

ADDITION OF ANNUAL BUILDING ENERGY  
ANALYSIS CAPABILITY TO A DESIGN  
LOAD CALCULATION PROGRAM

By

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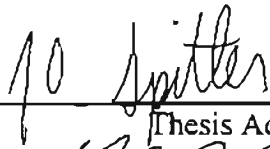
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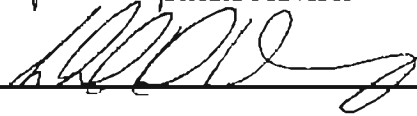
Submitted to the Faculty of the  
Graduate College of the  
Oklahoma State University  
in partial fulfillment of  
the requirements for  
the Degree of  
MASTER OF SCIENCE  
December, 1996

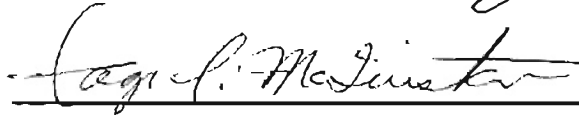
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## PREFACE

A comprehensive technical computer software, the HVAC program, for the professional purpose of building load calculation, was previously developed by Castelino, a former graduate student in Mechanical and Aerospace Engineering Department, Oklahoma State University. The program is designed under the Microsoft Windows™ environment and has a friendly user interface. The program can perform a series of basic calculations on design day cooling loads, heating loads, space heat extraction rates and space air temperatures of a building defined by the user.

For design day cooling load calculation, the transfer function method which was introduced by Stephenson and Mitilas (1967), was used as the major methodology in the load calculation procedures. To expand the capability of this program based on the existing version, further work has been done in this project to add annual simulation procedures to the program. The results from annual building load simulation is useful to analyze HVAC system annual energy consumption.

The results comparison between the HVAC program and other professional programs, which are considered as state-of-the-art, has also been done during this project. The simulation results carried out by the HVAC program is found to be acceptable for general engineering purposes in the field of HVAC.

I wish to express my sincere appreciation to my major advisor, Dr. Jeffrey D. Spitler for his intelligent guidance, patience, encouragement and friendship during the entire period of this project. I would also like to thank Dr. Ronald D. Delahoussaye for his invaluable advice, assistance and suggestions on the computer programming. My sincere appreciation extends to Dr. Faye McQuiston for serving on my committee. His contribution on the revised Transfer Function Method is remarkable in this thesis work. I

appreciate the help from all of my colleagues and friends, A. Manickam, J. Charles Bethea, C. Yavuzturk and Ojas, Wadivkar.

Finally, I would like to give my special thanks to my parents, Zhengjiou Chen , Jinhuan Ming, and my sister Ming Chen for their love, understanding, support and encouragement throughout this whole process.

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# Chapter I

## Introduction

### 1.1 Overview

When designing a cooling and heating system for either a new or an existing building, the building load calculation is one of the most important and fundamental tasks during the whole design procedure. The load calculation provides necessary design data for the engineer sizing the system, selecting equipment and estimating energy consumed by the operation of the heating, ventilating and air conditioning (HVAC) system. Generally, the peak load results obtained from the design day calculation are used to determine the required capacity of the HVAC system. The results from the design day calculation are not expected to reflect the actual performance of the system during the life of the system under the conditions other than design day. Therefore, the system capacity is usually oversized by designer by adding extra safety factors to the calculation results. When the cost of energy becomes more and more of a concern to the public, detailed (hour by hour) annual building load simulation is required by designers to evaluate the system life cycle performance and estimate the annual energy consumption budget.

For building load calculation, the heat balance method is considered as "the exact solution" (ASHRAE, 1993), because it is based on a comprehensive thermal network model combined with all building load components. The conduction heat transfer between interior and exterior wall surfaces is calculated by using conduction transfer function and all other kinds of heat transfer involved in the conditioned space have to be solved simultaneously. Because of the complexity of this method, it is impractical without the assistance of a digital computer. In 1967, a new load calculation concept was

carried out by Mitalas and Stephenson (1967a,b), which is called transfer function or weighting factor method. The transfer function method is considered as a simplification of the rigorous heat balance calculation procedure (ASHRAE 1993) and runs faster than the heat balance method. During the last 20 years, the transfer function method has been further developed and is feasible to calculate the cooling loads for almost all types of buildings. The detailed procedures for applying this method are already published by ASHRAE in "Cooling and Heating Load Calculation Manual, 2nd ed." (McQuiston and Spitler, 1992). Furthermore, the design day cooling load calculation by using the revised transfer function method has already been implemented in a comprehensive building load simulation computer software, which is called "HVAC for Windows™".(Castelino, 1992).

Currently, the HVAC for Windows™ program has the capability to perform a building design day cooling, heating load and system heat extraction rate calculation based on the building description and design day conditions defined by the user. The software was developed under the Microsoft Windows™ environment and has a friendly graphical user interface.

By using the HVAC program, the user can easily define a new building in the Windows™ environment and perform the design day calculation. The results of the calculation can provide not only the design day peak loads, but also the hourly loads profile for the whole building or each individual load component. This feature provide the user the possibility to make a detailed analysis on the thermal performance of the building or HVAC system .

For some applications in the HVAC field, some other data, such as the building's monthly total heating, cooling loads, monthly peak loads and peak loads occurring time, are also of interest to the user. The GLHEPRO program (Spitler, 1996), which is a software developed to simulate a long term performance of a ground loop heat exchanger serving a heat pump system, needs all of the information mentioned above to complete a simulation. Therefore, it is desirable to add the annual energy simulation procedure to enhance the program's capability.

This thesis describes the implementation of the annual simulation procedure in the current version of the HVAC program. To meet the requirement of completing an annual load simulation, the modification of the user interface to the HVAC program is also discussed in this thesis.

## **1.2 Literature Review**

In order to implement the new feature of annual simulation to the HVAC program and validate the results, some related papers have been reviewed in this project. The following sections describe a literature survey on the topics of: the transfer function method, the transfer functions' coefficients, the development of the HVAC for Windows™ program and the program validation.

### **The Transfer Function Method**

The "Thermal Response Factor Method", which was introduced by Stephenson and Mitalas (1967a,b), is based on the principle of superposition and response factors. In order to use the superposition technique, the system has to meet the prerequisite that it can be represented by linear and invariable equations. The heat transfer process in a conditioned space can meet this requirement as described by Mitalas (1965). Based on the further development of the response factor approach, Stephenson and Mitalas (1971) applied the z-transform to model the transient heat conduction through multiple layers. The method - which is known widely as "Transfer Function Method (TFM)" - is similar to the previous response factor method, but as expressed in the paper (Stephenson and Mitalas, 1971), "... they are much more economical in terms of computer memory space and running time". The transfer function method has become a popular practical load calculation method and accepted in the public domain during the last two decades. In 1970's, the ASHRAE sponsored research project, RP-138, was carried out under the

direction of Rudoy (1975) to improve the method and make it feasible in the HVAC field without the assistance of a digital computer. The project created tabulated values of room response factors corresponding to different zone geometric and construction characteristics based on the results carried out by Mitalas and Stephenson (1967). The results from the RP-138 were also incorporated in the ASHRAE Handbook of Fundamentals (1977,1981,1985). Later investigations and studies on the room response characteristics found the accuracy of the results carried out by RP-138 questionable. The results of a study carried out by Sowell (1984) showed that certain parameters of the zone geometry and construction can also affect the room thermal response considerably. In order to provide more appropriate room weighting factors which can be applied to a wider range of zone constructions, the research project (RP-472) was defined in 1985 by ASHRAE. In this project, the DOE-2.1B program was used to obtain a new set of room transfer function coefficients (Kerrisk, et al. 1981). There are fourteen zone parameters considered as important factors which can influence the room thermal characteristics. The detailed description can be found in the RP-472 companion papers (Sowell, 1988a,b,c). A complete description of the entire revised transfer function method has been made in the Cooling and Heating Load Calculation Manual (McQuiston and Spitler, 1992) published by ASHRAE. The latest version of the coefficients used for both conduction and room transfer functions are incorporated in this manual. Furthermore, as personal computers became available to the HVAC design routine, the database of the transfer function coefficients has been developed (Falconer, et al., 1992) and the database can be accessed by both user interactive computer software and specific C or FORTRAN programs. A comprehensive load calculation computer program, HVAC for Windows™ (Castelino, 1992), which can run under the Microsoft Windows™ environment was also developed applying the standard calculation procedures published in the Cooling and Heating Load Calculation Manual (McQuiston and Spitler, 1992).

A brief description of the transfer function method procedures in building cooling load calculation is given below.

- Calculate the hourly heat gains through opaque exterior surfaces:

To calculate the hourly heat gain conducted through building exterior wall and roof, the procedure has the following feature (ASHRAE, 1993):

- 1) The outdoor ambient condition is represented by sol-air temperature
- 2) A constant indoor space temperature is assumed for cooling load calculation
- 3) Interior and exterior surface combined coefficients are both set as constants

The conduction transfer function is employed to obtain the hourly heat gain through the opaque building constructions. The conduction transfer function can be expressed in form (ASHRAE, 1993):

$$q_{e,\theta} = A \left[ \sum_{n=0} b_n (t_{e,\theta-n\delta}) - \sum_{n=1} d_n \left\{ (q_{e,\theta-n\delta}) / A \right\} - t_{rc} \sum_{n=0} c_n \right] \quad (1.1)$$

where

$q_{e,\theta}$  = heat gain through wall or roof, at calculation hour,  $\theta$ , Btu/h

$A$  = indoor surface area of a wall or roof, ft<sup>2</sup>

$\theta$  = time, h

$\delta$  = time interval, h

$n$  = summation index (each summation has as many terms as there are non-negligible values of coefficients)

$t_{e,\theta-n\delta}$  = sol-air temperature at time  $\theta-n\delta$ , °F

$t_{rc}$  = constant indoor room temperature, °F

$b_n, c_n, d_n$  = conduction transfer function coefficients

The coefficients used in the conduction transfer function can be determined by the layer description, thermal and geometry properties of the wall or roof. A total of 41 representative wall groups and 42 roof groups can be used to represent all common wall and roofs. The database of the conduction transfer function coefficients is also able to be accessed by using computer software (Falconer, et al. 1992).

The heat gain caused by fenestration can be divided into two parts. One is the conduction heat transfer across the window material. The other is the solar radiative heat gain through the window glass. The conduction and transmitted parts of the heat gain can be calculated by Equation 1.2 and 1.3 (ASHRAE, 1993), respectively.

$$\text{Convective } q = UA(t_o - t_i) \quad (1.2)$$

$$\text{Solar } q = A (SC) (SHGF) \quad (1.3)$$

where

$t_o$  = outdoor current hourly dry-bulb temperature, °F

$t_i$  = inside design temperature, °F

$A$  = area of window

$U$  = overall window heat transfer coefficient, Btu/(hr-ft<sup>2</sup>-F)

$SC$  = shading coefficient

$SHGF$  = solar heat gain factor, Btu/(h-ft<sup>2</sup>)

As discussed in the Cooling and Heating Load Calculation Manual (McQuiston and Spitler, 1992), in the revised transfer function method, the Solar Heat Gain Factor is split into two parts - Transmitted Solar Heat Gain Factor (TSHGF) and Absorbed Solar Heat Gain Factor (ASHGF), and they are calculated separately by using formula 1.3a and 1.3b.

$$TSHGF = I_D \sum_{j=0}^5 t_j [\cos \theta]^j + 2I_d \sum_{j=0}^5 t_j / (j+2) \quad (1.3a)$$

$$ASHGF = I_D \sum_{j=0}^5 a_j [\cos \theta]^j + 2I_d \sum_{j=0}^5 a_j / (j+2) \quad (1.3b)$$

where:

$I_D$  : the direct solar radiation intensity

$I_d$  : the diffuse solar radiation intensity

$t_j$  : the transmission coefficients for DSA glass

$a_j$  : the absorption coefficients for DSA glass

DSA : standard double-strength sheet glass



The solar heat gain factor can then be obtained from the form below:

$$\text{Solar heat gain factor} = \text{Energy transmitted} + N_i (\text{Energy absorbed}) \quad (1.4)$$

where

$$N_i = h_i / (h_i + h_o) \quad (1.5)$$

$h_i, h_o$  = interior and exterior combined heat transfer coefficient, respectively

The value of  $N_i$  is called inward flowing fraction of absorbed heat through fenestration surface.

