
#19

20
R-value for A3
K-sqm/W\5.6745*\5.6745/
\MITAREA
0.0
10.0
3.0
#20

21
#20
Area A4
sqm/10.7639*\10.7639/
\MITAREA
1
500
10
#21

22
#21
R-value for A4
K-sqm/W\5.6745*\5.6745/
\MITAREA
0.0
```

```
10.0
3.0
#22

23
#22
Area A5

sqm/10.7639*\10.7639/
\MITAREA
1
500
10
#23

24
#23
R-value for A5
K-sqm/W\5.6745*\5.6745/
\MITAREA
0.0
10.0
3.0
$26

25
#24
Floor R-value
K-sqm/W\5.6745*\5.6745/
\FLOOR-R
0.0
10.0
3.0
$25

22
$25
Eqv Floor resistance to outside
\EQUIV-R
DMI
D
$26

23
\DDefault Calculation\MSet to maximum R=25\Iset to minimum R=2
\\
```

Appendix B

Listing of the GENERAL.EXP file.

GENERAL.EXP****

>NAME<

NAME should be a unique name for the house that is being audited. e.g., "John Public". Up to ten letters or symbols may be used. It is used by the program to identify the house.

>CITY<

CITY is the name of the nearest available city. Weather data from this city is used in the calculations. A list of cities is displayed in the upper right hand corner.

>LAT<

LATITUDE is the latitude of the location of the house being audited. It is used to calculate horizontal and vertical solar insolation. Pressing Ctrl-D will give the latitude of the city you choose.

>AZIM<

AZIMUTH is the compass direction the house faces. It is used to calculate the solar energy which falls on each window and wall. Depending on the house orientation, enter:

0 If the North wall of the house faces exactly North.

10 If it faces 10 degree East of North.

-20 If it faces 20 degrees West of North.

>SWING<

The Indoor Temperature Swing is the perceived float in the indoor temperature. A suggested value is 2.75 deg C. This information is used to calculate Solar Utilization factors.

>ALTITUDE<

The altitude or elevation of the house above sea level is required. It is used to correct the density of air for the infiltration calculations and for the calculations which involve air humidity. Pressing Ctrl-D gives the altitude of the weather station of the city you choose.

>THERMOSTAT<

The type of thermostat shows if your thermostat controls heating, cooling , both heating or cooling or neither. This information should be visible on the thermostat itself. For example it might have two pointers on the same scale, one marked "Heating" and the other marhed "Cooling"

>SETTING<

The thermostat setting is the setting you set on the dial. Day and night settings can be different and so can heating and cooling settings. If you turn the heat off at night enter the lowest permitted setting as the night setting.

>TEMPERATURE<

If you don't have or don't use a thermostat enter your estimate of the average temperature in your house in winter or summer.

>FLOOR AREA<

Floor area is the heated or cooled living space..A two-storey house with 2 floors of 750 sqft. each would therefore have a floor area of 1500 sqft. Include the basement area if it is heated.

>THICK<

Input the thickness of the floor slab just above the soil. i.e. the thikness of the slab-on-grade. You should input this value even if you are modelling a full basement or crawlspace in 'SUBFLOOR'. If you have chosen to model a Basement or a Crawlspace, then input the thickness of the floor slab above the basement.

>AVSOIL<

Input the value of the average soil conductivity surrounding the Basement, or the soil conductivity beneath a slab-on-grade floor.

>BCOND<

A conditioned basement is maintained at a particular temperature. This basement space is solicited as user-input under 'SUBFLOOR' component.

'Winter Only' refers to the months assumed to be heating by the program. In this case the summer basement space temperature is taken to be 10 deg C.

'Summer Only' refers to cooling months as decided by the program. In this case the Winter Basement space temperature is assumed to be 10 deg C.

'Unconditioned All year' means that the basement space temperature is not controlled. However the user is requested to input the unconditioned space temperature under 'SUBFLOOR'. A suggested value is 10 deg C.

>MASS<

House mass is related to the weight of the house that can store heat. The greater the MASS, the more sluggishly the house behaves, i.e. the longer it takes for the house to heat-up or cool down. The three options available are:

Heavy : Concrete construction with massive walls.

Medium: Light concrete structure or concrete structures where masonry is shielded by panelling or rugs.

Light : Wood-Frame construction.

>SUN STORE<

The SOLAR STORAGE FACTOR is the ability of the house to store daytime solar heat for release during the night. It is calculated per unit floor area. Concrete or brick floors without carpets (at least where the sun hits) have the highest solar storage factor.

If you press Ctrl-D the computer will give you a default value based on the HOUSE MASS you chose earlier.

>TMASS<

The SPECIFIC THERMAL MASS is the ability of the house to absorb or release heat (or "coolth") during a thermostat setback. It is calulated per unit floor area. The value is highest for masonry construction, especially indoor surfaces not shielded by carpets or wood panelling.

If you press Ctrl-D, the computer will give you an estimate of this parameter based on your earlier choice of HOUSE MASS.

Appendix C

Screen Management Procedures

Function: To create a virtual display and return an identifier, **DispID**, by which the display will be identified in the calling program and other subroutines.

When a display has been created, it will not be visible on the terminal until it is "pasted" on the terminal screen by calling PasteDisplay. It is possible, however, to write to a display while it is not visible by calling WriteToDisplay. The display may be made visible at any time by calling PasteDisplay. It may be removed from the screen by calling UnPasteDisplay. A display may be erased, whether it is visible or invisible by calling EraseDisplay.

Calling Sequence:

```
   call CreateDisplay(DispID,Rows,Columns,Border,Label,Rend)
or
   call CD(DispID,Rows,Columns,Border,Label,Rend)
```

Input Arguments:

Rows	{integer}	- number of Rows in virtual display
Columns	{integer}	- number of Columns in virtual display
Border	{integer}	- controls drawing a border around the display: 0 - no border is drawn 1 - a border is drawn
Label	{character}	- label to appear at the top of the virtual display. Enter 'NIL' if no label is to appear.
Rend	{character}	- characteristics of the label in any combination, any order: BO - BOld BL - BLinking RE - REversed UN - UNderlined Enter 'NO' if normal screen characteristic is to be used.

Output Argument:

DispID	{integer}	- identification of virtual display which is created. DispID is returned for future use of this virtual display such as writing, pasting, erasing, etc. Since it is an output, it must not be a constant. Instead it must be a declared or implicit integer variable in the calling program.

Example:

```
integer disl
   .
   .
call CreateDisplay(disl, 22, 78, 1, 'Main Display', 'REBO')
   .
   .
```

This example creates a virtual display, identified as disl. It will be the size of the screen with a border and a label in reverse bold.

Function: To delete a virtual display from both the screen and memory. After a display has been deleted, it cannot be used by any of the other subroutines with the exception that the same DispID may be used again to create a new version of the display.

Calling Sequence:

```
    call DeleteDisplay(DispID)
or
    call DeD(DispID)
```

Input Argument:

DispID (integer) - identification of virtual display to be deleted

Example:

```
    call DeleteDisplay(dis1)
```

This call would delete the virtual display dis1 which had been previously created .

Function: To erase an entire virtual display to blanks. The display may be visible or invisible when it is erased. After erasure, the display may still be used for writing since it has not been deleted from memory.

Calling Sequence:

```
    call EraseDisplay(DispID)
 or
    call ErD(DispID)
```

Input Argument:

DispID (integer) - identification of virtual display to be erased

Example:

```
    call EraseDisplay(dis1)
```

This erases the display dis1 to blanks. It does not delete it from memory or change its visibility.

Function: To erase selected lines of a virtual screen to blanks

Calling Sequence:

```
    call EraseLines(DispID,start,end)
  or
    call ErLi(DispID,start,end)
```

Input Arguments:

DispID	(integer)	- identification of virtual display
start	(integer)	- virtual display row number of first line to erase
end	(integer)	- virtual display row number of last line to erase

Example:

```
    call EraseLines(dis1,2,7)
```

This erases lines 2 to 7 (inclusive) in the virtual display dis1.

Function: Returns the integer value of a keystroke. It is not necessary to press the RETURN key. Shifted keys and all control keys are accepted, except BACKSPACE which is ignored.

Calling Sequence:

```
    call GetKey(ii)
  or
    call GeK(ii)
```

Output Arguments:

ii (integer) - identification of key which has been pressed.

If the key which was pressed is on the main keyboard on a VT-240 terminal, the returned value for ii will be the normal ASCII equivalent value for the key, including shifted or unshifted values and control key sequences. The normal system defaults for control key presses will apply. Thus, pressing <CTRL>Y will interrupt the program. For key presses on the rest of the keyboard, the following values will be returned:

Key Pressed	ii	Key Pressed	ii	Key Pressed	ii
DELETE	177	Keypad ENTER	270	F13	293
		Keypad -	271	F14	294
PF1	256	Keypad ,	272		
PF2	257	Keypad .	273	HELP	295
PF3	258			DO	296
PF4	259	Up Arrow	274		
		Down Arrow	275	F17	297
Keypad 0	260	Left Arrow	276	F18	298
Keypad 1	261	Right Arrow	277	F19	299
Keypad 2	262			F20	300
Keypad 3	263	F6	286		
Keypad 4	264	F7	287	FIND	311
Keypad 5	265	F8	288	INSERT_HERE	312
Keypad 6	266	F9	289	REMOVE	313
Keypad 7	267	F10	290	SELECT	314
Keypad 8	268	F11	291	PREV_SCREEN	315
Keypad 9	269	F12	292	NEXT_SCREEN	316

Example:

```
   call GetKey(ikey)
```

The program will halt until a key is pressed. It will then return the appropriate value in ikey to identify which key was pressed.

Function: To hold a virtual display while flashing a message at the bottom of the screen until a key is pressed

Calling Sequence:

```
    call HoldDisplay(DispID)
 or
    call HoD(DispID)
```

Input Argument:

DispID (integer) - identification of virtual display

Function: To paste a virtual display onto the visible screen

Calling Sequence:

```
    call PasteDisplay(DispID,row,column)
or
    call PaD(DispID,row,column)
```

Input Arguments:

DispID	(integer)	- identification of virtual display
Rows	(integer)	- screen row number at which row 1 of the virtual display is to be placed
Columns	(integer)	- screen column number at which column 1 of the virtual display is to be placed

Example:

```
    call PasteDisplay(dis1,2,2)
```

This pastes the virtual display, dis1, on the screen (to make it visible) such that the upper left corner of the virtual display is in row 2, column 2 of the screen.

Function: To delete from the screen and from memory the selected virtual display and all virtual displays which were pasted on the screen after the selected display.

Calling Sequence:

```
    call PopDisplay(DispID)
or
    call PoD(DispID)
```

Input Argument:

DispID (integer) - identification of virtual display

Example:

```
    call PopDisplay(dis1)
```

This will delete the display, dis1, and all virtual displays pasted after it.

Function: To access a specified help file, overlay the whole screen with information from the specified Section and SubSection, and wait for the user to read the screen.

Calling Sequence:

```
    call PrintExplains(FileName,Section,SubSection)
 or
    call PrE(FileName,Section,SubSection)
```

Input Arguments:

FileName (character)- name of the help file to be used. The help file must have an extension .EXP; however the non-extended name must be supplied to the subroutine. For example, if the help file, EXAMPLE.EXP is being used, FileName would be 'EXAMPLE'.

Section (character)- name of the Section within the help file to be displayed. Within a help file, Section names are enclosed in > and < at the beginning of otherwise blank lines. PrintExplains searches for the first occurrence of the specified Section identifier and displays the text information up to the next Section identifier.

SubSection (character)- name of SubSection within a Section. It is possible within a Section to first display common text material for the Section, and immediately following this, to display information starting at the first subsequent occurrence of the SubSection identifier and continuing on until the next subsequent SubSection or Section identifier.

Example:

```
    call PrintExplains('EXAMPLE','SECOND','A')
```

The help file, EXAMPLE.EXP, might be as follows:

```
>FIRST<
Some lines of text could be here.
.
.
There could be many of them
.
.
The display will be held for reading after each page.
.
.