The method to calculate the heat gain caused by people, infiltration, light and miscellaneous internal heat generating appliances is also described in the Chapter 26 in the ASHRAE Handbook (1993).

- Calculate the room cooling load based on the calculated hourly heat gain

When the hourly heat gain is obtained by using the procedures mentioned above, the hourly cooling load can then be calculated by applying the room transfer function. The cooling load due to different type (i.e. conduction, infiltration, etc.) of heat gain can be obtained from Equations 1.6 through 1.8 (ASHRAE, 1993):

$$Q_{\theta} = Q_{if} + Q_{sc} \quad (1.6)$$

$$Q_{if} = \sum_{i=1} (v_i q_{\theta,i} + v_1 q_{\theta,i-\delta} + v_2 q_{\theta,i-2\delta} + \dots) - (w_1 Q_{\theta-\delta} + w_2 Q_{\theta-2\delta} + \dots) \quad (1.7)$$

$$Q_{sc} = \sum_{j=1} q_{c,j} \quad (1.8)$$

where:

$Q_{if}$  = sensible cooling load from heat gain elements having convective and radiant components

$v$  and  $w$  = room transfer function coefficients

$q_{\theta}$  = each of  $i$  heat gain elements having radiant component

$\delta$  = time interval, h

$Q_{sc}$  = sensible cooling load from heat gain elements having only convective components

$q_c$  = each of j heat gain elements having only convective component

The latent cooling load is calculated by Equation 1.9 (ASHRAE, 1993):

$$\text{Latent } Q_l = \sum_{n=1} (q_{c,n}) \quad (1.9)$$

$q_c$  = each of n latent heat gain elements

Similar to the wall and roof conduction transfer function, the coefficients of the room transfer function imply the thermal response characteristics of a room. More discussion on the determination of the room transfer function coefficients will be continued in the next section.

- Calculate the heat extraction rate and room air temperature

When the space air temperature cannot be held as a constant of the value of the indoor design temperature because of the limitation of the A/C system capacity, the actual heat extraction rate of the system can then be calculated by the transfer function method.

The heat extraction and the space air temperature can be expressed approximately by a linear relationship as Equation 1.10:

$$ER_{\theta} = W_{\theta} + (St_{\theta}) \quad (1.10)$$

where:

$ER_{\theta}$  = heat extraction rate at time,  $\theta$

$t_{\theta}$  = the space air temperature at time,  $\theta$

$W, S$  = A/C system characteristics parameters

From the cooling loads calculated based on a constant design indoor dry bulb temperature, the heat extraction rate and the space air temperature can be calculated by the space air transfer function as shown in Equation 1.11:

$$\sum_{i=0}^1 p_i (ER_{\theta-\delta} - Q_{\theta-i\delta}) = \sum_{i=0}^2 g_i (t_r - t_{r,\theta-i\delta}) \quad (1.11)$$

$g_i$  and  $p_i$  are the coefficients used in the space air transfer function. The discussion of choosing these coefficients will be discussed in more detail in the following section and Chapter II of this thesis.

### Conduction Transfer Function Coefficients

As mentioned in the previous section, the first procedure during the cooling load calculation using transfer function method is to obtain the hourly heat gain through the building's exterior surfaces. In real life, the number of the material combinations of the wall or roof is huge. In order to represent all of these common wall or roof material combinations, the research project, RP- 472, was defined by the ASHRAE. The report of this project (Harris and McQuiston, 1988) described the procedure of wall and roof types grouping, important parameters selecting and the results applying.

In order to use a relatively small number of wall groups to represent all common wall combinations, a certain grouping method is employed in this project based on the defined error criteria used in RP-359 (Sowell, et al., 1984). In a same wall or roof group, the thermal characteristics, thermal lag and amplitude ratio, are supposed to be close to each other. This thermal characteristics can be affected by certain construction parameters, such as overall conductance, mass location and principle materials of the wall.

According to the procedure defined in the grouping procedure, the error criteria allows plus and minus one hour for the phase lag, plus zero percent and minus 20 percent for the amplitude ratio of error existing in the final results. The reason for keeping such a error range is that it "intended to lead to conservative results while keeping the number of groups reasonable" (Harris and McQuiston, 1988).

In the project RP-472, the thermal properties of about 2600 wall and 500 roof assemblies were studied. 41 wall groups and 42 roof groups were defined. The

coefficients for each wall and roof group are list in the Table 26.13 and 26.18 in ASHRAE Handbook of Fundamentals (ASHRAE, 1993).

### **Room Transfer Function Coefficients**

The latest available room transfer function coefficients are obtained from the results carried out by ASHRAE research project RP-472 (Sowell, 1988). By further study on the room thermal response characteristics, it was proved that the tabulated CLF and CLTD values listed in the ASHRAE - Fundamentals (1977,1981) had limitations with respect to a large range of zone constructions. Furthermore, certain geometry and construction parameters, which can affect the characteristic of room thermal response considerably, had not been taken into account (Sowell and Chiles 1984) due to the results of RP-138. Under this circumstance, the ASHRAE Load Calculation Technical Committee (TC 4.1) defined a research project (RP-472) to update the room weighting factors for a wider range of building constructions. The DOE-2 program was used to derive the zone weighting factor in this project and the procedure was described in the report created by Kerrisk (1981). To complete this task, an extra procedure, which was used to calculate the zone weighting factors and group the zones with similar thermal properties, has been implemented into the DOE-2 program. The detailed methodology employed in this process were also described in Kerrisk's report (1981).

According to the final results obtained from the RP-359, the zone weighting factors can be determined depending on 14 important zone parameters. They are:

- Room Geometry
- Room Height
- Exterior Wall Construction
- Number of Exterior Walls
- Roof Type
- Mid Floor Type
- Slab Type
- Floor Covering
- Partition Type
- Ceiling Type
- Furniture
- Interior Shade
- Room Location
- Glass Percent

These zone parameters are interactive with each other. Some parameters are considered as "weak variables" and some as "strong variables". Some parameters can be either weak or strong relating to certain circumstances. For more discussion on the effect of each of these zone parameters, refer to the book " Heating Ventilating, and air conditioning Analysis and Design" by McQuiston and Parker (1994).

### **Space Air Transfer Function Coefficients**

To calculate the heat extraction rate and room air temperature by using space air transfer function, appropriate space air transfer function coefficients need to be chosen properly depending on the building construction's mass level. In the ASHRAE Handbook (1993), three sets of coefficients are given for three different building mass levels, namely, light, medium and heavyweight, corresponding to 30,70 and 130 lb./ft<sup>2</sup> of floor area, respectively.

As mentioned by Barakat (1988), the mass level range covered in ASHRAE(1985) could not properly represent most of conventional wood-frame houses having a value of mass level generally between 10 and 12 lb./ft<sup>2</sup> of floor area, which is much lower than the range covered in the ASHRAE (1985).

In order to apply the space air transfer function properly to these low mass level buildings, experiments were carried out by Barakat, which had several test cases under an outdoor experimental facility. The experiment was designed to test the transfer function coefficients based on three different building mass levels, 9.4,26.6 and 110 lb./ft<sup>2</sup> of floor area. The methodology of determining the coefficients was described in the paper. Finally, the recommended data of space air transfer function coefficients used for buildings with low mass level are given in Table 1.1:

Table 1.1 Experimental Space Air Transfer Function Coefficients  
for Wood-frame Houses

Coefficients	Exptl. light	Exptl. medium	Exptl. heavy
mass level (lb./ft <sup>2</sup> )	9.4	26.6	110.0
$g_0$ (Btu/h-ft <sup>2</sup> -°F)	1.21	1.60	1.91
$g_1$ (Btu/h-ft <sup>2</sup> -°F)	-1.27	-1.64	-2.00
$g_2$ (Btu/h-ft <sup>2</sup> -°F)	0.06	0.04	0.09
$p_1$	-0.58	-0.76	-0.90

### The "HVAC for Windows™" Program

The existing load calculation program, HVAC for Windows™, was originally developed by Castelino in 1992. Castelino's thesis (1992) described the revised transfer function method in detail which had been implemented to calculate the building cooling load, system heat extraction rate and space air temperature calculation procedure.

Before the program can execute the design day cooling and heating load calculation, the user has to specify all necessary information, such as the building's location, construction, system control and infiltration, etc. When all calculation is done, the user can get the results of the hourly cooling load, heat extraction rate, and zone space air temperature from either graphical screen or out put files.

The design day direct and diffuse solar radiation calculation is based on the ASHRAE (1993) "Clear Sky" model. And the heat extraction rate and space air temperature calculation used the transfer function method which was described by the "Cooling and Heating Load Calculation Manual" (McQuiston and Spitler, 1992). The heat extraction rate calculation can handle a system's control profile with one set point temperature and a specified throttling range.

The HVAC program's built in data structures were also described by Castelino and will be discussed briefly in Chapter II of this thesis. All related data for a building are saved in the memory as a hierarchical linked list during the calculation procedure. The most primary part of the design day calculation is the elements cooling load calculation. The summation of the loads of all elements involved in a room make up the room loads, and the summation of all room loads makes the zone's load. Finally, the building's total loads are made up by the summation of all zone's loads. Sensible and latent cooling load calculations are performed separately.

The CLTD/SCL/CLF method, which is a simplification of the transfer function method is also discussed briefly in the thesis. The comparison between the results from the revised transfer function method and CLTD method was made with the purpose to validate the program's calculation results.

### **The Program Validation**

As described by Judkoff and Neymark (1993), to evaluate a building energy simulation software, there are only limited ways to estimate the accuracy of the program. They are experimental, analytical and comparative evaluation approaches. They developed a validation procedure using a comparative approach, which is called "Building Energy Simulation Test (BESTEST) and Diagnostic Method". The BESTEST intends to evaluate the program to be tested by comparing the simulation results with other programs which are considered "to be better validated, or more detailed and presumably more physically correct". Generally, among building load calculation program the required input files are not the same. The purpose of the BESTEST is to create a uniform building description for a set of test cases and compare the results carried out by the testing software to the results by other software used in public domain.

There are 14 qualification test defined in the BESTEST. There are two series, 600 and 900 series which represented lightweight and heavyweight building construction, respectively. These cases were designed to test the ability of a building load software to

simulate "such features as windows at different orientations, horizontal and vertical external shading devices, set-back thermostats", etc. The test results includes the comparison of building annual total heating and cooling loads, peak heating and cooling loads and their corresponding occurring times.

Another important feature of the BESTEST, diagnostic flow diagram, provides a convenient way to trace possible problems in the testing software when large disagreement is encountered in the comparison results. The procedure of the BESTEST is carefully designed to test the thermal process simulation capability of the testing software. A test always begins with a base case. For low mass cases, the base case is the case 600. For high mass cases, the base case is the case 900. For all test cases, the comparison should be made on both the absolute results and the sensitivity (differential) results. When the results carried out by the testing software for a certain case have a reasonable agreement with other reference programs, that specific case is considered to be "PASS". If the testing results cannot pass for a certain case, the BESTEST diagnostic procedure can be applied to figure out the software's potential problem. For example, if the test procedure cannot pass the base case 600 for low mass case, then the diagnostic procedure A1 through A11 should be run to find out what the problem could be. For each diagnostic procedure, only a single thermal process simulation capability is tested. For instance, the diagnostic procedure "A1" only tests the exterior wall conduction heat transfer; the procedure "A6" only tests the infiltration heat gain and the procedure "A8" only tests the exterior solar absorbtance. Because each thermal process simulation capability is tested separately in the BESTEST diagnostic procedure, the encountered problem in the testing software can be easily tried out and isolated. Also, the corresponding modification can be considered to the testing software to fix the problem.

From the comparison results of the BESTEST, either the program end user or developer can tell if the results of the program is acceptable and decide which software can be used properly for their certain purpose.



### **1.3 Objective**

The objective of this project is to add the following new features to the existing version of the HVAC program developed by Castelino (1992):

1. Add the capability of annual load simulation to the program based on the revised transfer function method. The annual simulation will be executed based on the user specified weather data file for a certain location.
2. Add the capability to calculate sensible and latent ventilation loads on the coil to the program.
3. Modify the procedure of heat extraction rate calculation and make the program simulate an A/C system with two set point temperatures or with a set back operation period.
4. Modify the existing user interface to make the program meet the requirement of performing an annual energy analysis.
5. Connect the annual simulation results calculated by the HVAC program to the GLHEPRO program to perform the ground loop heat pump simulation.
6. Validate the annual simulation results carried out by the HVAC program.

## Chapter II

### Building Load Annual Simulation

#### *2.1 Overview of HVAC Previous Version*

The previous HVAC program has the capability to calculate the design day's building cooling load, heating load, and A/C system heat extraction rate based on the building description file defined by the user's input data. The cooling load calculation is based on the revised transfer function method and is performed on each building heat transfer or heat generation load component. In order to perform the load calculation, a hierarchical data structure has been built in the previous HVAC program to save intermediate calculation information and simulation results.

##### **2.1.1 Design Day Cooling Load Calculation**

The design day cooling load calculation in the previous HVAC program is based on the revised transfer function method. For the design day calculation, because there is no history information available, the program needs to iterate for convergence of results. The solar radiation model used in the design day cooling load calculation is ASHRAE "Clear Sky" model. The clearness of the sky is supposed to be 1, which means very clear. The flow chart of the design day cooling load calculation procedure is shown in Figure 2.1.

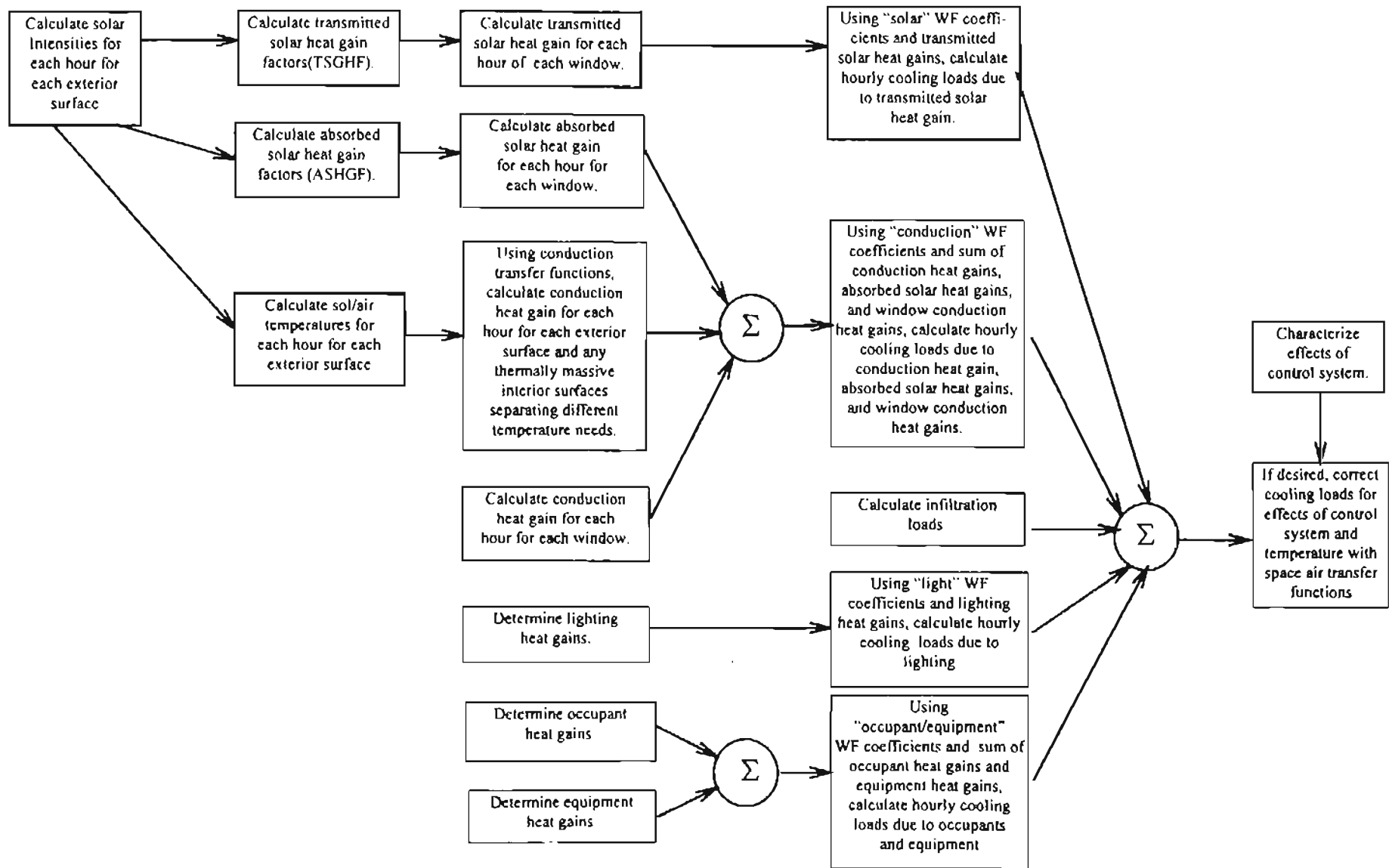


Figure 2.1 Cooling Load Calculation by Transfer Function Method(McQuiston and Spitler, 1992)

### **2.1.2 Design Day Heat Extraction Calculation**

The design day A/C system heat extraction rate calculation is performed on each zone. The input data for the extraction rate calculation function are the zone hourly total sensible cooling load and the system control profile. The previous HVAC program can only perform a system control profile, which has a single set point zone temperature. The zone space temperature is only allowed to float around this set point within a specified system throttling range. This limitation does not allow the program to analyze a system which has a "Dead Band" control profile. This feature will be modified in the new version of the HVAC program, and it will be discussed in section 2.2.

### **2.1.3 Data Structure Description**

The major data structure to hold all building input data and important relative parameters is shown in figure 2.2. An outline description of the major data structure used in previous HVAC program is given in the following section.

In each building description (\*.blg) file, data is saved based on four kinds of data structure; they are "building", "zone", "room", and "element" data structures. These data structures hold all of the information about the building necessary for program calculations. In addition, a "temporary" data structure is used to hold intermediate results.

#### **Building Data Structure**

The "building" data structure includes fields for the building's name, location(latitude, longitude, city and state), outdoor summer and winter design day conditions, solar radiation time alignment, and the cooling load calculation results for the design day. This data structure also includes some fields holding the intermediate calculation results like solar equation of time, declination, etc.

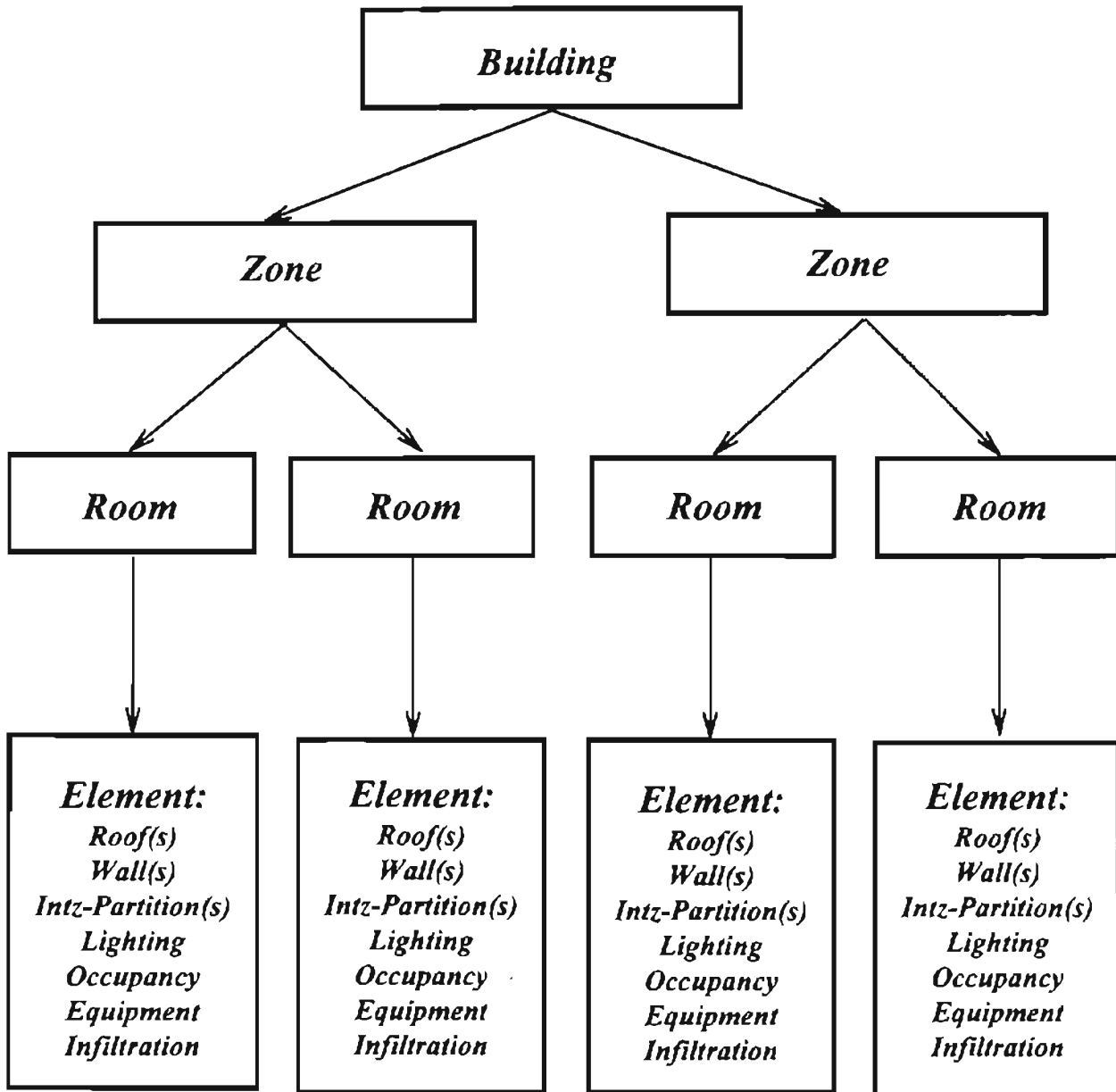


Figure 2.1 Hierarchy of the HVAC software program data structure(Castelino, 1992)

### Zone Data Structure

In the HVAC program, a zone represents a conditioned space which is controlled by a single thermostat, and is assumed to have a uniform space air temperature. The "zone" data structure holds the information of the zone's indoor design day condition, HVAC system capacity and throttling range, calculation results of the design day cooling load and heat extraction rate, and zone infiltration and system schedule information.

### Room Data Structure

In the HVAC program, the term "room" is defined as a conditioned space which is enclosed by the building constructions and hold all kinds of user defined load components, e.g. a single office, a single kitchen or a single classroom can all be defined as a room. The "room" data structure has the data of the room construction parameters and also the cooling load calculation results, such as hourly room sensible cooling loads, hourly room latent loads and hourly room total cooling loads.