>SECOND<
This  common material would be displayed by the call  given  in
the example.
.
.
.
.
End of common material.
>B<
If  the  SubSection argument had been 'B',  then this would  be
displayed after the common material.
.
.
End of SubSection B
>A<
Since  the SubSection argument was 'A' this will  be  displayed
instead.
>THIRD<
Some common material.
.
.
>A<
Some SubSection material
.
.
>C<
Some other SubSection.
>END<
```

Function: To read text from the current cursor position in a specified virtual display to the end of the current line

Calling Sequence:

```
    call ReadDisplay(DispID,text)
or
    call ReD(DispID,text)
```

Input Argument:

DispID (integer) - identification of virtual display

Output Argument:

text (character) - text to be read from virtual display and to be returned to the calling program

Example:

```
    call ReadDisplay(dis1,text)
```

This will read text from the virtual display at the current cursor position to the end of the line.

Function: To write text to a virtual display in a specified location with a specified rendition

Calling Sequence:

```
    call  WriteToDisplay(DispID,text,row,column,Rend)
 or
    call  WD(DispID,text,row,column,Rend)
```

Input Arguments:

DispID	(integer)	- identification of virtual display
text	(character)	- text to be written to the virtual display
Rows	(integer)	- row within the virtual display at which writing is to begin
Columns	(integer)	- column within the virtual display at which writing is to begin
Rend	(integer)	- characteristics of text in any combination, any order: BO - BOld BL - BLinking RE - REversed UN - UNderlined Enter 'NOR' if normal screen characteristic is to be used.

Example:

```
call WriteToDisplay(dis1,'apple',4,2,'NOR')
```

This writes the word 'apple' in normal type at row 4, column 2 of the virtual display, dis1.

Function: To remove a virtual display from screen without deleting it from memory. It may be re-pasted at a different (or the same) position at a later time.

Calling Sequence:

```
    call UnPasteDisplay(DispID)
or
    call UnPaD(DispID)
```

Input Argument:

DispID (integer) - identification of virtual display

Example:

```
call UnPasteDisplay(dis1)
```

This unpastes the virtual display, dis1, removing it from the screen, without deleting it. It can then be moved, re-used, etc.

Output Arguments:

Memory (character)- code letter for item which has been selected from list

Answer (character)- text of item which has been selected from list

Example:

```
   character anslist*255, defaultanslet*1, memoryanslet*1, memoryans*30
   1 PosAnsLst(15)*24, testquest*38, answer*38

   integer maindisplay, defaultdisplay
           .
           .
   testquest='Type of comp........................?'
           .
           .
   anslist='\GGas Furnace\LGas Boiler\FOil Furnace\'//
   1 'BOil Boiler\HHeat Pump\UUnit Gas Heater(s)\'//
   1 'EElectric furnace\RElectric Baseboard\SStove(s)\'//
   1 'WWood Burning equipment\NNone\'

   PosAnsLst( 1)='FERS'
   PosAnsLst( 2)='GWHNFERS'

   defaultanslet = 'E'
   memoryanslet  = 'W'

c create maindisplay
   call creatErDisplay(maindisplay,22,78,1,'Current Values', 'BOld')
   call PasteDisplay(maindisplay,2,2)

   do i = 1,2
   call  WD(maindisplay,testquest,i+2,2,'NOR')

   call SelectAnswer(defaultdisplay,
   1 anslist,
   1 defaultanslet,
   1 memoryanslet,
   1 answer,
   1 PosAnsLst(i),'HVACSYS','HEATING')

   call  WD(maindisplay,answer(1:index(answer,'     ')-1), i+2, 39, 'NOR')

   end do
           .
           .
```

Function: Shows a selection from a supplied set of text strings. These are shown in an automatically sized window in the left hand corner of the screen. A small window at the bottom of the screen gives terse instructions for use of the keys to obtain help and to select an answer from the displayed list. When the choice has been selected, it is sent to the calling program and the two windows disappear by being deleted.

Calling Sequence:

```
call SelectAnswer(DispID, BufAns, Default, Memory, Answer,
1 PosAnsLst, FileName, Section)
```

Input Arguments:

DispID	(integer)	- identification of virtual display
BufAns	(character)	- list of possible text strings to be displayed. Each item in the list must begin with a back slash followed by a code letter which is then followed by the string which is to be displayed on a single line in the window. The final item in the list must be followed by a back slash.
Default	(character)	- code for default answer in the list. This item would be chosen from the displayed list by pressing <CTRL>D.
PosAnsLst	(character)	- list of code letters from those appearing in BufAns. (BufAns may contain more text strings than are required in the list to be actually displayed on the screen. The actual selection is made by specifying the code letters in PosAnsLst.)
FileName	(character)	- name of the HELP file to be used when the HELP key is pressed. The file must exist and have an extension .EXP. (See PrintExplains for a description of help files).
Section	(character)	- name of the Section within the help file which is to be displayed when the HELP key is pressed. (See PrintExplains for a description of help files).

Appendix D

Sample HOUSE.DAT file listing

for CASE 2

Sample House.dat listing
House Name: Case 2
Location: Ottawa
Construction: Light

All numeric values which appear here are stored in the variable house val(kind=1 to 30 , 25). All charater values are stored in house str(kind=1 to 30,25). The House.Dat common block is defined as Common House.dat/house val(kind,25), house str(kind,25)/. This common block is stored in a FORTRAN file called 'COM HOUSE.FOR'. This Common block and hence the House.Dat values can be activated in any FORTRAN program by using the INCLUDE specificatiom.

```
1
Windows
Front
S
D
T
A
N
0.61
82.8174
5.16995
0.290281
0.510017
0.61
0.23
3.5
^@
^@
^@
^@
^@
^@
^@
^@
^@
2
Windows
SLID
S
D
T
A
N
0.61
60.092
6.66995
0.290281
0.300009
```

```
0.61
1.125
3.5
^@
^@
^@
^@
^@
^@
^@
^@
^@
3
Windows
REAR
N
D
T
A
N
0.61
42.7176
^@
0.290281
0.510017
0.61
^@
^@
^@
^@
^@
^@
^@
^@
^@
^@
^@
4
General
Case 2
D
45.3
0.0
412.899
69.9998
69.9998
80.0006
80.0006
^@
1175.99
L
0.22
1.79
D
```

```
^@
^@
^@
W
0.0
127
0.36
^@
5
Economic
Price & Use
20.
0.300000E-01
0.400000E-01
2000
G
N
0.559025E-05
0.280000E-01
^@
^@
0.131810E-04
0.150000E-01
^@
^@
^@
^@
^@
^@
^@
^@
^@
^@
6
HVAC-System
Heat - Cool
G
50021.9
0.75
F
L
N
0.500000E-01
C
24011.7
2
16004.8
50.0024
249.98
41976.6
^@
^@
^@
^@
```

```
^@
^@
^@
^@
7
Doors
FRONT
^@
P
W
N
^@
A
19.9993
^@
0.19
^@
O
^@
^@
^@
^@
^@
^@
^@
^@
^@
^@
8
Walls
FRONT
S
F
F
N
O
^@
173.17
4
1
1
7
^@
0.132847E-01
0.312879
^@
^@
^@
^@
^@
^@
^@
^@
```

```
9
Walls
RIGHT
E
F
F
N
O
^@
224.109
4
1
1
0.0
^@
0.312847E-01
0.996014E-01
^@
^@
^@
^@
^@
^@
^@
^@
10
Walls
REAR
N
F
F
N
O
^@
293.42
4
1
1
4
0.312847E-01
0.158361
^@
^@
^@
^@
^@
^@
^@
^@
11
WALLS
LEFT
W
F
```

F
N
O
^@
224.109
4
1
1
0.0
^@
0.0312847E-01
0.996014E-01
^@
^@
^@
^@
^@
^@
^@
^@
12
Appliances
LIFE
S
1.0007
140
308.23
G
40012.1
1240.37
L
225
396
100.03
E
0.181821
25.9718
^@
^@
^@
^@
^@
^@
^@
^@
13
Landscape
Yard & Trees
0.24
1.
1.
1.
1.
1.