### Elements Data Structure

Data of various building load components, for example, wall, roof, infiltration, and lights, is stored in the same type of data structure - element data structure. Some fields in the data structure are only used for some specific types of building components. If it is a structure for wall, valid fields will involve wall type, wall actual U factor, wall area, etc. If it is a structure for infiltration, valid fields will involve the air change rate and schedule of the infiltration. Element data structures also include some fields which specify the necessary parameters used for transfer function method load calculations.

### Temporary Data Structure

There is another important temporary data structure which holds all temporary information that is necessary during calculation procedures, such as hourly solar angles, local solar times, the intensity of the solar beam, diffuse radiation, and hourly summer

outdoor dry bulb temperatures. The room space air transfer function coefficients are also included in this data structure.

## ***2.2 Modification on Design Day Heat Extraction Rate Calculation***

The system heat extraction rate calculation in the previous version of the HVAC program is limited in that it can not analyze a HVAC system with two set point temperatures, with the zone space temperature floating between these two set points. In order to simulate a more realistic system which not only can have two set points, but also be allowed to have a set back period, the of heat extraction rate calculation procedure has been modified.

### **2.2.1 System With One Set Point Temperature**

Generally, for a cooling system with a single set point temperature, the relationship between heat extraction rate and room air temperature can be represented approximately by a linear expression as shown below:

$$ER_{\theta} = W + S \times t_{r,\theta} \quad (2.1)$$

Where:

W and S: equipment parameters represent the performance of  
a A/C system

$ER_{\theta}$ : Heat extraction rate at time,  $\theta$

$t_{r,\theta}$ : Room air temperature at time,  $\theta$

This relationship can also be illustrated as in figure 2.3:

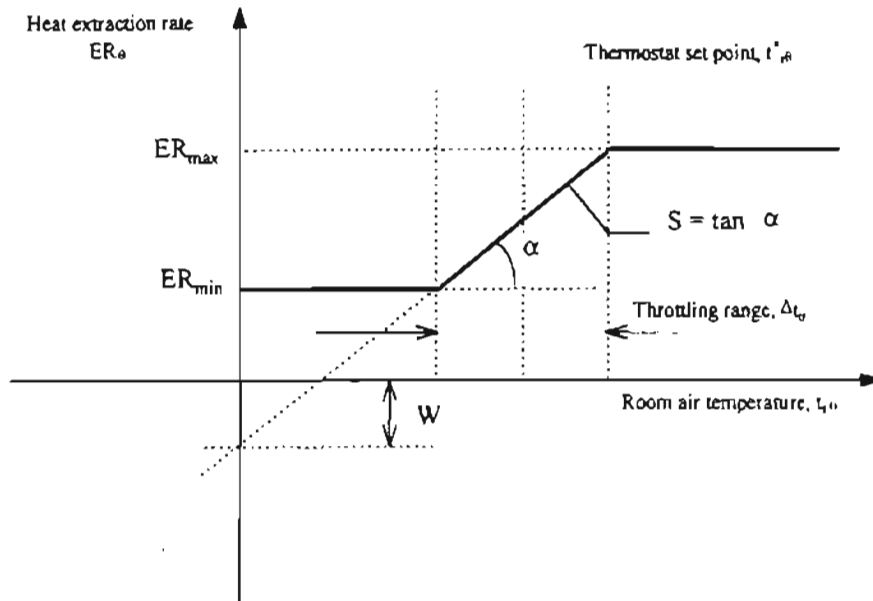


Figure 2.3: A/C System's Equipment Characteristic (with one set point)

Where:

$ER_{max}$ : system maximum heat extracting capacity

$ER_{min}$ : system minimum heat extracting capacity

$\Delta t_v$ : throttling range

$t_{r\theta}^*$ : thermostat set point temperature at time,  $\theta$ , is chosen as the middle point of the system throttling range

The linear relationship expressed in equation 2.1 is supposed to hold when room air temperature lies in the system throttling range. When the room air temperature lies outside the throttling range, the rate of heat extraction will be equal to  $ER_{min}$  or  $ER_{max}$ , depending on whether the zone air temperature is above or below the range.



The S value represents the slope of the linear function, which can be calculated by:

$$S = \frac{ER_{\max} - ER_{\min}}{\Delta t_r} \quad (2.2)$$

The interception value of equation 2.1, W, is calculated by:

$$W = \left[ \frac{ER_{\max} + ER_{\min}}{2} \right] - S \times t_{r,0} \quad (2.3)$$

### 2.2.2 System With Two Set Point Temperature

Unlike the heat extraction rate calculation in the previous version of the HVAC program, the new version of the HVAC program provides a feature which allows the zone space temperature to float between two specified set point temperatures. It can also be considered as a combination of two “one set point” profiles. When the temperature is below the low set point, the system will add heat to the space, and when the temperature is above the high set point, the system will extract heat from the space. If the zone space temperature is between the two set points, the A/C system will be turned off, and the zone space temperature is allowed to float. The characteristic of system is illustrated in figure 2.4.

### 2.2.3 System Operation State Description

During the heat extraction rate calculating procedure, the system has the same throttling range for both heating and cooling. There are two set point temperatures defined for a single A/C system profile. One is for heating and another is for cooling.

Each set point temperature is the middle point of its respective throttling range. Under this definition, a system has five running states related to the value of zone air temperature as shown in Figure 2.5.

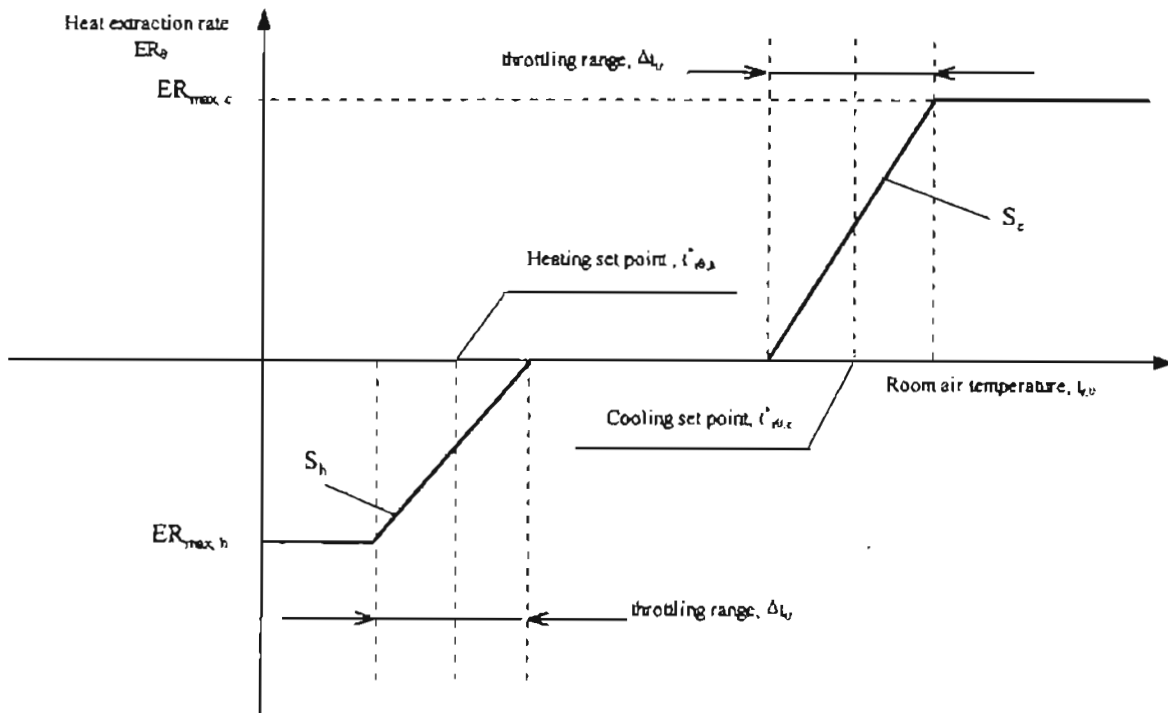


Figure 2.4 A/C Equipment Characteristic(with two set points)

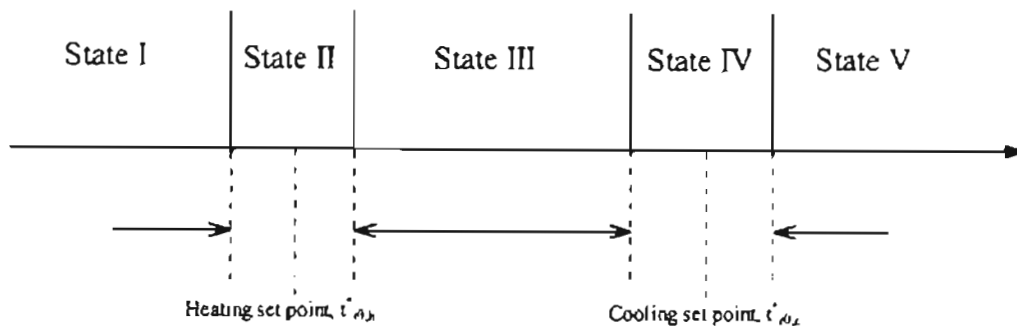


Figure 2.5 System operation states illustration

State I: System is turned on with maximum heating capacity.

State II: System heating is turned on. The relationship between heat extraction rate and zone air temperature follows the equations as below:

$$ER_{\theta} = W_{h,\theta} + S_{h,\theta} \times t_{r\theta} \quad (2.4.1)$$

$$S_{h,\theta} = \frac{ER_{\max,h}}{\Delta t_{ir}} \quad (2.4.2)$$

$$W_{h,\theta} = \frac{ER_{\max,h}}{2} - S_{h,\theta} \times t_{r\theta}^* \quad (2.4.3)$$

State III: System is turned off, and zone air temperature is allowed to float.

State IV: System cooling is turned on, and the relationship between heat extraction rate and room air temperature follows the equations as below:

$$ER_{\theta} = W_{c,\theta} + S_{c,\theta} \times t_{r\theta} \quad (2.5.1)$$

$$S_{c,\theta} = \frac{ER_{\max,c}}{\Delta t_{ir}} \quad (2.5.2)$$

$$W_{c,\theta} = \frac{ER_{\max,c}}{2} - S_{c,\theta} \times t_{r\theta}^* \quad (2.5.3)$$

State V: System turned on with maximum cooling capacity.

## 2.2.4 System Set Back Operation

The A/C system set back period definition is allowed in the new version of the HVAC program. Any A/C system can be scheduled to operate either in a normal operating state, or the set back state. For these two states, the system has two sets of different system control profiles described in the previous section. For example, during the normal operating state, the system lets the space air temperature float between 68°F and 80°F. During set back period, the space air temperature can float between 50°F and 90°F. If the user desires a period over which the system is totally turned off, then this period can be defined as a set back period which has a pair of extremely low and high set point temperatures, like 0°F and 200°F. Then the space air temperature can never reach that point so that the system will not be turned on at all during the period.

## 2.2.5 Space Air Transfer Function

The hourly system heat extraction rate and zone air temperature can be calculated by using the space air transfer function:

$$\sum_{i=0}^i p_i (ER_{\theta-i\delta} - Q_{\theta-i\delta}) = \sum_{i=0}^2 g_i (t_{rc} - t_{r\theta-i\delta}) \quad (2.6)$$

where:

$g_i$  and  $p_i$  = the coefficients used in the space air transfer function

$Q$  = the cooling load calculated base on an assumed constant zone temperature  $t_{rc}$  at time  $\theta$

The normalized values of  $g$ 's and  $p$ 's can be found in the ASHRAE handbook of fundamental(1993). The values are given for three different categories of building envelope construction types; namely, light, medium and heavyweight construction, characterized by 30,70 and 130 lb./ft<sup>2</sup> of floor area. This range can represent most general building construction in current HVAC design tasks. However as pointed out by

Barakat(1987), for conventional wood frame houses with mass values as low as 10-12 lb./ft<sup>2</sup>, (much lower than the value of the lightweight case listed in ASHRAE), the accuracy of applying the space air transfer function may deteriorate. An extra building construction level was added to the program to expand its energy analysis capability to buildings with very low mass levels.

In Barakat's paper, a series of experimental data of space air transfer function coefficients with three different building construction mass levels, 9.4,26.6 and 110 lb./ft<sup>2</sup> was presented. Barakat's values for a building with 9.4 lb./ft<sup>2</sup> are used as the "Extra Light" level for the HVAC program.

The complete coefficients value used in the HVAC program's space air transfer function are shown in Table 2.1:

TABLE 2.1 The Normalized values of space air transfer function coefficients

<b>Room Envelope Construction</b>	<b><math>g_0</math></b>	<b><math>g_1</math> Btu/h·ft<sup>2</sup>·°F</b>	<b><math>g_2</math></b>	<b><math>P_0</math> Dimensionless</b>	<b><math>P_1</math></b>
Extra Light	+1.21	-1.27	+0.06	1.0	-0.58
Light	+1.68	-1.73	+0.05	1.0	-0.82
Medium	+1.81	-1.89	+0.08	1.0	-0.87
Heavy	+1.85	-1.95	+0.10	1.0	-0.93

### 2.2.6 Heat Extraction Rate and Space Air Temperature Calculation

From equations 2.6 and 2.1 in the previous sections, the following expression can be derived to calculate space air temperature:

$$t_{r,\theta} = (I_\theta - ER_\theta) / g_{0,\theta} \quad (2.7)$$

where:

$$I_{\theta} = t_{rc} \sum_{i=0}^2 g_{i,\theta} - \sum_{i=1}^2 g_{i,\theta} t_{r\theta-i\delta} + \sum_{i=0}^1 p_i Q_{r\theta-i\delta} - \sum_{i=1}^1 p_i ER_{\theta-i\delta} \quad (2.8)$$

All terms involved in the right hand side of equation 2.7 and 2.8 are history terms, except the current heat extraction rate( $ER_{\theta}$ ) in equation 2.7 and the current space air temperature, which also depends on the current value of the heat extraction rate.

The procedure of getting the current heat extraction rate and space air temperature is described below in detail.

a) Assume the system is totally turned off, namely,  $ER_{\theta}$  is set to be zero. Use equation 2.7 to calculate out the space air temperature  $t_{\theta}$ . If the  $t_{\theta}$  lies in the range of state III shown in the figure 2.5, then the heat extraction rate of the current hour will be zero. If  $t_{\theta}$  lies in the range below state III, then go to step b. If  $t_{\theta}$  lies in the range above state III, then go to step c.

b) In the case of  $t_{\theta}$  below state III from the step a, set the system heat extraction rate equal to the maximum system heating capacity( $ER_{max,h}$ ), and find out the value of  $t_{\theta}$  by equation 2.7 again. If  $t_{\theta}$  lies in the range below state II, then set the heat extraction rate equal to  $ER_{max,h}$  and stop. Otherwise,  $t_{\theta}$  will certainly be in the range of state II, and go to step e.

c) In the case of  $t_{\theta}$  above state III from the step a, set the system heat extraction rate equal to the maximum system cooling capacity( $ER_{max,c}$ ), and find out the value of  $t_{\theta}$  by equation 2.7 again. If  $t_{\theta}$  lies in the range above state IV, then set the heat extraction rate equal to  $ER_{max,c}$  and stop. Otherwise,  $t_{\theta}$  will certainly be in the range of state IV, and go to step e.

e) From the previous steps, it is already clear that the value of  $t_{\theta}$  will certainly lie in the range of state II or state IV. In both cases, the program will use a search method to find out the exact value of the heat extraction rate and space air temperature. The calculation procedure is shown in figure 2.6. Only the case of state II is described below, and the case of state IV follows a similar procedure.

Figure 2.6 shows the algorithm. Symbols used in Figure 2.6 are defined as follows:

$T_{max}$  : the maximum space air temperature in the range of state II, which is the system low set point temperature plus half of the throttling range.

$T_{min}$  : the minimum space air temperature in the range of state II, which is the system low set point temperature minus half of the throttling range

$T_{test}$  : test space air temperature during calculation

$ER_{test}$  : calculated heat extraction rate value with current test space air temperature

$T_{result}$  : calculated space air temperature with  $ER_{test}$

$T_{high}$  : the high temperature of the current searching range

$T_{low}$  : the low temperature of the current searching range

$\Delta$  : the difference between  $T_{high}$  and  $T_{low}$

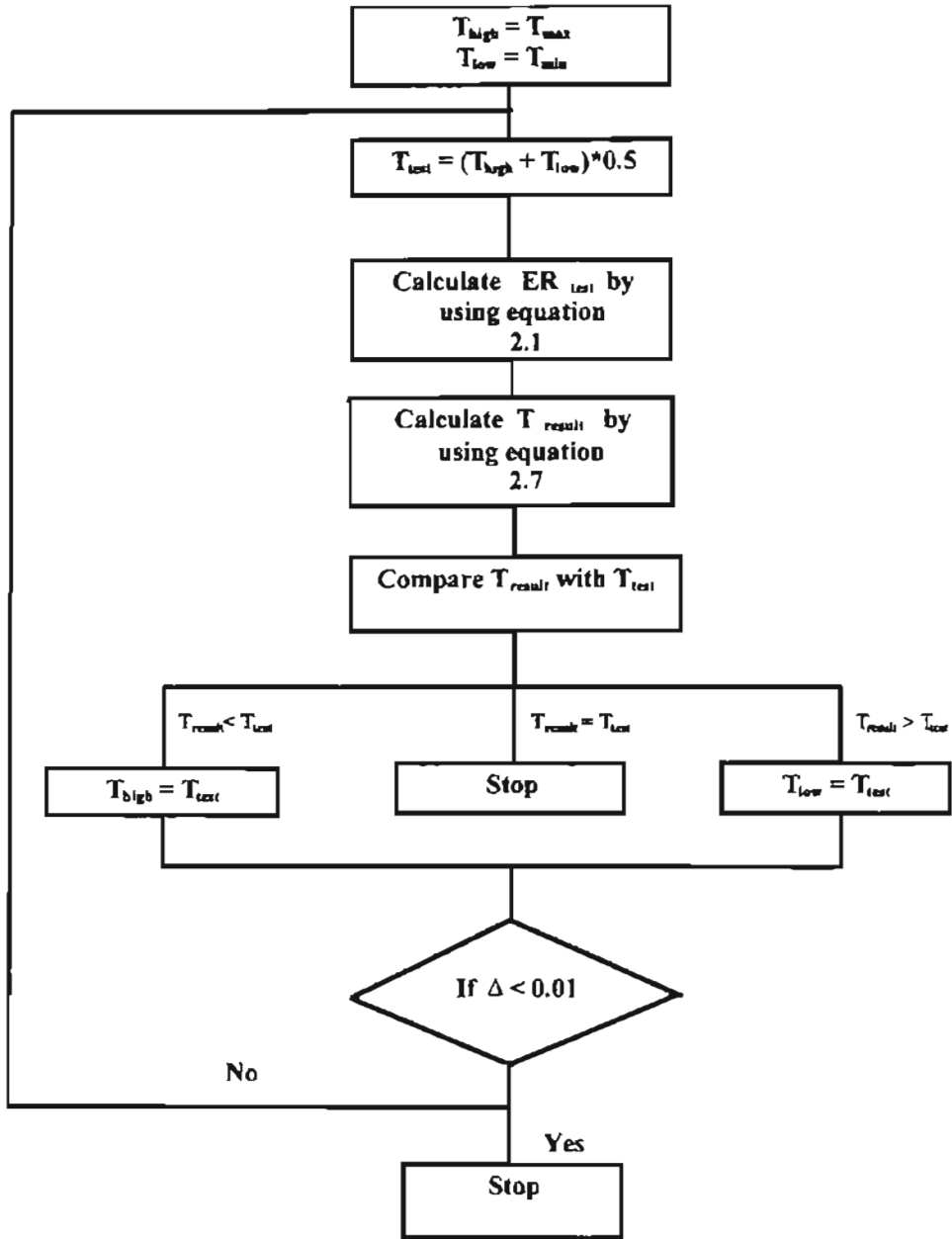


Figure 2.6 The Heat Extraction Rate Calculation when the Floats in the System Throttling



### 2.2.7 Example on Heat Extraction Rate Calculation

The calculated zone cooling load based on a constant design zone temperature is given in Table 2.2 column 5. The zone summer design temperature is 70 °F. The A/C system is set to the normal operation state from 0600 to 2100 hours, and the zone temperature is allow to float between 68 °F and 70 °F. Between 2100 to 0600 hours, the system is set to set back state, and the zone temperature is allowed to float between 62 °F and 75 °F. System throttling range is 0.1 °F.

During heat extraction calculation, some important intermediate value are listed below:

- S and W:

Normal Operation Period: Low S = 50000; Low W = -3402500

High S = 50000; High W = -3497500

Setback Operation Period: Low S = 50000; Low W = -3102500

High S = 50000; High W = -3747500

- System Operation States:

Normal Operation Period:

State I: Less than 67.95 °F

State II: 67.95 °F ~ 68.05 °F

State III: 68.05 °F ~ 69.95 °F

State IV: 69.95 °F ~ 70.05 °F

State V: Larger than 70.05 °F

Setback Operation Period:

State I: Less than 61.95 °F

State II: 61.95 °F ~ 62.05 °F

State III: 62.05 °F ~ 74.95 °F

State IV: 74.95 °F ~ 75.05 °F

State V: Larger than 75.05 °F

The heat extraction rate and zone space air temperature were calculated for this sample case, and the calculation results are listed in Table 2.2, column 6 and 7. For example, for 14th hour period, the system operation state is the “State IV” of normal operation period. The S and W values are 50000 and -3497500, respectively. The calculated value of the space air temperature is 69.9843674 °F. The heat extraction rate of that hour is 1678.72 Btu/h( = 69.9843674 \* 50000 - 3497500 ).

Table 2.2 Data and Calculation results for example 2.2.7

1	2	3	4	5	6	7
Hours	Set Back	L.S.P	H.S.P.	Cooling Load	Heat Extraction Rate	Space Temp.
	Yes/No	°F	°F	Btu/hr	Btu/hr	F
1	Yes	62	70	-635.79	0	63.7244873
2	Yes	62	70	-684.6	0	62.950058
3	Yes	62	70	-715.3	0	62.2418213
4	Yes	62	70	-750.39	-105.705	62.0478859
5	Yes	62	70	-781.48	-227.775	62.0454445
6	Yes	62	70	-809.26	-329.055	62.0434189
7	No	68	70	-826.03	-1553.19	68.0189362
8	No	68	70	-699.62	-1267.47	68.0246506
9	No	68	70	-54.65	-522.84	68.0395432
10	No	68	70	147.28	-238.645	68.0452271
11	No	68	70	533.58	0	69.175766
12	No	68	70	801.78	215.38	69.9543076
13	No	68	70	976.79	490.035	69.9598007
14	No	68	70	2091.13	1679.075	69.9835815
15	No	68	70	2171.75	1824.415	69.9864883
16	No	68	70	1863.67	1571.505	69.9814301
17	No	68	70	672.93	429	69.95858
18	No	68	70	216.89	10.145	69.9502029
19	No	68	70	-4.46	0	69.002518
20	No	68	70	-133.79	0	68.2752304
21	No	68	70	-214.48	-66.225	68.0486755
22	Yes	62	70	-269.22	0	67.2720108
23	Yes	62	70	-314.87	0	66.7780151
24	Yes	62	70	-350.42	0	66.3122864

The Results of the calculated heat extraction rate compared with the cooling load are shown in Figure 2.7, and the space air temperature's profile is shown in Figure 2.8.

From the Figure 2.8, it is clearly shown that the zone space air temperature floats between 68°F and 70°F during the normal operating period, and between 50°F and 70°F during the set back period.