```
1.
G
^@
^@
^@
^@
^@
^@
^@
^@
^@
^@
^@
^@
^@
^@
14
Infiltration
Ventilation
8.0039
3
3
^@
^@
^@
^@
N
N
161.29
129.032
322.58
A
9402.48
^@
^@
^@
^@
^@
^@
15
Roof-Ceiling
ATTIC
U
0.263778
F
O
A
1175.96
6
.200194E-01
0.501537
0.95
0.2262
```

5.
10.
^@
^@
^@
^@
^@
^@
^@
^@
16
Subfloor
Slab
S
W
^@
^@
^@
^@
140.
20.
^@
^@
^@
^@
^@
^@
^@
^@
^@
^@
40.
D
^@
^@

Appendix E

Variable List for the Data Compression Program,

COMP.FOR

The following is a list of variables used in the COMP.FOR file. The variables house str(30,25) and house val(30,25) are present in a common block 'House.dat' and this common block resides in a file called COM HOUSE.FOR. All internal calculations within the program are performed in British units. The final answers are converted to SI units before being displayed on the screen.

REAL VARIABLES	Description
House_val(30,25)	Numeric house data
therm(2,2)	Indoor temperatures day/night winter/summer (deg F)
rated_capacity(2)	Capacity of heating and cooling plants
rated_efficiency(2)	Efficiency of heating and cooling units
distribution_loss(2)	User input loss (heating & cooling) (%)
avgtmp(2,12)	Monthly average day/night temperatures from weather file (deg F)
wet_bulb(12)	Monthly average wet bulb temperatures. (deg F) from weather file
Sky_loss(2,12)	Radiated heat loss to sky from (Btu/day).
infil(2,12)	Stack & wind specific infiltration ($m^3/hr-cm^2$) from weather file
Eprice(5)	Economic data. Prices
Erate(5)	Economic data. Rates of discount & Escalation
Eyear(5)	Life of house
Epvf(5)	Present worth factor
Ebase(5)	Base prices.
totsa(2,5)	Accumulated total solar apertures for heating/cooling and 5 directions(NSEWH)

sflux(6,12)	Solar flux. Monthly values for 5 directions
sit_mod(5,12)	Modifiers for passive solar routines
degree_day(2,2,3)	degree-day coefficients from weather file
pvs(12)	Vapor pressure of water.
indic(12)	Heating/Cooling month indicator.
S(5)	Steady state basement loss shape factor.
V(5)	Variable basement loss shape factor.
A(5)	Areas of basement segments (m^2)
R(5)	R-values of basement segments (W/m^2-K)
Qbase2(12)	Basement heat loss through segment 2. (Watts)
Qbase3(12)	Basement heat loss through segment 3. (Watts)
Qbase4(12)	Basement heat loss through segment 4. (Watts)
Qbase5(12)	Basement heat loss through segemnt 5. (Watts)
Qbase_tot_month(12)	Total monthly heat loss from basement. (Watts)
T_g	Ground surface temps (deg C)
T_v	Amplitude of first harmonic of ground surface temperature(deg C)
T_b	Basement space temperature(C)
B_7	Basement identifier.

diffuse(12)	Diffuse component of solar radiation.
Ovhg_mod(12)	Modifier for South window overhang.
psoh_mod(12)	Modifier used in the PSOVM routine.
ref_mod(12)	Modifier based on ground reflectivity
temp(5,12)	Values of solar flux coefficients from weather file
latdec(12)	Monthly sub elevations
sin_dayangle(12)	Sine of day of year.
eps_sky(2)	Clear sky emissivities day/night.
itype_econ(5)	Economic info. Holds what fuel is used for heating and cooling.
req(6)	Component identifier.
typ_passive(5)	Type of passive solar system.
are_passive(5)	Area of passive solar system.
blc_green(5)	Greenhouse load coefficients..
green_area(5)	Greenhouse area.
sun_store	Solar storage factor. (unitless)
thermal_mass	Thermal mass of the house
lvcspc_ht	Height of living space.
house_area	Area of house
la	leakage area for each component.
totalla	Accumulated leakage area Obtained by summing leakage areas.
totalua	Accumulated UA-values from each component.

totallacei	Total leakage area due to ceiling (cm^2)
totallaflr	Total leakage area due to floor. (cm^2)
uacei	UA due to ceiling. (Btu/hr-F)
uawal	UA due to wall.(Btu/hr-F)
hO	Outside air film coeff for convection Heat Transfer.
totalpsa	Solar aperture due to passive solar system.
totalpsua	Total UA due to passive solar system.
xcollec	Dimensionless quantities used for determining active solar contribution to space heating.
ycollec	Same as above.
rho_ground	Ground reflectivity.
swing	Swing in indoor temp.(deg F)
thick	Floor slab thickness.(mm)
bar_press	Pressure corrected for altitude.
bypassl	Coil bypass factor.
fan_flow	User_input fan flow rate
rhocp std	Product of specific heat and density of air as a function of bar press.
house_volume	Volume of the house.
iter_class	Terrain class of building surroundings.
ishld_class	Shielding class of surroundings.

alpha gamma	Terrain parameters for standard terrain classes.
cprime	Local shielding parameter
sg fact	Solar gain factor.
humidity_ratio (12)	Humidity ratio of space.
free_heat	Internal gains excluding solar gains.(Btu/hr)
qinfbal(2)	Unbalanced infiltration Minimum of exhausts and supplies.
qinfinb(2)	Resultant forced infiltration
abgua	Above grade UA value due to basement.

Character variables	Description
house_name*30	User input name for house.
Occupant_name*30	Name of occupants.
City_name*30	City name.
Adjust_str*1	Check to adjust results to actual use
Usecol_str syscol_str	Solar collector strings
Natvent_str	Natural ventilation (Y/N)
heat_type*1	Heating type
Cool_type*1	Cooling type
foss_type*1	Fossil type
dist_type*1	Distribution type
Direction_letter(5)*1	'NSEWH'
dhw_type*1	Water heater type

Appendix F

Shape and Attenuation Factors for Basement Heat Loss Calculations

Source: G.P. Mitalas.

TABLE 1 SHAPE, AMPLITUDE ATTENUATION, TIME LAG AND CORNER ALLOWANCE FACTORS FOR BASEMENT HEAT LOSS CALCULATIONS (from Mitalas)[2]

In all cases for the range $1 \le R \le 5$:

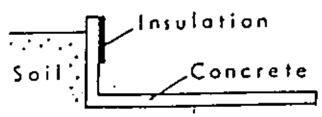
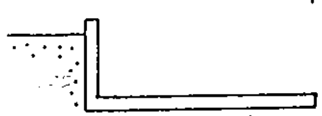
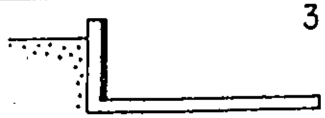
$\sigma_2 = 0.9$	$\Delta t_2 = 0$	
$\sigma_3 = 0.7$	$\Delta t_3 = -1$	
$\sigma_4 = 0.4$	$\Delta t_4 = -2$	
$\sigma_5 = 0.3$	$\Delta t_5 = -4$	

Units:

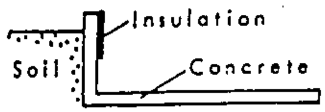
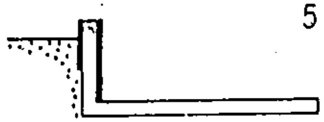
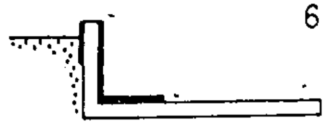
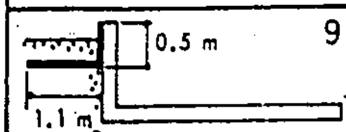
S, $W/(m^2 \cdot K)$	R, $m^2 \cdot K/W$
V, $W/(m^2 \cdot K)$	σ, dimensionless
C, m^2 or dimensionless	Δt, month

(Δt is the time delay of heat flux sine wave relative to the ground surface temperature sine wave.)

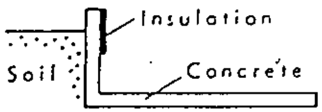
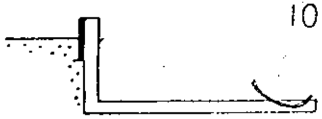
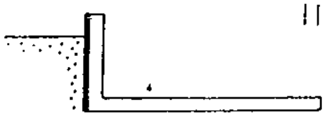
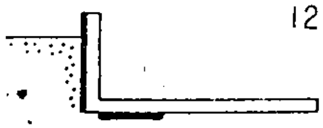
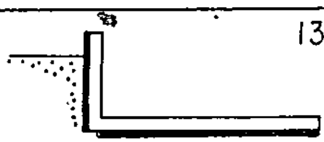
SECTION A: SOIL THERMAL CONDUCTIVITY, k upper = [illegible] W/(m.K); k lower = 0.9 W/(m.K)

Insulation System	S_n, V_n, and C_n Factors	Wall Segments: Top strip just below grade, n = 2	Wall Segments: Bottom strip, n = 3	Floor Segments: 1 m strip adjacent to wall, n = 4	Floor Segments: Centre n = 5
 Insulation, Concrete, Soil					
1 	S=	1.9	0.74	0.42	0.17
	V=	1.9	0.65	0.24	0.05
	C=	0	1.0	2.6	0.5
2 	S=	$(0.53 + 1.42 \cdot R)^{-1}$	$(1.06 - 0.013 \cdot R)^{-1}$	0.41	0.18
	V=	$(0.53 + 1.43 \cdot R)^{-1}$	$(1.15 - 0.016 \cdot R)^{-1}$	0.25	0.05
	C=	0	1.0	2.6	0.5
3 	S=	$(0.58 + 1.10 \cdot R)^{-1}$	$(1.23 + 1.45 \cdot R)^{-1}$	$(1.81 - 0.054 \cdot R)^{-1}$	0.19
	V=	$(0.58 + 1.12 \cdot R)^{-1}$	$(1.34 + 1.55 \cdot R)^{-1}$	$(2.77 - 0.11 \cdot R)^{-1}$	0.07
	C=	0	0.6	2.4	0.5

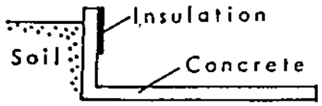
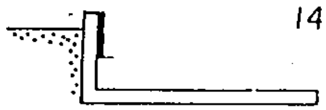
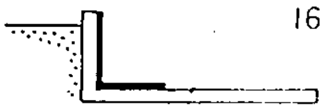
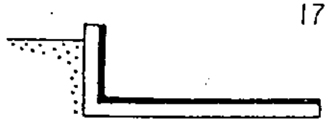
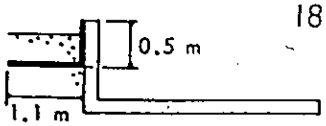
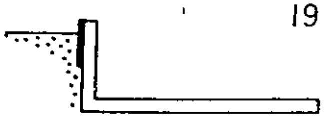
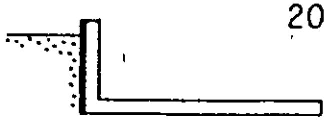
SECTION A: SOIL THERMAL CONDUCTIVITY: k upper = 0.8 W/(m.K); k lower = 0.9 W/(m.K)

Insulation System	S_n, V_n, and C_n Factors	Wall Segments: Top strip just below grade, n = 2	Wall Segments: Bottom strip, n = 3	Floor Segments: 1 m strip adjacent to wall, n = 4	Floor Segments: Centre n = 5
					
4 	S= V= C=	$(0.60 + 1.07 \cdot R)^{-1}$ $(0.60 + 1.09 \cdot R)^{-1}$ 0	$(1.22 + 1.22 \cdot R)^{-1}$ $(1.33 + 1.34 \cdot R)^{-1}$ 0.6	$(3.45 + 0.64 \cdot R)^{-1}$ $(5.38 + 0.98 \cdot R)^{-1}$ 2.4	$(4.42 - 0.14 \cdot R)^{-1}$ $(11.08 - 0.58 \cdot R)^{-1}$ 0.5
5 	S= V= C=	$(0.67 + 1.12 \cdot R)^{-1}$ $(0.67 + 1.14 \cdot R)^{-1}$ 0	$(1.30 + 1.47 \cdot R)^{-1}$ $(1.42 + 1.58 \cdot R)^{-1}$ 0.6	$(1.82 - 0.055 \cdot R)^{-1}$ $(2.79 - 0.11 \cdot R)^{-1}$ 2.4	0.19 0.07 0.5
6 	S= V= C=	$(0.69 + 1.08 \cdot R)^{-1}$ $(0.69 + 1.11 \cdot R)^{-1}$ 0	$(1.28 + 1.23 \cdot R)^{-1}$ $(1.41 + 1.36 \cdot R)^{-1}$ 0.6	$(3.48 + 0.64 \cdot R)^{-1}$ $(5.43 + 0.95 \cdot R)^{-1}$ 2.4	$(4.44 - 0.13 \cdot R)^{-1}$ $(11.13 - 0.58 \cdot R)^{-1}$ 0.5
7 	S= V= C=	$(0.73 + 1.04 \cdot R)^{-1}$ $(0.72 + 1.08 \cdot R)^{-1}$ 0	$(1.42 + 1.03 \cdot R)^{-1}$ $(1.53 + 1.21 \cdot R)^{-1}$ 0.6	$(2.60 + 0.92 \cdot R)^{-1}$ $(4.21 + 1.58 \cdot R)^{-1}$ 2.4	$(4.93 + 0.71 \cdot R)^{-1}$ $(12.91 + 1.25 \cdot R)^{-1}$ 0.5
8 	S= V= C=	$(0.63 + 1.03 \cdot R)^{-1}$ $(0.62 + 1.07 \cdot R)^{-1}$ 0	$(1.35 + 1.03 \cdot R)^{-1}$ $(1.44 + 1.20 \cdot R)^{-1}$ 0.6	$(2.59 + 0.92 \cdot R)^{-1}$ $(4.17 + 1.57 \cdot R)^{-1}$ 2.4	$(4.93 + 0.71 \cdot R)^{-1}$ $(12.84 + 1.24 \cdot R)^{-1}$ 0.5
9 	S= V= C=	$(1.24 + 0.60 \cdot R)^{-1}$ $(1.22 + 0.65 \cdot R)^{-1}$ 0	$(1.78 + 0.084 \cdot R)^{-1}$ $(2.07 + 0.12 \cdot R)^{-1}$ 1.0	0.39 0.22 2.6	0.17 0.05 0.5

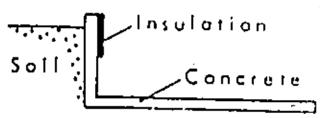
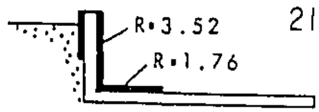
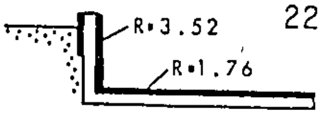
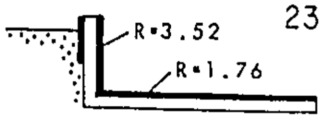
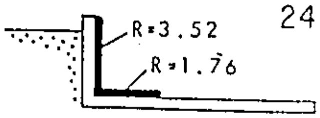
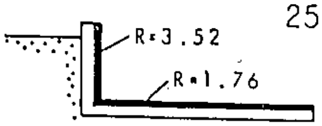
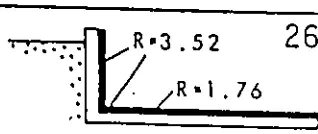
SECTION A: SOIL THERMAL CONDUCTIVITY: k upper = 0.8 W/(m.K); k lower = 0.9 W/(m.K)

Insulation System	S_n, V_n, and C_n Factors	Wall Segments		Floor Segments	
		Top strip just below grade, n = 2	Bottom strip, n = 3	1 m strip adjacent to wall, n = 4	Centre n = 5
					
10 	S= V= C=	$(1.41 + 0.41 \cdot R)^{-1}$ $(1.42 + 0.42 \cdot R)^{-1}$ 0	$(1.52 + 0.0047 \cdot R)^{-1}$ $(1.72 + 0.006 \cdot R)^{-1}$ 1.0	0.42 0.25 2.6	0.17 0.05 0.5
11 	S= V= C=	$(0.73 + 1.08 \cdot R)^{-1}$ $(0.72 + 1.11 \cdot R)^{-1}$ 0	$(1.92 + 0.30 \cdot R)^{-1}$ $(2.16 + 0.40 \cdot R)^{-1}$ 0.6	0.43 0.25 2.4	0.15 0.06 0.5
12 	S= V= C=	$(0.74 + 1.07 \cdot R)^{-1}$ $(0.74 + 1.1 \cdot R)^{-1}$ 0	$(1.88 + 0.26 \cdot R)^{-1}$ $(2.14 + 0.36 \cdot R)^{-1}$ 0.6	$(2.99 + 0.11 \cdot R)^{-1}$ $(4.91 + 0.14 \cdot R)^{-1}$ 2.4	0.19 0.07 0.5
13 	S= V= C=	$(0.76 + 1.05 \cdot R)^{-1}$ $(0.75 + 1.09 \cdot R)^{-1}$ 0	$(1.91 + 0.17 \cdot R)^{-1}$ $(2.18 + 0.28 \cdot R)^{-1}$ 0.6	$(2.80 + 0.064 \cdot R)^{-1}$ $(4.74 + 0.12 \cdot R)^{-1}$ 2.4	$(5.47 + 1.05 \cdot R)^{-1}$ $(17.07 + 2.9 \cdot R)^{-1}$ 0.5

SECTION B: SOIL THERMAL CONDUCTIVITY: k upper = 1.2 W/(m.K); k lower = 1.35 W/(m.K)

Insulation System	S_n, V_n, and C_n Factors	Wall Segments: Top strip just below grade, n = 2	Wall Segments: Bottom strip, n = 3	Floor Segments: 1 m strip adjacent to wall, n = 4	Floor Segments: Centre n = 5
					