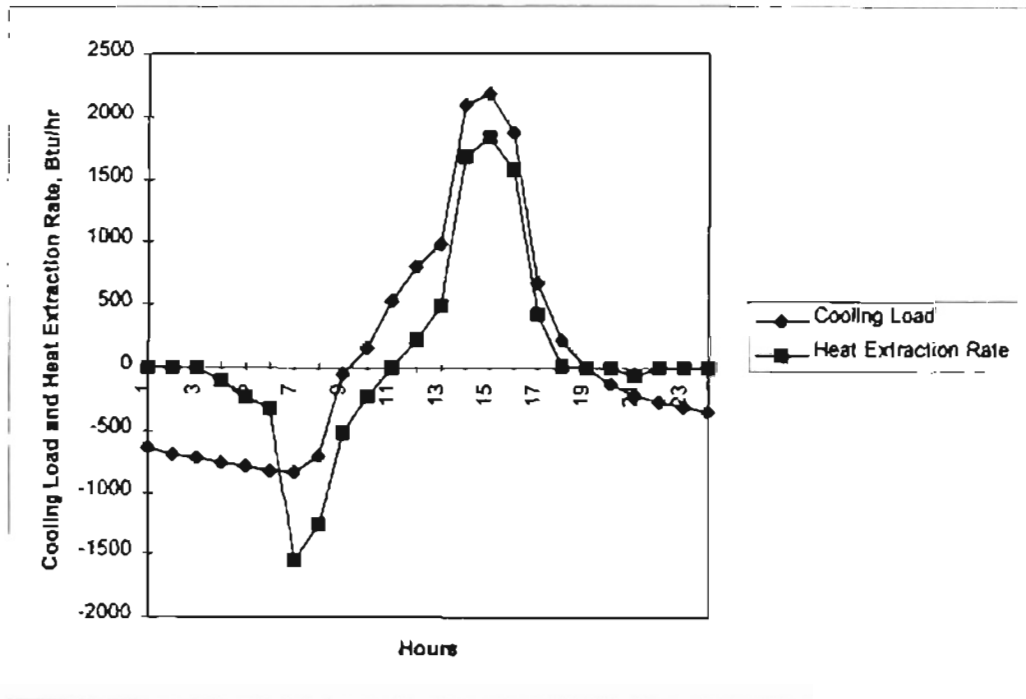


Figure 2.7 Heat Extraction Rate Results for the Example

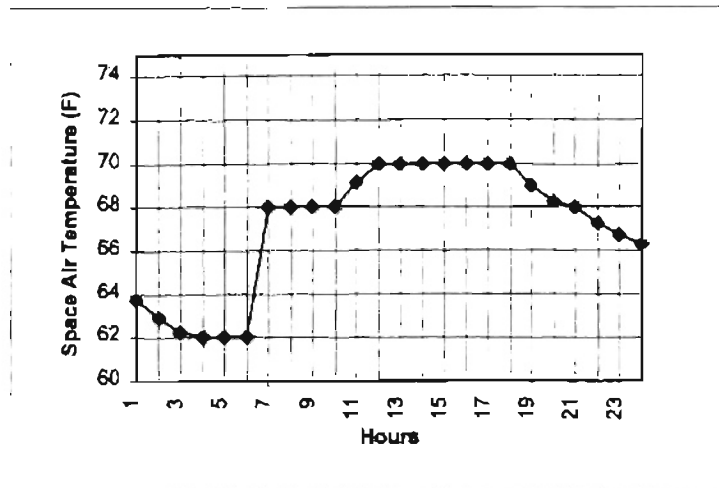


Figure 2.8 Space Temperature Results for the Example

### **2.3 Annual Energy Analysis**

There are two major calculation loops in the annual energy simulation. One is the month loop. During this loop, the program performs the annual simulation from the beginning month to the end month, which can both be specified by the user. Inside the month loop, there is another loop which is the day calculation loop. In this loop, the program performs the daily calculations from the beginning date to the ending date of that month. If the current month is either the beginning month or the end month, then the start and stop days may be specified by the user. Otherwise the daily calculations will be executed from the first day to the end day of that month. During the daily calculation loop, the cooling loads for 24 hours of each day are calculated by using the transfer function method.

The flow chart of the building annual cooling load calculation is illustrated in Figure 2.9.

### 2.3.1 Weather Data for the Annual Simulation

Outdoor weather information during a typical design year is recorded on a companion weather file for each specific design location. For a specific location, the HVAC weather data file is created by using BLAST(1992) "Weather Information File Encoder(WIFE) program" to process the weather data tapes. Raw weather data tapes obtained from the National Climatic Center of National Oceanic and Atmospheric Agency(NOAA) and other sources. The weather data file formats, such as "TRY", "TMY", "1440, T1440", "SOLMET" and etc., can be processed by the WIFE program. One hour is used as the time step in the HVAC weather data file. There are 8760 hours ( $365 * 24$ ) in a typical year. The time period of 12:00 midnight to 1:00 am is defined as hour 1 in the weather file. Temperature is sampled at the midpoint of each hour. For each hour, the weather file contains the following data:

- outdoor dry bulb air temperature
- outdoor specific humidity
- beam solar radiation in normal direction
- diffuse solar radiation
- ambient ground reflective solar radiation

As mentioned above, there are 8760 hours in a standard year. In the annual energy simulation, the calculation is performed day by day. At the beginning of each day's calculation, the program finds out the reading position for the first hour of that day and then reads weather data for the next 24 hours. When the calculation of that day is done, the program reads the weather data of the next 24 hours and starts the calculation for the next day. Figure 2.9 is a flow chart for the annual analysis.

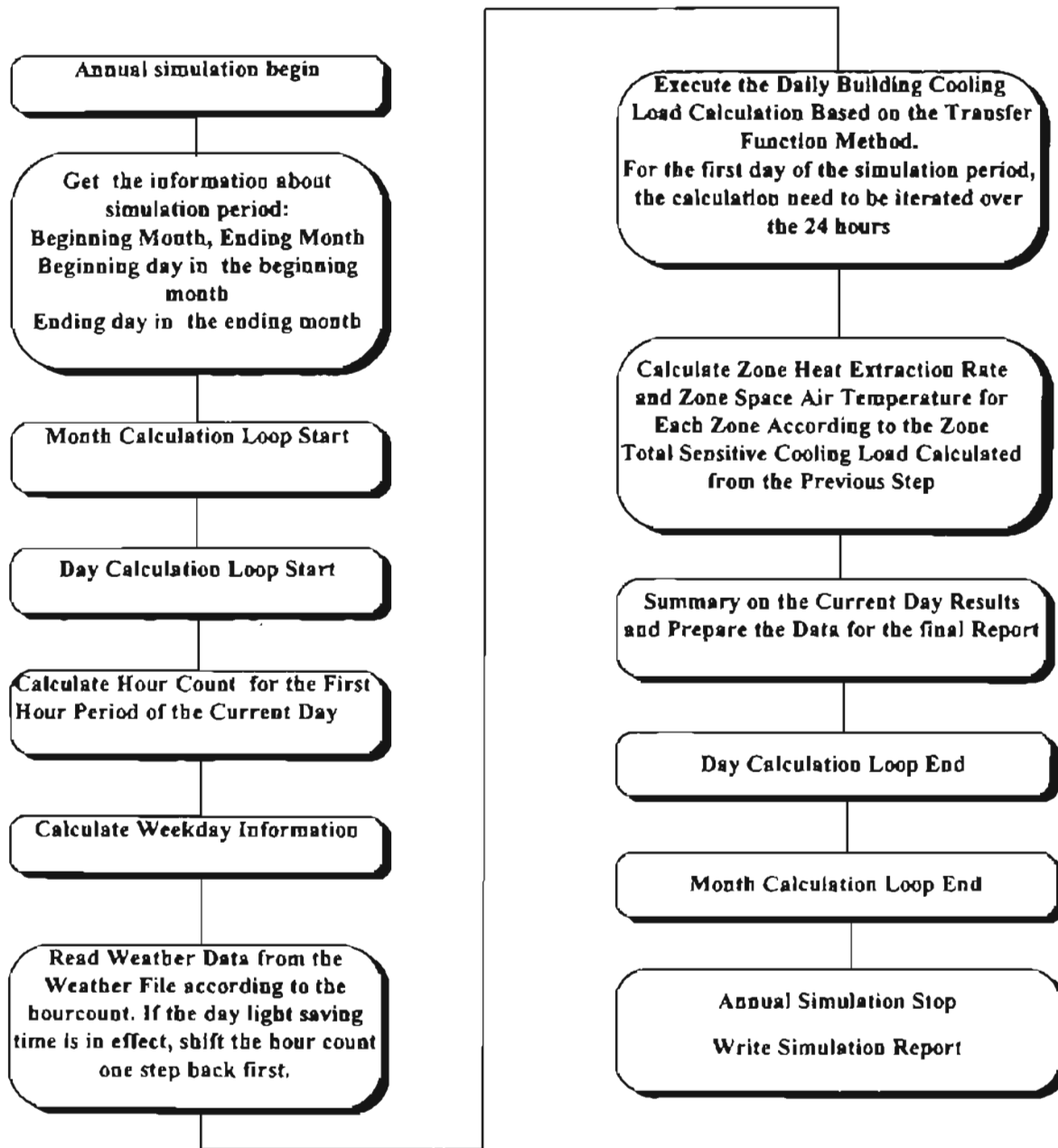


Figure 2.9 Annual Simulation Flow Chart

### 2.3.2 Solar Time Calculation

The time used in the weather file is standard local time. During the annual simulation, when daylight savings time is in effect, the program will convert it to local standard time first, and then calculate the actual hour position to extract the weather data from the weather file.

At the beginning of each daily calculation, the hour of the year is calculated first, in order to locate the correct position to extract the weather data from the companion weather file.

The hour calculation follows the steps below:

1) Determination of current month and current day:

Information is obtained from the loop accumulating value.

2) Calculate the number of days before the current month:

$$\text{number of days before current month} = \sum_{i=0}^{\text{current month}-1} \text{days in month}[i] \quad (2.9)$$

where:

i: the month count;

days in month[i]: the regular day's number in month i,

e.g. days in month of January is 31 and of February is 28, etc.

3) Calculate the day's number before the current day:

$$\text{number of days before current day} = \text{days before current month} + \text{current day} - 1 \quad (2.10)$$

4) Calculate hour count:

$$\text{hour count} = \text{number of days before current day} * 24 \quad (2.11)$$

5) Calculate the weekday information of the current day (which is used for schedule

assignment:

$$\text{weekday} = \text{the remainder of } (\text{number of days before current day} / 7) \quad (2.12)$$

where: 0 stands for Sunday, 1 for Monday, 2 for Tuesday and so on.

The hour and weekday calculation is illustrated in the following example:

### Hour Count and Weekday Calculation Example:

Suppose the current calculation date is June 21st. Find the hour count and the weekday information:

Solution:

- The day's number before current month is the summation of the days number in each month before, by using equation (2.9):
- day's number before current month =  $31 + 28 + 31 + 30 + 31 = 151$
- By equation (2.10), the day's number before current day is  $151 + 21 - 1 = 170$ .
- Substitute 170 into equation (2.11), the hour count is  $170 * 24 = 4080$ .
- From Equation (2.12), the value of weekday is  $170 \% 7 = 2$ , which represents **Tuesday**.

All necessary time information about the current day is calculated in the above procedure. The value of the hour count will be used to read weather data from the weather data file. The weekday value will be used to assign schedule to schedule load components and the zone A/C system.

### 2.3.3 Solar Irradiation Calculation

Differing from the procedure used in the design day calculation, the solar irradiation values in the annual simulation employ the source data from the weather file directly.

Weather data of solar irradiation from the weather data file includes:

- Solar beam radiation in normal direction ( $I_{ND}$ )
- Solar diffuse radiation incident on horizontal surface ( $I_{d,H}$ )
- Ground reflected solar radiation ( $I_{GR}$ )

In the design day solar irradiation calculation, the ASHRAE Clear Sky Model(1993) is employed to derive the values of the above three terms. For the annual simulation, these values are available directly from the weather file. For an exterior



surface with a particular orientation, the beam radiation ( $I_D$ ) on a certain surface is determined by

$$I_D = I_{ND} \cos \theta \quad (2.13)$$

where:

$\theta$ : incidence angle of beam radiation on that surface for the mid-point of each hour period. If  $\cos \theta \leq 0$ , then the beam radiation is treated as zero.

In the design day clear sky solar radiation calculation for a vertical surface, if the  $\cos \theta$  is greater than -0.2, the ratio of the diffuse radiation incident on the surface to that on a horizontal surface with same area can be calculated by equation (Threlkeld, 1963):

$$Y = 0.55 + 0.437 \cos \theta + 0.313 \cos^2 \theta \quad (2.14)$$

Otherwise the  $Y$  will be set to a constant value of 0.45. For the surfaces with any other tilt angle,  $Y$  value is calculated using an isotropic sky assumption:

$$Y = (1 + \cos \alpha) / 2 \quad (2.15)$$

where:

$\alpha$ : the surface tilt angle:  $90^\circ$  for vertical surface and  $0^\circ$  for horizontal.

During annual simulation, because the real weather data is applied instead of using clear day model, the  $Y$  value is calculated by using Formula 2.15 for surfaces with all tilt angles.

The diffuse radiation from sky incident on a surface ( $I_d$ ) is

$$I_d = I_{d,H} * Y \quad (2.16)$$

Because the ground reflected solar radiation can be extracted directly from the weather data file, the diffuse radiation from ground incidenting on a surface ( $I_g$ ) can be calculated by using the formula 2.17.

$$I_g = I_{GR} * (1 - Y) \quad (2.17)$$

The total solar irradiation(I) on a specific surface will be calculated by the summation

$$I = I_D + I_d + I_g \quad (2.18)$$

The total solar irradiation on a certain surface is then used in the following equation (McQuiston and Spitler, 1992) to find out the surface hourly sol-air temperature( $t_e$ ).

$$t_e = t_o + \alpha \frac{I}{h_o} - \frac{\epsilon \Delta R}{h_o} \quad (2.19)$$

where:

- $t_o$  : the outdoor air dry bulb temperature
- $\alpha$  : the surface absorptance to solar irradiation;
- $\epsilon$  : the surface hemispherical emittance;
- $h_o$  : exterior combined surface coefficient;
- $\epsilon \Delta R / h_o$  : the longwave radiation factor;

When the hourly surface sol-air temperature is determined, it will be used in the wall conduction heat transfer calculation following the same procedure used in the design day cooling load calculation.

#### 2.3.4 Daylight Saving Time Adjustment

Generally, in the United States, daylight saving time is supposed to begin on the first Sunday of April and terminate on the last Sunday of October. In the HVAC program,

it is always assumed that the first day of a year is Sunday. According to this assumption, the annual energy simulation will be executed under daylight savings time during the period between day count of 119 and 302, which represents the first Sunday in April and the last Sunday in October, respectively.

Whenever the daylight savings time is encountered at the day count of 119, during the annual energy simulation, the hour count, which is used to extract the weather data from the weather file, will be shifted one hour earlier to make the time alignment in the program compatible with that in the weather file. When daylight saving time is ended at the day count of 302, the hour count will be shifted one hour back to extract the weather data.

### **2.3.5 Heat gain, Cooling Load Calculation for the first day**

Using the transfer function method to calculate heat gain and cooling load, some previous values are involved in the calculation. Obviously, however, for the first day of an annual simulation period no history data is available. Initially these data values are assigned to be zero. After the calculation for the first 24 hours is done, the values of the last few hours of that day are then used as the initial set of values for the next iteration on the first day calculation. The iteration is continued over the 24 hour period until the results converge to a steady periodic solution. This iteration procedure is used for all calculations on the heat gain and cooling load for the first day of an annual simulation.

In the annual simulation, when the calculation of the first day is completed, all history values become available from the previous results, and the iteration is no longer needed. In the annual simulation procedure, there is an identifier which indicates if the current calculation day is the first day of the simulation period. If it is, the program executes the iteration and checks the convergence, if it is not, program just takes the results of previous day and assigns it to the history terms.

### 2.3.6 System Coil Load Calculation

In the HVAC program, the system heat extraction rate calculation is based on the total sensible system coil loads. The system coil load is the summation of the space cooling load and some extra loads caused by system operation, such as heat gain from the fan motor and heat gain from outdoor fresh air due to ventilation. In this project, the sensible and latent heat gain due to ventilation are taken as part of the system coil load. In order to provide satisfactory IAQ, the outdoor fresh air is generally mixed with recirculated conditioned air and then supplied to the conditioned space. The minimum requirement of outdoor fresh air for certain representative buildings is discussed in Chapter 23, ASHRAE (1993). The ventilation air is generally treated by the A/C system, so the heat gain caused by ventilation is not a part of room heat gain. Therefore this part of heat gain should be added directly to the system coil load instead of space cooling load.

In the current HVAC program, the volumetric flow rate of outdoor air (ODA) can be defined for each zone. To define the ODA, the user needs to specify the maximum volume flow rate of the system total supply air, the maximum volume flow rate of outdoor fresh air, ventilation design day operation schedule and ventilation annual operation schedule. The ventilation schedule specifies the hourly fraction percentage of the peak amount of the outdoor air flow rate.

What need to be emphasized is that bringing in ODA generally introduces extra outside air to the space by electrical fan, that results in that inside room pressure being higher than that of ambient. Therefore, the part of infiltration may significantly reduced(ASHRAE, 1993). The interaction between a ventilation and infiltration involved in a single zone should be considered carefully during building description procedure.

The sensible and latent cooling loads calculation for ventilation follows the same procedure as infiltration calculation. The equation for calculating sensible cooling load due to ventilation is

$$Q_{\text{sensible}} = 1.10 * (T_o - T_i) * V \quad (2.20)$$

where:

$Q_{\text{sensible}}$  : The sensible cooling load due to ventilation (Btu/h)

$T_o$  : out door air dry bulb temperature (°F)

$T_i$  : indoor constant design temperature (°F)

$V$  : volume flow rate of outdoor fresh air caused by ventilation (cfm)

The equation for calculating latent cooling load due to ventilation is

$$Q_{\text{latent}} = 4840 * (W_o - W_i) * V \quad (2.21)$$

where:

$Q_{\text{latent}}$  : The latent cooling load due to ventilation (Btu/h)

$W_o$  : outdoor air specific humidity (lbmv/lbma)

$W_i$  : indoor air design specific humidity (lbmv/lbma)

When the value of  $Q_{\text{latent}}$  is positive, it will be added to the system cooling load. Otherwise, it will be added to the system heating load.

The hourly ventilation sensible and latent cooling loads are calculated for each zone and then added to the zone sensible and latent cooling loads, respectively, to make up the zone system coil sensible and latent cooling loads.

The one problem with this approach is that it assumes a fixed indoor air specific humidity. In actuality, the humidity may float up or down. The actual humidity level depends on the infiltration, ventilation, internal latent heat gain, water adsorption/absorption in the building mass, and the heat pump operating characteristics. A more detailed model could be utilized to better estimate the latent coil loads. This is an area for future research.

### **2.3.7 Summary on the Annual Simulation Results**

In order to prepare the final report of a building annual energy simulation, results need to be collected during the simulation. The following information was extracted from the calculation:

- Zone total cooling load (heat extraction rate plus latent cooling load) for each month
- Zone peak hourly cooling and heating load and corresponding times of occurrence
- Building total monthly cooling load
- Building peak hourly cooling and heating load and corresponding times of occurrence
- Building peak hourly load for each month

In HVAC program, a zone is defined as a conditioned space which is controlled by a single thermostat. The hourly cooling or heating load results for each zone will be different with each other. Therefore, the peak load occurring time for a single zone may or may not be the same for the whole building.

The building total monthly cooling and heating load and the peak hourly load for each month will be used to create ".GLL" file, which will be used directly as the GLHEPRO (Spitler, et al., 1996) input data file to simulate the ground loop heat exchanger performance.

## ***2.4 On Line Global Schedule Library***

### **2.4.1 Load Schedule and System Schedule Overview**

In order to perform the annual energy analysis, miscellaneous load components' schedules have to be taken into account during the calculation. In contrast to the design day calculation, the schedule for the annual simulation may become much more complicated and realistic. The load schedule is the schedule related to the building loads components, while the system schedule is the schedule related to the A/C system control profile. To define a schedule for an entire year, a hierarchical schedule data structure is

established which can extract from and save schedule data to a global schedule library. The global schedule library could be categorized into annual, weekly and daily libraries.

### 2.4.2 Annual Schedule Library

For the annual building load calculations, each element has a field for holding a name of an annual schedule. An annual schedule is defined by the user and is stored in the annual schedule library. The schedules saved in the annual schedule library are globally useable.

The data structure which is used to hold an annual schedule data is defined below in “struct.h” file:

```
typedef struct
{
    char        name[20];
    int         begin_date[4], end_date[4];
    char        week_schedule_name[4][20];
    HANDLE     hNext;
} annual_schedule;
```

The first field, “name”, holds the name of a specific annual schedule. The number of characters for a schedule’s name could be as many as 20.

An annual schedule can have as many as four periods of time with different weekly schedules. These four time periods can not be overlapped. For each time period, the user should define a beginning date (month and day) and an ending date. Beginning and ending dates are transferred to an integer number of days count (0 ~ 365) and saved in the fields of “begin\_date” and “end\_date” in the annual schedule data structure.

Also, for each time period, there is a field which can hold the name of a weekly schedule. This field is defined as a matrix type which can save four names of different weekly schedules for different time periods.

Annual schedules are extracted from the annual schedule library at the beginning of the execution of the program. During the program running time, the annual schedule exists as a linked list of annual schedule structures, and user can add new schedules to the list or delete schedules from the list. Before the termination of the program, if the schedule list is changed during the current execution, the user will be prompted if the schedule needs to be saved. If the answer is “Yes”, the global annual schedule library will be updated.

### 2.4.3 Weekly Schedule Library

As mentioned above, the annual schedule can hold as many as four different time periods, and for each time period, the weekly schedule is different. In the annual schedule data structure, these different weekly schedule are represented by the names of the weekly schedule.

Similar to the annual schedule, the weekly schedule holds a different schedule name for each day of a week. There are seven days in a week, from Monday to Sunday, and for each of them, the user can define a daily schedule name for that specific day.

The data structure of a weekly schedule is outlined below in the “struct.h” file:

```
typedef struct
{
    char name[20];
    char day_schedule_name[7][20];
    HANDLE hNext;
} week_schedule;
```



The "name" field holds the name of each weekly schedule. For each different week day, the weekly schedule also saves a daily schedule name in a field of matrix type.

The data of weekly schedules are stored in the weekly schedule library. During the starting of the program, weekly schedule data are extracted from the global library and stored in the weekly schedule's linked list. When necessary, the user can define new weekly schedules to the linked list. When the user intends to delete a weekly schedule from the linked list, the program will check if this weekly schedule is currently used by any higher level schedule (annual schedule). If it is used by any annual schedule, the delete action will not be allowed. This protection is necessary, because during the annual simulation, schedule load elements just hold the name of a annual schedule, and from this point, program has to find out all weekly schedules and then the daily schedules for this annual schedule. Only the daily schedule holds the value of each schedule's hourly fraction which will be used in load calculation.

When the program is terminated, all weekly schedules in the weekly schedule linked list can be saved to the weekly schedule library if the user wants to update the schedule library.

#### **2.4.4 Daily Schedule Library**

The daily schedule is the most basic schedule. It is used directly in the load calculation procedure to determine the actual load of an element or the state of an air-conditioning system.