14 	S= V= C=	$(0.48 + 1.37 \cdot R)^{-1}$ $(0.48 + 1.38 \cdot R)^{-1}$ 0	$(0.85 - 0.008 \cdot R)^{-1}$ $(0.93 - 0.0094 \cdot R)^{-1}$ 1.0	0.59 0.35 2.6	0.27 0.09 0.5
15 	S= V= C=	$(0.51 + 1.09 \cdot R)^{-1}$ $(0.52 + 1.11 \cdot R)^{-1}$ 0	$(0.97 + 1.38 \cdot R)^{-1}$ $(1.06 + 1.49 \cdot R)^{-1}$ 0.6	$(1.36 - 0.03 \cdot R)^{-1}$ $(2.11 - 0.062 \cdot R)^{-1}$ 2.4	0.29 0.11 0.5
16 	S= V= C=	$(0.52 + 1.06 \cdot R)^{-1}$ $(0.53 + 1.08 \cdot R)^{-1}$ 0	$(0.96 + 1.2 \cdot R)^{-1}$ $(1.06 + 1.33 \cdot R)^{-1}$ 0.6	$(2.76 + 0.54 \cdot R)^{-1}$ $(4.39 + 0.88 \cdot R)^{-1}$ 2.4	$(2.93 - 0.07 \cdot R)^{-1}$ $(7.25 - 0.30 \cdot R)^{-1}$ 0.5
17 	S= V= C=	$(0.56 + 1.02 \cdot R)^{-1}$ $(0.55 + 1.06 \cdot R)^{-1}$ 0	$(1.08 + 1.01 \cdot R)^{-1}$ $(1.15 + 1.18 \cdot R)^{-1}$ 0.6	$(1.90 + 0.89 \cdot R)^{-1}$ $(3.14 + 1.58 \cdot R)^{-1}$ 2.4	$(3.27 + 0.76 \cdot R)^{-1}$ $(8.46 + 1.55 \cdot R)^{-1}$ 0.5
18 	S= V= C=	$(1.19 + 0.47 \cdot R)^{-1}$ $(1.18 + 0.51 \cdot R)^{-1}$ 0	$(1.43 + 0.058 \cdot R)^{-1}$ $(1.60 + 0.077 \cdot R)^{-1}$ 1.0	0.41 0.26 2.6	0.17 0.05 0.5
19 	S= V= C=	$(1.29 + 0.29 \cdot R)^{-1}$ $(1.31 + 0.30 \cdot R)^{-1}$ 0	$(1.12 + 0.0027 \cdot R)^{-1}$ $(1.27 + 0.0033 \cdot R)^{-1}$ 1.0	0.59 0.35 2.6	0.26 0.08 0.5
20 	S= V= C=	$(0.62 + 1.06 \cdot R)^{-1}$ $(0.61 + 1.09 \cdot R)^{-1}$ 0	$(1.58 + 0.26 \cdot R)^{-1}$ $(1.79 + 0.35 \cdot R)^{-1}$ 0.6	0.60 0.36 2.4	0.27 0.09 0.5

SECTION C: SOIL THERMAL CONDUCTIVITY: k upper = 0.8 W/(m.K); k lower = 0.9 W/(m.K)

Insulation System	S_n, V_n and C_n Factors	Wall Segments: Top strip just below grade n = 2	Wall Segments: Bottom strip n = 3	Floor Segments: 1 m strip adjacent to wall n = 4	Floor Segments: Centre n = 5
 Soil, Insulation, Concrete					
 21 R=3.52, R=1.76	S=	0.22	0.18	0.23	0.25
	V=	0.22	0.16	0.15	0.10
	C=	0	0.6	2.4	0.5
 22 R=3.52, R=1.76	S=	0.22	0.19	0.26	0.16
	V=	0.22	0.17	0.15	0.07
	C=	0	0.6	2.4	0.5
 23 R=3.52, R=1.76	S=	0.23	0.19	0.16	0.18
	V=	0.22	0.17	0.10	0.07
	C=	0	0.6	2.4	0.5
 24 R=3.52, R=1.76	S=	0.23	0.18	0.24	0.26
	V=	0.22	0.16	0.13	0.09
	C=	0	0.6	2.4	0.5
 25 R=3.52, R=1.76	S=	0.23	0.19	0.27	0.17
	V=	0.23	0.16	0.13	0.06
	C=	0	0.6	2.4	0.5
 26 R=3.52, R=1.76	S=	0.23	0.20	0.17	0.18
	V=	0.23	0.16	0.09	0.06
	C=	0	0.6	2.4	0.5

Appendix G-1

Modified HOUSE.LOD file listing for Case 2

CIRA energy data
21

1$Occupants' Name
LIFE

1$House name
Case 2

1#House Area (sqm)
109

1#House Volume (cum)
266

1$city
OTTAWA

1#Latitude (deg)
45

1#Altitude (meters)
125

1#Azimuth (deg)
0

1#Solar Storage Factor (unitless)
0.22

1#Therml time constant (hr)
13.7953

1#Free Heat (W)
670.442

1#Moisture (Kg.day)
1.9835

3# Building Load Coefficient (W/C): yearly/heating/cooling
80.4722
87.9405
73.0039

3# Conduction Coefficient (W/C): Total/ Ceiling / Floor
56.6769
12.1843
0.113606

3#Leakage Area (sqcm) Total / Ceiling / Floor
322.580

161.290
129.032

5#North/East/South/West/Horizontal December Solar access(%)
100.000
100.000
83.5427
100.000
100.000

5#North/East/South/West/Horizontal June Solar access(%)
100.000
100.000
44.2521
100.000
100.000

5#North/East/South/West/Horizontal heating season SA(sqm)
2.57936
0.121076
8.18879
0.12107E-01
0.541762

5#North/East/South/West/Horizontal cooling season SA(sqm)
2.57936
0.121076
8.18879
0.12107E-01
0.541762

4#Heating day/night thermostats(degC) Cooling dy/night thermostats(degC)
21
21
26
26

4#Yearly Electric Cons.(Kwh)/Cost($) -- Yearly Other fuel Cons.(GJ)/($)
3688.46
165.980
70.6572
374.400

Daytime Sensible Load
Dload
GJ
###.#
0.000001055

0.129742E+07
769356
399855
116828
-96039.5
-830555
-858492
-0.117796E+07
-500425
-339931
270183
0.119901E+07

Nighttime Sensible Load
Nload
GJ
###.#
.000001055
0.337684E+07
0.252916E+07
0.184404E+07
8078990.
0.000000E+00
0.000000E+00
0.000000E+00
0.000000E+00
0.000000E+00
0.000000E+00
981107
0.280650E+07

Daytime HVAC on-time
Dayon

###.#
100
0.101731
0.676658E-01
0.330263E-01
0.115843E-01
0.166050E-01
0.149212
0.158757
0.204205
0.921967E-01
0.567858E-01
0.237614E-01
0.942161E-01

Nighttime HVAC on-time
Niton

###.#
100
0.259845
0.215933
0.143382
0.66376E-01
0.000000E+00
0.000000E+00
0.000000E+00
0.000000E+00
0.000000E+00
0.000000E+00
0.800618E-01
0.216414

Space Cond. Energy Use.
SpEgy
GJ
###.#
.000001055
0.681883E+07
0.483551E+07
0.333032E+07
0.142406E+07
-58308.8
-565396
-648326
-819319
-324225
-187840
0.189666E+07
0.586389E+07

Infiltration
Infil
ac/hr
#.##
0.375589E-02
101.327
99.2696
89.2992
74.4679
59.2587
46.8873
33.2205
33.1831
48.1351
59.9200
75.3436
97.6057

Overall gas use
Tgas
####
1E-05
0.103863E+08
0.807661E+07
0.694754E+07
0.495025E+07
0.366472E+07
0.354650E+07
0.366472E+07
0.366472E+07
0.354605E+07
0.366472E+07
0.541614E+07
0.944497E+07

Overall Elec Use
Telec
KWh
####
.9291E-04
916358
808802
866602
812990
877410
0.135808E+07
0.146743E+07
0.163842E+07
0.111690E+07
0.100694E+07
819731
902737

Indoor Dew Point
DewPt
deg C
###.#

-11.7992
-8.12101
-3.47064
1.74628
7.42444
10.9785
14.9005
13.4412
11.3232
7.39551

2.77344
-8.52635

Useful Solar Gain
Sgain
GJ
#.##
0.00002532
118042
112396
115306
78944.2
67233.4
76527.7
63625.9
82736.1
83229.8
106525
74685.6
98270.6
28235.7
25056.1
22093.6
23305.8
23754.1
26733.3
26827.2
28442.7

Var. Base Degree days
VBDDy
C-day
####

619.860
440.719
311.690
136.494
-15.1474
-138.754
-153.444
-210.585
-83.1061
-53.4595
184.016
538.068

Space Cond. cost
Spce$

###.#

38.1190
27.0317
18.6173
7.96086
0.768569
7.45249
8.45858
10.7994
4.27361
2.47591
10.6030
32.7806

Overall Gas Cost
Gas$

###.#
0.559025E-05
0.103863E+08
0.807661E+07
0.694754E+07
0.495025E+07
0.366472E+07
0.354650E+07
0.366472E+07
0.366472E+07
0.354605E+07
0.366472E+07
0.541614E+07
0.944497E+07

Overall Elec Cost
Elec$

####
0.13181E-04
916358
808802
866602
812990
877410
0.135808E+07
0.146743E+07
0.163842E+07
0.111690E+07
0.100694E+07
819731
902737

Effective Temperature (day)
Teffd
deg C
###.#
11.706
15.838
20.590
26.277
22.968
33.678
34.660
37.814
29.557
26.529
21.390
11.944

Effective Temperature (Night)
Teffn
Deg C
###.#
-4.692
0.951
9.326
16.429
14.873
19.511
21.976
21.605
18.483
15.565
14.920
0.545

NOTE: THE VALUES FOR BASEMENT LOSS ARE 0.0 IN THIS CASE BECAUSE THE SUBFLOOR IS OF SLAB-ON-GRADE CONSTRUCTION

Basement Loss
Bloss
GJ
###.#
.000001055
0.000000E+00
0.000000E+00
0.000000E+00
0.000000E+00
0.000000E+00
0.000000E+00
0.000000E+00
0.000000E+00

0.000000E+00
0.000000E+00
0.000000E+00
0.000000E+00

Solar Util Factors
SolUF
%
###.#
100
0.967
0.954
0.931
0.886
0.000
0.000
0.000
0.000
0.000
0.000
0.926
0.968

NOTE: Solar Utilization factors are not calculated for cooling months.

Available Solar Gain
AvSol
GJ
###.#
.000002532
122061
117787
123818
89093.5
67233.4
76527.7
63625.9
82736.1
83229.8
106525
80573.1
101427

Appendix G-2

Sample Listing of the Related Data.Pri;n file

Sample Listing of the Related Data.Pri File

RBEAP ENERGY DATA

Occupants Name: LIFE

House Name: Case 2

House Area (sqm): 109.0000

House Volume (cum): 266.0000

City: OTTAWA

Latitude (deg): 45.0000

Altitude (meters): 125.0000

Azimuth (deg): 0.0000

Solar Storage Factor (unitless): 0.2200

Thermal Time constant (hr): 13.8148

Free Heat (W): 670.442

Moisture (Kg/day): 1.9835

Building Load Coefficient (W/C): Yearly / Heating / cooling:

80.3856 87.2869 72.8903

Conduction Coefficient (W/C): Total / Ceiling / Floor:

56.56 12.18 0.00

Leakage Area (sqcm): Total / Ceiling / Floor:

322.58 161.29 129.032

North/East/South/West Horizontal December Solar Access (%):

100.000 100.000 83.5427 100.000 100.000

North/East/South/West Horizontal June Solar Access(%):

100.0000	100.0000	44.2521	100.0000	100.0000

North/East/South/West Horizontal heating season SA (sqm):

2.5794	0.1211	8.1888	0.1021	0.541

North/East/South/West Horizontal cooling season SA (sqm):

2.5794	0.1211	8.1888	0.1021	0.541

Heating Day/night thermostats (deg C) Cooling day/night thermostats:

21.0000	21.0000	26.0000	26.0000

Yearly Electric Cons.(KWh)/COst ($) -- Yearly other fuel Cons.(GJ)/Cost ($):

3681.76	165.6790	68.7318	364.1970

Appendix H

Variable List for the Energy Calculation Program, CEGY.FOR

The following is a list of variables that appear in the Energy Calculation Program, CEGY.FOR. The units are the ones used in actual program calculations. The variables are converted to SI units before finally appearing in HOUSE.LOD and 'Graph Data' (Tabular Display).

Real Variables:

Name	Description
tempav(12)	Average Daily Temperature (deg F)
tend(2,2)	Heating/cooling end temperatures (deg F)
tavg(2,2)	Heating/cooling average temperatures.(deg F)
sol_gain(12)	Average daily solar gain from Solar apertures and fluxes (Btu/day)
qinfil(12)	Infiltration (ft^3/min)
efftemp(2,12)	Monthly day/night effective temperatures. (deg F)
blc(12)	Monthly building load coefficients. (Btu/hr-F)
dd(2,12)	Monthly degree days/nights
ld(2,12)	Monthly loads day/Night. (Btu)
plr(2,12)	Part load ratio for systems
energy(2,12)	The value that appears in Spegy (Btu)
phi3(2,12)	The fraction of the 'On-time' for HVAC systems.
store_max(2)	Amount of heat stored/released
rfossuse(12)	Fossil use (wood, oil, gas etc) (Btu)
relecuse(12)	Electric use (Btu)
lcr(12)	Load collector ratio.
slr(12)	Solar load ratio.

ssf(12)	Active solar arrays.
fchart_heat(12)	Active solar arrays
fchart_watr(12)	Active solar arrays.
del_humidity_ratio_in(2)	Indoor humidity ratio change.
taul2	Thermal time constant. (hr)
ell2	Temperature drop parameter as a function of taul2.
me	Mass flow through cooling unit. (lb)
ihc	heating/cooling section flag
sun_fact	Modified solar storage factor.

Appendix I

Variable List for

The Plotting Program

.GRAPH HOUSE.FOR

The following is a list of variables used in the plotting program, GRAPH HOUSE.FOR.

Integer Variables

NAME	DESCRIPTION
Pastebd	Pasteboard Identifier.
Main	Display Identifier for main display
dis_insert	Display identifier for 'insert column' window.
dis_long	Display Identifier for 'Long Names' window.
dis_data(100)	Display identifier for data item display.
dis_message	Display Identifier for messages.
saved_dis	Display Identifier for saved display when graphing.
cur_pos	Cursor position on screen.
old_cur_pos	Old cursor position.
Col(8)	Data displays to be pasted. Eight columns for each screen display.
oldcol(8)	Data display to be unpasted.
graph_num(4)	Number of variables to be bar graphed
num_files	Number of files in House.Lod

Character Variables

Name	Description
short(100)	Short names of data items.
Long(100)	Long names of data items
unit(100)	Units of data items.
form(100)	Format code for data items.

cur_type(5)	Rendition of scrolling cursor. Reverse, Bold, Underline, Blink or combinations.
pos_ans_list	Possible answer list.
formula	Character string to hold formula.
Months	Character data for name of months.

Appendix J-1

CIRA Input Listings for the Passive Solar Ranch House (Case 1)

Current answers for GENERAL named Casel:

```
A ) NAME of this house...................? 'Casel'
B ) What CITY............................? 'Portland MN' OTTAWA
C ) AZIMUTH of north face (degrees).......? '0' degrees
D ) What type of THERMOSTAT...............? 'Dual heating & cooling'
E ) Heating THERMOSTAT setting (degF).....? '70' degF
F ) Heating NIGHT setting (degF)..........? '70' degF
G ) Cooling THERMOSTAT setting (degF).....? '80' degF
H ) Cooling NIGHT setting (degF)..........? '80' degF
I ) Total house FLOOR AREA (sqft).........? '1176' sqft
J ) House MASS............................? 'Light'
K ) Solar STORAGE factor (unitless).......? '.22' unitless
L ) SPECIFIC THERMAL MASS (Btu/Fsqft).....? '1.79' Btu/Fsqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

Which menu ITEM(S)...................?

Current answers for WALLS named Front:

```
A ) NAME for the following walls..........? 'Front'
B ) Which wall ORIENTATION................? 'South walls'
C ) Wall TYPE.............................? 'Two by Four Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (inches).........? '4' inches
F ) INSULATABLE wall THICKNESS (inches)...? '0' inches
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (F-sqft/Btuh)............? '13' F-sqft/Btuh
I ) Wall AREA wo/ windows & doors (sqft)..? '173.14' sqft
J ) No. of WINDOWS (No.)..................? '7' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqin/sqft).....? '.048483' sqin/sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

Which menu ITEM(S)...................?

```
Current answers for WALLS named Right:

A ) NAME for the following walls..........? 'Right'
B ) Which wall ORIENTATION................? 'East walls'
C ) Wall TYPE.............................? 'Two by Four Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (inches).........? '4' inches
F ) INSULATABLE wall THICKNESS (inches)...? '0' inches
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (F-sqft/Btuh)............? '13' F-sqft/Btuh
I ) Wall AREA wo/ windows & doors (sqft)..? '224' sqft
J ) No. of WINDOWS (No.)..................? '0' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqin/sqft).....? '.0154378' sqin/sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for WALLS named Rear:

A ) NAME for the following walls..........? 'Rear'
B ) Which wall ORIENTATION................? 'North walls'
C ) Wall TYPE.............................? 'Two by Four Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (inches).........? '4' inches
F ) INSULATABLE wall THICKNESS (inches)...? '0' inches
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (F-sqft/Btuh)............? '13' F-sqft/Btuh
I ) Wall AREA wo/ windows & doors (sqft)..? '293.28' sqft
J ) No. of WINDOWS (No.)..................? '4' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqin/sqft).....? '.0245452' sqin/sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for WALLS named Left:

A ) NAME for the following walls..........? 'Left'
B ) Which wall ORIENTATION................? 'West walls'
C ) Wall TYPE.............................? 'Two by Four Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (inches).........? '4' inches
F ) INSULATABLE wall THICKNESS (inches)...? '0' inches
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (F-sqft/Btuh)............? '13' F-sqft/Btuh
I ) Wall AREA wo/ windows & doors (sqft)..? '224' sqft
J ) No. of WINDOWS (No.).................? '0' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqin/sqft).....? '.0154378' sqin/sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)...................?
```

```
Current answers for WINDOWS named Front:

A ) NAME of the following windows.........? 'Front'
B ) Which window ORIENTATION..............? 'South'
C ) Window TYPE...........................? 'Double hung'
D ) GLAZING...............................? 'Double pane'
E ) DRAPES & SHUTTERS.....................? 'None'
F ) U-value (Btuh/sqft/F).................? '.48' Btuh/sqft/F
G ) Average sash FIT......................? 'Average'
H ) Specific LEAKAGE AREA (sqin/sqft).....? '.0790502' sqin/sqft
I ) Summer SOLAR GAIN factor (%)..........? '71' %
J ) Winter SOLAR GAIN factor (%)..........? '71' %
K ) Window AREA (sqft)....................? '82.82' sqft
L ) Overhang PROTRUSION (inches)..........? '42' inches
M ) HEIGHT above top of window (inches)...? '2.76' inches
N ) Average window HEIGHT (feet)..........? '5.17' feet
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)...................?
```

```
Current answers for WINDOWS named Slid:

A ) NAME of the following windows.........? 'Slid'
B ) Which window ORIENTATION..............? 'South'
C ) Window TYPE...........................? 'Horizontal Sliding'
D ) GLAZING...............................? 'Double pane'
E ) DRAPES & SHUTTERS.....................? 'None'
F ) U-value (Btuh/sqft/F).................? '.48' Btuh/sqft/F
G ) Average sash FIT......................? 'Average'
H ) Specific LEAKAGE AREA (sqin/sqft).....? '4.650011E-02' sqin/sqft
I ) Summer SOLAR GAIN factor (%)..........? '71' %
J ) Winter SOLAR GAIN factor (%)..........? '71' %
K ) Window AREA (sqft)....................? '60.03' sqft
L ) Overhang PROTRUSION (inches)..........? '42' inches
M ) HEIGHT above top of window (inches)...? '13.5' inches
N ) Average window HEIGHT (feet)..........? '6.67' feet
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)...................?
```

```
Current answers for WINDOWS named Rear:

A ) NAME of the following windows.........? 'Rear'
B ) Which window ORIENTATION..............? 'North'
C ) Window TYPE...........................? 'Double hung'
D ) GLAZING...............................? 'Double pane'
E ) DRAPES & SHUTTERS.....................? 'None'
F ) U-value (Btuh/sqft/F).................? '.48' Btuh/sqft/F
G ) Average sash FIT......................? 'Average'
H ) Specific LEAKAGE AREA (sqin/sqft).....? '.0790502' sqin/sqft
I ) Summer SOLAR GAIN factor (%)..........? '71' %
J ) Winter SOLAR GAIN factor (%)..........? '71' %
K ) Window AREA (sqft)....................? '42.72' sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)...................?
```

```
Current answers for DOORS named Front:

A ) NAME of the following doors...........? 'Front'
B ) Door TYPE.............................? 'Plain (Hinged)'
C ) Door MATERIAL.........................? 'Wood Solid Core'
D ) Approximate glass AREA (%)............? '0' %
E ) Any STORM doors.......................? 'None'
F ) U-value (Btuh/sqft/F).................? '.4' Btuh/sqft/F
G ) Door FIT..............................? 'Average'
H ) Specific leakage AREA (sqin/sqft).....? '.0294501' sqin/sqft
I ) Door AREA (sqft)......................? '20' sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for ROOF-CEI named Attic:

A ) NAME for attic/roof or ceiling........? 'Attic'
B ) Roof-Ceiling TYPE.....................? 'Unfinished attic'
C ) Insulation TYPE.......................? 'Fiberglass batts'
D ) Insulation THICKNESS (inches).........? '6' inches
E ) Insulatable AIR SPACE (inches)........? '0' inches
F ) Ceiling R-value (F-sqft/Btuh).........? '25' F-sqft/Btuh
G ) Ceiling AREA (sqft)...................? '1176' sqft
H ) No. of ceiling VENTS (count)..........? '5' count
I ) No. of ceiling PENETRATIONS (count)...? '10' count
J ) Ceiling sp. LEAKAGE area (sqin/sqft)..? '4.088539E-02' sqin/sqft
K ) Roof PITCH (%)........................? '22.62' %
L ) Roof top MATERIAL.....................? 'Asphalt Shingles'
M ) Roof ABSORPTIVITY (%).................? '95' %
N ) Attic VENTILATION (cfm/sqft)..........? '.5' cfm/sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for SUBFLOOR named Slab:

A ) Subfloor NAME..........................? 'Slab'
B ) Subfloor TYPE..........................? 'Slab-on-grade'
C ) Floor AREA (Joists) (sqft).............? '20' sqft
D ) Exposed PERIMETER (feet)...............? '140' feet
E ) Soil CONDUCTIVITY (Btuh-in/F-sqft).....? '2.5' Btuh-in/F-sqft
F ) Floor R-VALUE (F-sqft/Btuh)............? '40' F-sqft/Btuh
G ) Eqv Floor RESIST' outs'd (F-sqft/Btuh)? '100' F-sqft/Btuh
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for ECONOMIC named Price & Use:

A ) Economic HORIZON (years)..............? '20' years
B ) REAL DISCOUNT rate (%)................? '3' %
C ) REPLACEMENT-RETROFIT esc. rate (%)....? '4' %
D ) Maximum INVESTMENT ($)................? '2000' $
E ) NON-ELECTRIC fuel.....................? 'Gas'
F ) GAS price ($/Therm)...................? '.559' $/Therm
G ) GAS escalation rate (%)...............? '2.8' %
H ) YEARLY Gas use (Therms)...............? '960' Therms
I ) Gas BASE use (Therms/Mo)..............? '48.33333' Therms/Mo
J ) ELECTRICITY price ($/kwh).............? '.0449999' $/kwh
K ) ELECTRICITY escalation rate (%).......? '1.5' %
L ) YEARLY Electricity use (kWh)..........? '13500' kWh
M ) Electricity BASE use (kWh/Mo).........? '325.7387' kWh/Mo
N ) ADJUST results to ACTUAL use..........? 'No'
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for INFILTRA named Ventilation:

A ) Is there MECHANICAL Ventilation.......? 'None'
B ) NATURAL Cooling Ventilation...........? 'No'
C ) TERRAIN class.........................? 'Class 3'
D ) SHIELDING class.......................? 'Class 3'
E ) HEIGHT of living space (feet).........? '8' feet
F ) Approx. house VOLUME (cubic feet).....? '9408' cubic feet
G ) HOW was leakage area MEASURED.........? 'All three measured'
H ) TOTAL leakage area (sqin).............? '117' sqin
I ) CEILING leakage area (sqin)...........? '61.00011' sqin
J ) FLOOR leakage area (sqin).............? '48.99991' sqin
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...


Which menu ITEM(S)...................?
```

```
Current answers for LANDSCAP named Yard & Trees:

A ) Ground SURFACE TYPE...................? 'Green grass'
B ) Ground REFLECTANCE (%)................? '24' %
C ) SOUTH solar EXPOSURE - DECEMBER (%)...? '100' %
D ) SOUTH solar EXPOSURE - JUNE (%).......? '100' %
E ) EAST solar EXPOSURE - DECEMBER (%)....? '100' %
F ) EAST solar EXPOSURE - JUNE (%)........? '100' %
G ) WEST solar EXPOSURE - DECEMBER (%)....? '100' %
H ) WEST solar EXPOSURE - JUNE (%)........? '100' %
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...


Which menu ITEM(S)...................?
```

```
Current answers for APPLIANC named Life:

A ) NAME of occupants....................? 'Life'
B ) How many DAYTIME OCCUPANTS (people)...? '1' people
C ) How many NIGHT OCCUPANTS (people).....? '2' people
D ) DAILY hot water USE (gal/day).........? '75' gal/day
E ) WATER HEATER type....................? 'Gas'
F ) Input RATING (kBtu/hr)................? '40' kBtu/hr
G ) Hot water THERMOSTAT setting (degF)...? '140' degF
H ) WHERE is water heater.................? 'Living space'
I ) Stdby/plumb. LOSSES (kBtu/hr).........? '.95' kBtu/hr
J ) REFRIGERATOR type.....................? 'Man. defrost & sep. freezer'
K ) Average MONTHLY CONSUMPTION (kWh/mo)..? '65' kWh/mo
L ) DRYER and RANGE type..................? 'Both Electric'
M ) Internal MOISTURE generation (lb/dy)..? '4.360011' lb/dy
N ) LIGHTS & OTHER HEAT GAINS (kBtu/hr)...? '.1' kBtu/hr
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)...................?
```

```
Current answers for HVAC-SYS named Heat-Cool:

A ) What HEATING EQUIPMENT................? 'Gas Furnace'
B ) Rated INPUT capacity (kBtu/hr)........? '50' kBtu/hr
C ) Steady-state EFFICIENCY (%)...........? '75' %
D ) FLUE gas temperature (degF)...........? '250' degF
E ) What DISTRIBUTION system..............? 'Forced Air'
F ) WHERE are pipes or ducts..............? 'Living Space'
G ) INSULATION on pipes or ducts..........? 'None'
H ) Insulatable duct/pipe LENGTH (feet)...? '50' feet
I ) Distribution LOSSES to outside (%)....? '5' %
J ) What COOLING EQUIPMENT................? 'Central Air Conditioning'
K ) Rated TOTAL capacity (kBtu/hr)........? '24' kBtu/hr
L ) Rated SENSIBLE capacity (kBtu/hr).....? '16' kBtu/hr
M ) Rated COP (unitless)..................? '2' unitless
N ) Actual Fan FLOW (cfm).................? '700' cfm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)...................?
```

Appendix J-2

RBEAP Input listings for the

Passive Solar Ranch house (Case 1)

Since the Passive Solar Ranch house is of slab-on-grade construction, the input data for RBEAP is quite similar to CIRA except for two additional questions asked under 'GENERAL' component. These are:

1) Indoor temperatue swing......... 0.0 or 2.75 or 5.5
2) Floor slab thickness............127 mm.

Various construction levels and indoor temperature swings may be modelled using this input data.

Appendix J-3

CIRA Input listings for the Passive Solar Ranch house (Case 2)

The same input data as in Appendix J-1 with the following changes.

WALLS

Wall R-value: 5.639 K-Sqm/W

ROOF

Ceiling R-value: 8.811 K-sqm/W

WINDOWS:

All windows are triple glazed

U-value: 1.6456 W/sqm-K

Summer Solar gain factor: 61%

Winter Solar Gain factor: 61%

INFILTRATION

Total Leakage area : 322.58 cm^2

Ceiling leakage area : 161.29 cm^2

Floor Leakage area : 129.03 cm^2

NOTE: The same input is used to model houses of varying construction. Only the response to the 'House Mass...' question would have to be changed from 'Light' to 'Medium' or 'Heavy' as desired. Also, various indoor temperature swings can be modelled.

Appendix J-4

RBEAP Input Listings for the

Passive Solar Ranch House (Case 2)

The same input data as in Appendix J-1 with the following changes.

WALLS

Wall R-value: 5.639 K-Sqm/W

ROOF

Ceiling R-value: 8.811 K-sqm/W

WINDOWS:

All windows are triple glazed

U-value: 1.6456 W/sqm-K

Summer Solar gain factor: 61%

Winter Solar Gain factor: 61%

INFILTRATION

Total Leakage area : 322.58 cm^2

Ceiling leakage area : 161.29 cm^2

Floor Leakage area : 129.03 cm^2

Also two additional questions will be asked under 'GENERAL'. These are:

1) Indoor temperature swing........0.0 or 2.75 or 5.5 deg C

2) Floor Slab thickness...........127 mm.

NOTE: The same input is used to model houses of varying construction. Only the response to the 'House Mass...' question would have to be changed from 'Light' to 'Medium' or 'Heavy' as desired. Also different temperature swings could be modelled by choosing either 0.0 or 2.75 or 5.5 deg C.

Appendix K-1

Comparison of Available and Useful Solar Gains and free heats in

CIRA, RBEAP and DOE 2.1A

Table: K-1-1 Case 1

Comparison of Solar Gains

MONTH	CIRA (GJ) Avl.	CIRA (GJ) Use.	RBEAP (GJ) Avl.	RBEAP (GJ) Use.	DOE 2.1A (GJ) Avl.	DOE 2.1A (GJ) Use.
JAN	3.09	3.09	3.09	2.78	3.08	3.08
FEB	3.08	3.08	3.08	2.59	2.99	2.94
MAR	3.31	3.31	3.31	2.54	3.27	2.86
APR	2.33	2.33	2.33	1.57	2.26	1.49
MAY	1.69	1.69	1.69	0.93	1.53	0.52
OCT	2.71	2.71	2.71	1.69	2.24	1.09
NOV	1.83	1.83	1.83	1.64	2.11	1.79
DEC	2.43	2.43	2.43	2.28	2.53	2.48
TOTAL	20.47	20.47	20.47	16.02	19.92	16.25

Table: K-1-2 Case 2

Comparison of Solar Gains

MONTH	CIRA (GJ) Avl.	CIRA (GJ) Use.	RBEAP (GJ) Avl.	RBEAP (GJ) Use.	DOE 2.1A (GJ) Avl.	DOE 2.1A (GJ) Use.
JAN	3.22	3.22	3.22	2.49	3.44	2.86
FEB	3.12	3.12	3.12	2.29	3.24	2.44
MAR	3.24	3.24	3.24	2.18	3.23	2.03
APR	2.23	2.23	2.23	1.28	2.20	0.91
MAY	1.58	1.58	1.58	0.60	1.43	0.24
OCT	2.77	2.77	2.77	0.99	2.38	0.53
NOV	2.01	2.01	2.01	1.37	2.37	1.24
DEC	2.61	2.61	2.61	2.05	2.84	2.27
TOTAL	20.78	20.78	20.78	14.12	21.13	12.12

Table: K-1-3 Case 1

Comparison of Free Heats

MONTH	CIRA (GJ) Avl.	CIRA (GJ) Use.	RBEAP (GJ) Avl.	RBEAP (GJ) Use.	DOE 2.1A (GJ) Avl.	DOE 2.1A (GJ) Use.
JAN	4.65	4.65	4.65	4.34	4.65	4.65
FEB	4.49	4.49	4.49	4.00	4.41	4.36
MAR	4.87	4.87	4.87	4.10	4.75	4.42
APR	3.84	3.84	3.84	3.08	3.78	2.87
MAY	3.25	3.25	3.25	2.49	3.10	1.69
OCT	4.27	4.27	4.27	3.25	3.81	2.52
NOV	3.33	3.33	3.33	3.15	3.62	3.31
DEC	3.99	3.99	3.99	3.84	4.09	4.05
TOTAL	32.69	32.69	32.69	28.25	32.21	27.87

Table: K-1-4 Case 2

Comparison of Free Heats

MONTH	CIRA (GJ) Avl.	CIRA (GJ) Use.	RBEAP (GJ) Avl.	RBEAP (GJ) Use.	DOE 2.1A (GJ) Avl.	DOE 2.1A (GJ) Use.
JAN	4.91	4.91	4.91	4.18	5.08	4.49
FEB	4.65	4.65	4.65	3.82	4.72	3.91
MAR	4.94	4.94	4.94	3.87	4.87	3.67
APR	3.86	3.86	3.86	2.92	3.78	2.32
MAY	3.27	3.27	3.27	2.21	3.07	1.25
OCT	4.46	4.46	4.46	2.62	4.02	1.75
NOV	3.65	3.65	3.65	3.00	3.95	2.81
DEC	4.29	4.29	4.29	3.97	4.48	3.85
TOTAL	34.03	34.03	34.03	26.59	33.97	21.05

Appendix K-2

Comparison of Heating Loads between

CIRA, RBEAP and DOE 2.1 A for

Case 1 and Case 2

Indoor Temperature Swing is 0.0 deg C

Thermostat 70/70

Mass levels: Light, Medium and Heavy

Table:K-2-1 CASE 1 LIGHT 70/70

MONTH	CIRA GJ	RBEAP GJ	DOE 2.1A GJ	VAR C/D %	VAR R/D %
JAN	13.61	14.12	14.61	-6.84	-3.35
FEB	9.91	10.60	11.00	-9.91	-3.64
MAR	7.07	7.85	7.65	-7.58	+2.61
APR	3.17	3.83	3.96	-19.95	-3.28
MAY	1.27	1.66	1.66	-23.49	0.00
OCT	1.48	2.13	2.26	-34.43	-5.63
NOV	4.66	5.13	4.89	-4.80	+4.80
DEC	11.81	12.35	12.81	-7.81	-3.59
TOTAL	53.15	57.67	58.27	-8.79	-1.03

Table:K-2-2 CASE 2 LIGHT 70/70

MONTH	CIRA GJ	RBEAP GJ	DOE 2.1A GJ	VAR C/D %	VAR R/D %
JAN	4.33	4.94	5.06	-14.49	-2.45
FEB	2.88	3.49	3.65	-21.05	-4.41
MAR	1.79	2.37	2.36	-24.33	+0.38
APR	0.72	1.02	1.13	-36.17	-9.57
MAY	0.00	0.34	0.38	-100.00	-10.53
OCT	0.00	0.50	0.55	-100.00	-9.09
NOV	0.96	1.33	1.40	-31.58	-5.56
DEC	3.75	4.24	4.40	-14.79	-3.75
TOTAL	14.43	18.22	18.94	-23.81	-3.79

Table:K-2-3 CASE 1 MEDIUM 70/70

MONTH	CIRA	RBEAP	DOE 2.1A	VAR C/D	VAR R/D
	GJ	GJ	GJ	%	%
JAN	13.67	13.83	14.20	-3.73	-2.61
FEB	10.02	10.35	10.65	-5.92	-2.82
MAR	6.45	7.28	7.27	-11.28	+0.14
APR	3.10	3.65	3.70	-16.22	-1.35
MAY	1.24	1.46	1.49	-16.78	-2.01
OCT	1.38	1.96	2.01	-31.34	-2.49
NOV	4.38	4.51	4.63	-5.40	-2.59
DEC	12.11	12.14	12.41	-2.42	-2.18
TOTAL	52.35	55.18	56.36	-7.11	-2.09

Table:K-2-4 CASE 2 MEDIUM 70/70

MONTH	CIRA	RBEAP	DOE 2.1A	VAR C/D	VAR R/D
	GJ	GJ	GJ	%	%
JAN	4.19	4.59	4.82	-13.07	-4.77
FEB	2.66	3.54	3.72	-28.49	-4.84
MAR	1.42	2.01	2.17	-34.56	-7.37
APR	0.52	0.91	1.03	-49.51	-11.65
MAY	0.00	0.29	0.33	-100.00	-12.12
OCT	0.00	0.41	0.47	-100.00	-12.77
NOV	0.77	1.18	1.27	-39.37	-7.09
DEC	3.66	4.09	4.28	-14.49	-4.44
TOTAL	13.22	17.02	18.09	-26.92	-5.91

Table:K-2-5 CASE 1 HEAVY 70/70

MONTH	CIRA GJ	RBEAP GJ	DOE 2.1A GJ	VAR C/D %	VAR R/D %
JAN	13.84	14.12	14.50	-4.55	-2.62
FEB	10.08	10.59	10.87	-7.72	-2.58
MAR	6.42	7.22	7.37	-12.89	-2.04
APR	3.06	3.34	3.66	-16.39	-8.74
MAY	1.09	1.32	1.39	-21.58	-5.04
OCT	1.20	1.77	1.90	-36.84	-6.84
NOV	4.55	4.61	4.69	-2.99	-1.71
DEC	12.11	12.32	12.64	-4.19	-2.53
TOTAL	52.35	55.29	57.02	-8.19	-3.03

Table:K-2-6 CASE 2 HEAVY 70/70

MONTH	CIRA GJ	RBEAP GJ	DOE 2.1A GJ	VAR C/D %	VAR R/D %
JAN	4.16	4.53	4.74	-12.24	-4.43
FEB	2.58	3.04	3.30	-21.82	-7.88
MAR	1.23	1.88	2.01	-38.81	-6.47
APR	0.35	0.84	0.93	-62.37	-9.68
MAY	0.00	0.00	0.29	-100.00	-100.00
OCT	0.00	0.33	0.37	-100.00	- 10.81
NOV	0.67	1.07	1.15	-41.65	-6.96
DEC	3.64	4.10	4.22	-13.74	-2.84
TOTAL	12.63	15.79	17.01	-25.74	-7.17

Appendix K-3

Comparison of Heating Load between RBEAP and DOE 2.1A

Temperature swings of 2.75 and 5.5 deg C

Mass Levels: Light, Medium and Heavy

Table:K-3-1 CASE 1 LIGHT 70/75

MONTH	RBEAP GJ	DOE 2.1A GJ	VARIATION %
JAN	14.09	14.61	-3.60
FEB	10.53	10.98	-4.10
MAR	7.61	7.54	+0.90
APR	3.82	3.80	+0.52
MAY	1.44	1.47	-2.04
OCT	1.93	2.05	-5.85
NOV	4.70	4.80	-2.08
DEC	12.74	12.80	-0.50
TOTAL	56.86	58.06	-2.06

Table:K-3-2 CASE 1 LIGHT 70/80

MONTH	RBEAP GJ	DOE 2.1A GJ	VARIATION %
JAN	14.11	14.61	-3.42
FEB	10.56	10.97	-3.73
MAR	7.33	7.51	-2.30
APR	3.62	3.72	-2.70
MAY	1.36	1.39	-2.16
OCT	1.84	1.96	-6.12
NOV	4.67	4.77	-2.09
DEC	12.67	12.79	-0.90
TOTAL	56.16	57.72	-2.66

Table:K-3-3 CASE 1 MEDIUM 70/75

MONTH	RBEAP GJ	DOE 2.1A GJ	VARIATION %
JAN	13.61	14.20	-4.15
FEB	10.24	10.63	-3.67
MAR	7.14	7.17	-0.42
APR	3.23	3.50	-7.71
MAY	1.14	1.25	-8.80
OCT	1.62	1.76	-7.95
NOV	4.43	4.52	-1.99
DEC	12.10	12.39	-2.34
TOTAL	53.51	55.42	-3.45

Table:K-3-4 CASE 1 MEDIUM 70/80

MONTH	RBEAP GJ	DOE 2.1A GJ	VARIATION %
JAN	13.66	14.20	-3.80
FEB	9.99	10.63	-6.07
MAR	7.12	7.15	-0.42
APR	3.18	3.43	-7.29
MAY	1.07	1.17	-8.55
OCT	1.53	1.68	-8.93
NOV	4.41	4.49	-1.78
DEC	11.92	12.39	-3.79
TOTAL	52.88	55.14	-4.11

Table:K-3-5 CASE 1 HEAVY 70/75

MONTH	RBEAP GJ	DOE 2.1A GJ	VARIATION %
JAN	13.74	14.50	-5.24
FEB	10.17	10.86	-6.35
MAR	7.10	7.31	-2.87
APR	3.25	3.46	-6.07
MAY	1.03	1.12	-8.04
OCT	1.47	1.63	-10.04
NOV	4.37	4.57	-4.38
DEC	12.16	12.63	-3.72
TOTAL	53.29	56.08	-4.98

Table:K-3-6 CASE 1 HEAVY 70/80

MONTH	RBEAP GJ	DOE 2.1A GJ	VARIATION %
JAN	12.35	12.56	-1.67
FEB	10.22	10.87	-5.98
MAR	7.03	7.31	-3.83
APR	3.16	3.45	-8.41
MAY	0.94	1.05	-10.48
OCT	1.44	1.59	-9.43
NOV	4.39	4.58	-4.15
DEC	12.11	12.63	-4.12
TOTAL	51.64	54.04	-4.44

Table:K-3-7 CASE 2 LIGHT 70/75

MONTH	RBEAP GJ	DOE 2.1A GJ	VARIATION %
JAN	4.73	4.83	-2.07
FEB	3.31	3.40	-2.65
MAR	1.95	2.07	-5.80
APR	0.79	0.88	-10.23
MAY	0.00	0.18	-100.00
OCT	0.24	0.28	-14.29
NOV	1.04	1.11	-6.31
DEC	4.11	4.30	-4.42
TOTAL	16.17	17.05	-5.16

Table:K-3-8 CASE 2 LIGHT 70/80

MONTH	RBEAP GJ	DOE 2.1A GJ	VARIATION %
JAN	4.59	4.72	-2.75
FEB	3.14	3.26	-3.68
MAR	1.76	1.90	-7.37
APR	0.66	0.76	-13.16
MAY	0.13	0.14	-7.14
OCT	0.00	0.16	-100.00
NOV	0.91	0.98	-7.14
DEC	4.06	4.19	-3.10
TOTAL	15.25	16.11	-5.34

Table:K-3-9 CASE 2 MEDIUM 70/75

MONTH	RBEAP GJ	DOE 2.1A GJ	VARIATION %
JAN	4.34	4.56	-4.82
FEB	3.01	3.13	-3.83
MAR	1.71	1.86	-8.06
APR	0.64	0.72	-11.11
MAY	0.00	0.12	-100.00
OCT	0.00	0.15	-100.00
NOV	0.85	0.91	-6.59
DEC	3.92	4.05	-3.21
TOTAL	14.47	15.50	-6.65

Table:K-3-10 CASE 2 MEDIUM 70/80

MONTH	RBEAP GJ	DOE 2.1A GJ	VARIATION %
JAN	4.30	4.50	-4.44
FEB	2.77	3.00	-7.67
MAR	1.50	1.61	-6.83
APR	0.53	0.60	-11.67
MAY	0.10	0.10	0.00
OCT	0.00	0.06	-100.00
NOV	0.74	0.79	-6.23
DEC	3.87	3.97	-2.52
TOTAL	13.81	14.63	-5.59

Table:K-3-11 CASE 2 HEAVY 70/75

MONTH	RBEAP GJ	DOE 2.1A GJ	VARIATION %
JAN	4.33	4.56	-4.99
FEB	2.73	3.01	-9.30
MAR	1.43	1.59	-10.06
APR	0.52	0.59	-11.86
MAY	0.00	0.09	-100.00
OCT	0.00	0.06	-100.00
NOV	0.66	0.77	-14.29
DEC	3.88	4.01	-3.24
TOTAL	13.55	14.67	-7.63

Table:K-3-12 CASE 2 HEAVY 70/80

MONTH	RBEAP GJ	DOE 2.1A GJ	VARIATION %
JAN	4.28	4.54	-5.73
FEB	2.77	2.96	-6.42
MAR	1.32	1.48	-10.81
APR	0.43	0.51	-15.69
MAY	0.00	0.07	-100.00
OCT	0.00	0.01	-100.00
NOV	0.60	0.69	-13.04
DEC	3.84	3.98	-3.52
TOTAL	13.24	14.24	-7.00

Appendix L-1

CIRA Input listings for the

'Villages of Riverside' house

(With and Without Basement wall insulation)

```
Current answers for GENERAL named V of RI:

A ) NAME of this house....................? 'V of RI'
B ) What CITY.............................? 'Detroit Mich'
C ) AZIMUTH of north face (degrees).......? '0' degrees
D ) What type of THERMOSTAT...............? 'Heating only'
E ) Heating THERMOSTAT setting (degF).....? '70' degF
F ) Heating NIGHT setting (degF)..........? '70' degF
G ) Avg Indoor SUMMER temperature (degF)..? '78' degF
H ) Total house FLOOR AREA (sqft).........? '1443' sqft
I ) House MASS............................? 'Light'
J ) Solar STORAGE factor (unitless).......? '.22' unitless
K ) SPECIFIC THERMAL MASS (Btu/Fsqft).....? '1.9' Btu/Fsqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...


Which menu ITEM(S)...................?
```

```
Current answers for WALLS named Front:

A ) NAME for the following walls..........? 'Front'
B ) Which wall ORIENTATION................? 'South walls'
C ) Wall TYPE.............................? 'Two by Four Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (inches).........? '3.5' inches
F ) INSULATABLE wall THICKNESS (inches)...? '0' inches
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (F-sqft/Btuh)............? '11' F-sqft/Btuh
I ) Wall AREA wo/ windows & doors (sqft)..? '323.46' sqft
J ) No. of WINDOWS (No.)..................? '1' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqin/sqft).....? '.0158623' sqin/sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...


Which menu ITEM(S)...................?
```

```
Current answers for WALLS named Rear:

A ) NAME for the following walls..........? 'Rear'
B ) Which wall ORIENTATION................? 'North walls'
C ) Wall TYPE.............................? 'Two by Four Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (inches).........? '3.5' inches
F ) INSULATABLE wall THICKNESS (inches)...? '0' inches
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (F-sqft/Btuh)............? '11' F-sqft/Btuh
I ) Wall AREA wo/ windows & doors (sqft)..? '276' sqft
J ) No. of WINDOWS (No.)..................? '1' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqin/sqft).....? '.0174103' sqin/sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for WALLS named Right:

A ) NAME for the following walls..........? 'Right'
B ) Which wall ORIENTATION................? 'East walls'
C ) Wall TYPE.............................? 'Two by Four Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (inches).........? '3.5' inches
F ) INSULATABLE wall THICKNESS (inches)...? '0' inches
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (F-sqft/Btuh)............? '11' F-sqft/Btuh
I ) Wall AREA wo/ windows & doors (sqft)..? '260.93' sqft
J ) No. of WINDOWS (No.)..................? '0' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqin/sqft).....? '.0150394' sqin/sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for WALLS named Left:

A ) NAME for the following walls..........? 'Left'
B ) Which wall ORIENTATION................? 'West walls'
C ) Wall TYPE.............................? 'Two by Four Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (inches).........? '3.5' inches
F ) INSULATABLE wall THICKNESS (inches)...? '0' inches
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (F-sqft/Btuh)............? '11' F-sqft/Btuh
I ) Wall AREA wo/ windows & doors (sqft)..? '167.22' sqft
J ) No. of WINDOWS (No.)..................? '1' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqin/sqft).....? '.0262936' sqin/sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for WINDOWS named Front:

A ) NAME of the following windows.........? 'Front'
B ) Which window ORIENTATION..............? 'South'
C ) Window TYPE...........................? 'Double hung'
D ) GLAZING...............................? 'Double pane'
E ) DRAPES & SHUTTERS.....................? 'Shades or Blinds'
F ) Are window covers USED at DAYtime.....? 'No'
G ) U-value (Btuh/sqft/F).................? '.519443' Btuh/sqft/F
H ) Average sash FIT......................? 'Average'
I ) Specific LEAKAGE AREA (sqin/sqft).....? '.0790502' sqin/sqft
J ) Summer SOLAR GAIN factor (%)..........? '77' %
K ) Winter SOLAR GAIN factor (%)..........? '77' %
L ) Window AREA (sqft)....................? '9.45' sqft
M ) Overhang PROTRUSION (inches)..........? '0' inches
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for WINDOWS named Left:

 A ) NAME of the following windows.........? 'Left'
 B ) Which window ORIENTATION..............? 'West'
 C ) Window TYPE...........................? 'Double hung'
 D ) GLAZING...............................? 'Double pane'
 E ) DRAPES & SHUTTERS.....................? 'Shades or Blinds'
 F ) Are window covers USED at DAYtime.....? 'No'
 G ) U-value (Btuh/sqft/F).................? '.519443' Btuh/sqft/F
 H ) Average sash FIT......................? 'Average'
 I ) Specific LEAKAGE AREA (sqin/sqft).....? '.0790502' sqin/sqft
 J ) Summer SOLAR GAIN factor (%)..........? '77' %
 K ) Winter SOLAR GAIN factor (%)..........? '77' %
 L ) Window AREA (sqft)....................? '93.71' sqft
 Y) < DELETE this Component >...
 Z) < Changes COMPLETED >...

Which menu ITEM(S)......................?
```

```
Current answers for WINDOWS named Rear:

 A ) NAME of the following windows.........? 'Rear'
 B ) Which window ORIENTATION..............? 'North'
 C ) Window TYPE...........................? 'Double hung'
 D ) GLAZING...............................? 'Double pane'
 E ) DRAPES & SHUTTERS.....................? 'Shades or Blinds'
 F ) Are window covers USED at DAYtime.....? 'No'
 G ) U-value (Btuh/sqft/F).................? '.519443' Btuh/sqft/F
 H ) Average sash FIT......................? 'Average'
 I ) Specific LEAKAGE AREA (sqin/sqft).....? '.0790502' sqin/sqft
 J ) Summer SOLAR GAIN factor (%)..........? '77' %
 K ) Winter SOLAR GAIN factor (%)..........? '77' %
 L ) Window AREA (sqft)....................? '35' sqft
 Y) < DELETE this Component >...
 Z) < Changes COMPLETED >...

Which menu ITEM(S)......................?
```

1. Subfloor without basement insulation:

a) Subfloor Name....................... ? 'VRHEBASE'
b) Subfloor type....................... ? 'Basement'
c) Joist insulation.................... ? 'Heated Basement'
d) Total Joist R-value (K-sqm/W)....... ? '.9251935 K-sqm/W
e) Floor area (joists) (sqm)........... ? '44.686' sqm
f) No. of floor penetrations (No.)..... ? ' ' No.
g) Floor Sp. Lkg. area (sqmm/sqm)...... ? '315.9796' sqmm/sqm
h) Subfloor wall insulation material... ? 'None'
i) Above grade wall R-value (K-sqm/W).. ? '1.938497' K-sqm/W
j) Above grade height (M).............. ? '.03048' m
k) Exposed perimeter (m)............... ? '28.28544' m
l) Soil Conductivity (W/m-K)........... ? '1.2972' W/m-K
m) No. of Windows (No.)................ ? '0' No.
n) No. of wall vents (No.)............. ? '0' No.
o) No. of wall penetrations (No.)...... ? '0' No.
p) Wall sp. leakage area (sqmm/sqm).... ? '1159.576 sqmm/sqm
q) Below grade wall R-value (K-sqm/W).. ? '.8247423' K-sqm/W
r) Floor R-value (K-swm/W)............ ? '352454' K-sqm/W
s) Eqv Floor resist' outs'd (K-sqm/W).. ? '6.247263' K-sqm/W

2. Subfloor with Basement insulation:

The same input data as above with the following changes:

q) Below grade R-value (K-sqm/W)....... ? '1.938497' K-sqm/W

```
Current answers for DOORS named Front:

A ) NAME of the following doors...........? 'Front'
B ) Door TYPE.............................? 'Plain (Hinged)'
C ) Door MATERIAL.........................? 'Wood Solid Core'
D ) Approximate glass AREA (%)............? '0' %
E ) Any STORM doors.......................? 'None'
F ) U-value (Btuh/sqft/F).................? '.33' Btuh/sqft/F
G ) Door FIT..............................? 'Average'
H ) Specific leakage AREA (sqin/sqft).....? '.0294501' sqin/sqft
I ) Door AREA (sqft)......................? '18.09' sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...


Which menu ITEM(S)....................?
```

```
Current answers for ROOF-CEI named TOP:

A ) NAME for attic/roof or ceiling........? 'TOP'
B ) Roof-Ceiling TYPE.....................? 'Unfinished attic'
C ) Insulation TYPE.......................? 'Fiberglass batts'
D ) Insulation THICKNESS (inches).........? '6' inches
E ) Insulatable AIR SPACE (inches)........? '6' inches
F ) Ceiling R-value (F-sqft/Btuh).........? '22' F-sqft/Btuh
G ) Ceiling AREA (sqft)...................? '481' sqft
H ) No. of ceiling VENTS (count)..........? '5' count
I ) No. of ceiling PENETRATIONS (count)...? '10' count
J ) Ceiling sp. LEAKAGE area (sqin/sqft)..? '.0551685' sqin/sqft
K ) Roof PITCH (%)........................? '30' %
L ) Roof top MATERIAL.....................? 'Asphalt Shingles'
M ) Roof ABSORPTIVITY (%).................? '85' %
N ) Attic VENTILATION (cfm/sqft)..........? '.5' cfm/sqft
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for INFILTRA named Ventilation:

A ) Is there MECHANICAL Ventilation.......? 'None'
B ) NATURAL Cooling Ventilation...........? 'No'
C ) TERRAIN class.........................? 'Class 3'
D ) SHIELDING class.......................? 'Class 3'
E ) HEIGHT of living space (feet).........? '18.23' feet
F ) Approx. house VOLUME (cubic feet).....? '11385' cubic feet
G ) HOW was leakage area MEASURED.........? 'All three measured'
H ) TOTAL leakage area (sqin).............? '75' sqin
I ) CEILING leakage area (sqin)...........? '27.7754' sqin
J ) FLOOR leakage area (sqin).............? '16.12701' sqin
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)......................?
```

```
Current answers for LANDSCAP named Yard & Trees:

A ) Ground SURFACE TYPE...................? 'Green grass'
B ) Ground REFLECTANCE (%)................? '24' %
C ) SOUTH solar EXPOSURE - DECEMBER (%)...? '60' %
D ) SOUTH solar EXPOSURE - JUNE (%).......? '80' %
E ) EAST solar EXPOSURE - DECEMBER (%)....? '60' %
F ) EAST solar EXPOSURE - JUNE (%)........? '80' %
G ) WEST solar EXPOSURE - DECEMBER (%)....? '60' %
H ) WEST solar EXPOSURE - JUNE (%)........? '80' %
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)......................?
```

```
Current answers for APPLIANC named RESIDENTS:

A ) NAME of occupants....................? 'RESIDENTS'
B ) How many DAYTIME OCCUPANTS (people)...? '2' people
C ) How many NIGHT OCCUPANTS (people).....? '4' people
D ) DAILY hot water USE (gal/day).........? '75' gal/day
E ) WATER HEATER type.....................? 'Electric'
F ) Input RATING (kW).....................? '4' kW
G ) Hot water THERMOSTAT setting (degF)...? '140' degF
H ) WHERE is water heater.................? 'Living space'
I ) Stdby/plumb. LOSSES (kBtu/hr).........? '.423336' kBtu/hr
J ) REFRIGERATOR type.....................? 'Man. defrost & sep. freezer'
K ) Average MONTHLY CONSUMPTION (kWh/mo)..? '65' kWh/mo
L ) DRYER and RANGE type..................? 'Both Electric'
M ) Internal MOISTURE generation (lb/dy)..? '4.360011' lb/dy
N ) LIGHTS & OTHER HEAT GAINS (kBtu/hr)...? '1.24' kBtu/hr
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for HVAC-SYS named Heat-Cool:

A ) What HEATING EQUIPMENT................? 'Electric Baseboard'
B ) Rated INPUT capacity (kBtu/hr)........? '30' kBtu/hr
C ) Steady-state EFFICIENCY (%)...........? '100' %
D ) What DISTRIBUTION system..............? 'In Room'
E ) Distribution LOSSES to outside (%)....? '0' %
F ) What COOLING EQUIPMENT................? 'None'
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S)....................?
```

```
Current answers for ECONOMIC named Price & Use:

A ) Economic HORIZON (years)...............? '20' years
B ) REAL DISCOUNT rate (%).................? '3' %
C ) REPLACEMENT-RETROFIT esc. rate (%).....? '4' %
D ) Maximum INVESTMENT ($).................? '2000' $
E ) NON-ELECTRIC fuel......................? 'Gas'
F ) GAS price ($/Therm)....................? '.559' $/Therm
G ) GAS escalation rate (%)................? '2.8' %
H ) YEARLY Gas use (Therms)................? '960' Therms
I ) Gas BASE use (Therms/Mo)...............? '48.33333' Therms/Mo
J ) ELECTRICITY price ($/kwh)..............? '.0449999' $/kwh
K ) ELECTRICITY escalation rate (%)........? '1.5' %
L ) YEARLY Electricity use (kWh)...........? '13500' kWh
M ) Electricity BASE use (kWh/Mo)..........? '325.7387' kWh/Mo
N ) ADJUST results to ACTUAL use...........? 'No'
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...

Which menu ITEM(S).....................?
```

Appendix L-2

RBEAP Input listings for the

'Villages of Riverside House'

(With and without basement wall insulation)

The input data for all the components is the same as in Appendix L-1 except for 'SUBFLOOR' which is described below.

1. Subfloor without Basement wall insulation.

Subfloor Name	VRHEBASE	
Subfloor Type	Basement	
Soil Type...................................	Well drained clay	
Where is the Basement Insulation	Inside	
Basement Temperature	21.11111	deg C
Above grade R-value	1.938497	K-sqm/W
Above-Grade Height	0.030480	m
Exposed Perimeter	28.28544	m
Floor Area (Joists)	44.68641	sqm
Floor Sp. Leakage Area	315.9796	sqmm/sqm
No. of Windows	0.0	No.
Wall Specific Leakage Aree	1159.576	sqmm/sqm
Area A2....................................	16.4592	sqm
R-value for A2	0.82474	K-sqm/W
Area A3	33.708	sqm
R-value for A3	0.82474	K-sqm/W
Area A4	23.432	sqm
R-value for A4	0.35245	K-sqm/W
Area A5	22.462	sqm
R-value for A5	0.35245	K-sqm/W

2. Subfloor with Basement Wall insulation:

The same input data as mentioned abpve with the following changes:

1. R-value for A-2.......................... 1.938497 K-sqm/W
2. R-value for A-3.......................... 1.938497 K-sqm/W

In addition two extra questions are asked under GENERAL. These are:

1. Indoor temperature swing................ 0.0 deg C
2. Floor slab thickness.................... 127 mm

Appendix M

Comparison of Heating Loads between CIRA, RBEAP and DOE 2.1A for 'Villages of Riverside'

1) Using RBEAP with Mitalas basement model only.
2) Using RBEAP with Mitalas model as well as utilization factors.

Table M-1:

Villages of Riverside (With Basement Wall insulation)

RBEAP with Mitalas basement model only.

MONTH	CIRA	RBEAP	DOE 2.1A	VAR C/D	VAR R/D
	GJ	GJ	GJ	%	%
JAN	11.11	11.10	11.56	-3.89	-3.98
FEB	9.03	9.20	9.59	-5.84	-4.07
MAR	5.05	5.70	5.75	-12.17	-0.87
APR	1.55	2.60	2.76	-43.84	-5.80
OCT	1.46	2.10	2.16	-32.41	-2.78
NOV	4.76	5.10	5.22	-8.81	-2.30
DEC	9.14	9.20	9.44	-3.18	-2.54
TOTAL	42.10	45.00	46.48	-9.42	-3.18

Table M-2:

Villages of Riverside (Without Basement Wall insulation)

RBEAP with Mitalas basement model only.

MONTH	CIRA	RBEAP	DOE 2.1A	VAR C/D	VAR R/D
	GJ	GJ	GJ	%	%
JAN	11.70	11.70	12.13	-3.54	-3.54
FEB	9.50	9.80	10.27	-7.50	-4.58
MAR	5.50	6.30	6.94	-20.75	-9.22
APR	1.70	3.00	3.11	-45.34	-3.54
OCT	1.70	2.30	2.43	-30.04	-5.35
NOV	5.10	5.51	5.61	-9.09	-1.78
DEC	9.80	9.80	10.14	-3.35	-3.35
TOTAL	45.00	48.41	50.63	-11.12	-4.38

Table M-3

Villages of Riverside (without basement wall insulation)

RBEAP with Mitalas model and Utilization factors.

MONTH	CIRA	RBEAP	DOE 2.1A	VAR C/D	VAR R/D
	GJ	GJ	GJ	%	%
JAN	11.70	11.80	12.13	-3.54	-2.72
FEB	9.50	9.90	10.27	-7.50	-1.60
MAR	5.50	6.40	6.94	-20.75	-7.78
APR	1.70	3.10	3.11	-45.34	-0.32
OCT	1.70	2.40	2.43	-30.04	-1.23
NOV	5.10	5.50	5.61	-9.09	-1.96
DEC	9.80	9.90	10.14	-3.35	-2.37
TOTAL	45.00	49.00	50.63	-11.12	-3.32

Table M-4

Villages of Riverside (with basement wall insulation)

RBEAP with Mitalas model and Utilization factors.

MONTH	CIRA	RBEAP	DOE 2.1A	VAR C/D	VAR R/D
	GJ	GJ	GJ	%	%
JAN	11.10	11.20	11.53	-3.89	-3.11
FEB	9.00	9.30	9.59	-5.84	-3.02
MAR	5.05	5.90	5.75	-12.17	-2.61
APR	1.55	2.80	2.76	-43.84	1.45
OCT	1.46	2.10	2.16	-32.41	-2.78
NOV	4.76	5.10	5.22	-8.81	2.30
DEC	9.14	9.30	9.44	-3.18	-1.48
TOTAL	42.10	45.70	46.48	-9.42	-1.68

VITA AUCTORIS

1963 Born in Hyderabad, Andhra Pradesh, India on November 29 1963.

1981 Completed the Indian School Certificate Examination from the Hyderabad Public School, Begumpet, India.

1985 Completed the Bachelor of Engineering degree in Mechanical Engineering from the University College of Engineering, Osmania University, Hyderabad, India.

1987 Currently a candidate for the degree of Master of Applied Science in Mechanical Engineering at the University of Windsor, Canada.