There are two different types of daily schedules in the HVAC program. One is for the building element's cooling load calculation-"load daily schedule", and another is for the heat extraction rate calculation-"system daily schedule".

A load daily schedule for cooling load calculation holds the percent value of each hour based on the element's peak load. For example, if the user defined a "light" type element with a peak load of 100 Btu per hour, and the schedule percent value of hour

19:00 is 50, than for the hour 19:00, the actual element's load is 50 Btu per hour, and so on.

The system daily schedule for the heat extraction rate calculation hold the state parameter of the system for each hour of a day. There are two different states of an air-conditioning system defined in the HVAC program. One is normal operating state, and another is set back state.

#### **2.4.5 Schedule Library Scope Discussion**

In the current development of the program, the global schedule library is shared by all buildings which are currently opened by the HVAC window. If the user deleted some schedules from the global library, and the schedule is used by another building simulation, then when the user begins the calculation of that building, the HVAC program will tell the user that some schedule used by the current building does not exist in the global schedule library. Then the user must define the schedule again.

## Chapter III

### User Interface Modification

#### ***3.1 Overview of User Interface Modification in HVAC***

The HVAC load calculation program was originally developed under Microsoft Windows™ environment. A convenient way is provided for the user to input building description data and to specify an execution command through a graphical user interface. In order to perform an annual simulation, some extra data need to be defined by the user through user interface. In addition to the existing user interface in the old version of the HVAC program, some new features are added to complete the building annual energy simulation.

#### ***3.2 Dialog Boxes serving Main Application Window***

##### **3.2.1 Annual Simulation Setup Dialog Box**

The annual simulation setup dialog box is shown in Figure 3.1.

The user should specify the simulation period, weather file and reporting level before executing the building annual cooling load simulation. The major fields in the annual simulation setup dialog box are described below:

##### "Simulation Period" Edit Group:

The HVAC program has the capability to perform a annual simulation of a typical year from January 1st to December 31st. But for the convenience of the user, who might

like to perform a partial annual simulation, a specific period can be defined by specifying the simulation beginning date and ending date. The program can also check if the simulation period is defined properly by the user.

"Weather File" Specification Group:

In order to perform an annual simulation, the name of a weather file has to be specified by user. The weather file can be located from the current directory or any other directory.

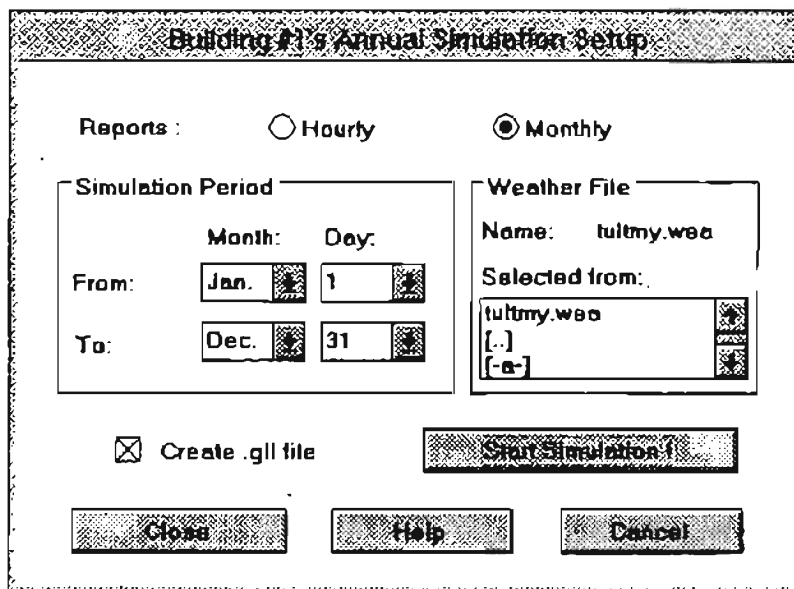


Figure 3.1 Annual Simulation Setup Dialog Box

"Create .gll File" Check Box:

If this button is checked, a ".gll" file, which holds the results of building monthly loads information, will be created automatically after the annual simulation. But an entire year simulation period is required to create a ".gll" file. The ".gll" file is used by the GLHEPRO program(Spitler, 1996).

"Start Simulation" Button:

After the user click this button, the program will begin to execute the annual simulation. The simulation period and the weather file are according to the fields "Simulation Period" and "Weather File", respectively.

"Close" Button:

If the user has defined all items in the annual setup dialog box and prefers not to execute the annual simulation right away, the user can click the "Close" button. The program will then save all options and go back to the main window.

### 3.2.2 Annual Simulation Results Dialog Box

The annual simulation results are displayed in the dialog box shown in Figure 3.2. This dialog box just displays the annual simulation results, but does not accept any input data.

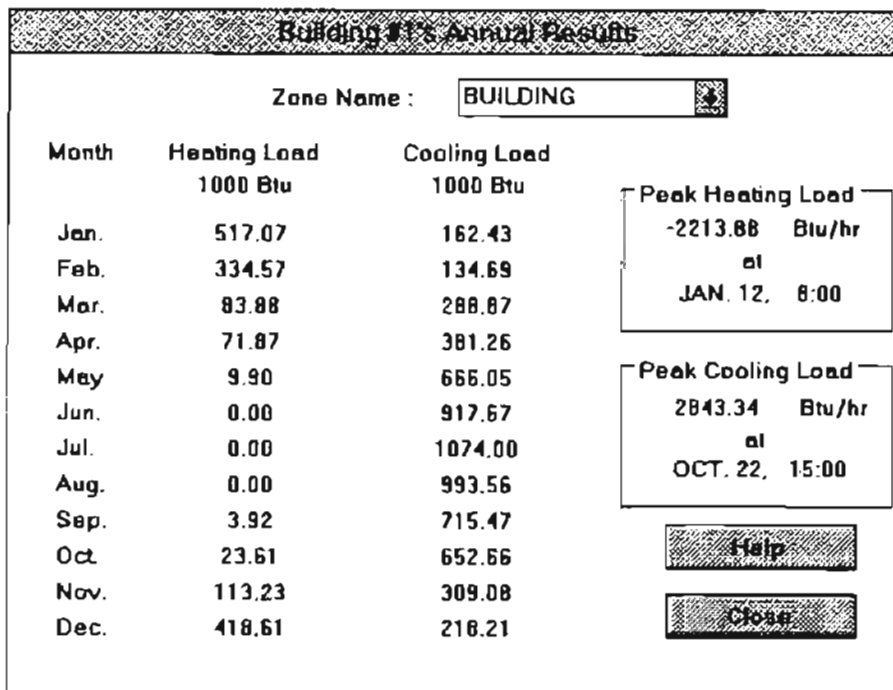


Figure 3.2 Annual Simulation Dialog Box

The monthly total heating and cooling loads of the building are the main results for an annual simulation. In the HVAC program, since the term "Zone" is defined as a space which hold a same space temperature and a unique A/C system, the total monthly loads of each zone may also be of interest to the user.

The annual simulation results displayed in the dialog box shows the total monthly cooling and heating load of the building and zones contained in that building. The peak heating and cooling loads with their occurring time are also displayed in this dialog box.

### 3.3 Dialog Boxes serving Zone Child Window

#### 3.3.1 Ventilation Setup Dialog Box

The ventilation calculation for a zone is one of the new features implemented in the new version of the HVAC program. The ventilation setup dialog box is shown in Figure 3.3.

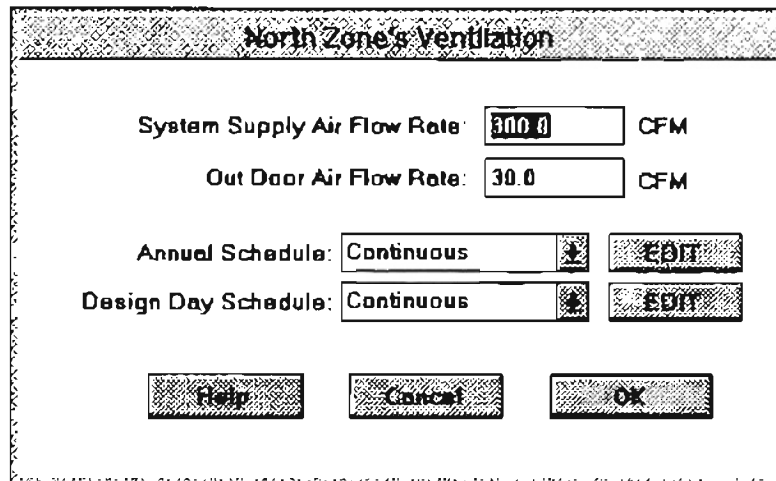


Figure 3.3 Ventilation Setup Dialog Box

To describe the ventilation characteristic of a zone, the user needs to define the following items:

System Supply Air Flow Rate: Defined as the air flow rate supplied by zone A/C system.

Out Door Air Flow Rate: Defined as the flow rate of outdoor fresh air introduced to the space by ventilation.

Annual Schedule: the name of a ventilation annual schedule.

Design Day Schedule: the name of a ventilation design day schedule.

The reason for separating the ventilation schedule from the zone A/C system schedule is that ventilation represents the operation of fan, while A/C system represents the operation of system's cooling or heating.

### **3.3.2 Zone Heat Extraction Dialog Box**

To calculate the zone heat extraction rate using a space air transfer function, the zone construction type and system characteristics have to be defined in the zone heat extraction dialog box. The box is shown in Figure 3 4.

The major fields in the zone heat extraction dialog box are described below:

Room Envelope Construction:

In this field, the user needs to define the construction type of the zone. There are four different radio buttons in this field to specify "Extra light construction", "Light construction", "Medium construction" and "Heavy construction".

Heat Extraction Capacity:

The maximum and minimum cooling load capacities are defined in this field. If the value of minimum cooling load is negative, it represents the maximum heating capacity of the A/C system.

System Throttling:

For each A/C system, one throttling range value has to be defined to calculate the heat extraction rate. It is recommended that this value be larger than 0.1 °F. Otherwise the convergence of the results of the heat extraction rate may become difficult.

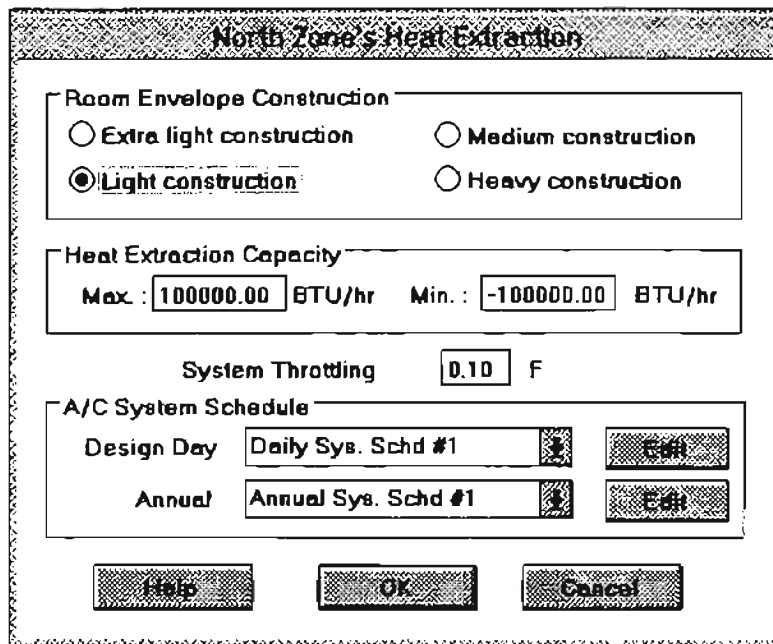


Figure 3.4 Zone Heat Extraction Dialog Box

A/C System Schedule:

In this field, the user can select the names of the A/C system annual and design day schedules from the schedule list boxes. If the schedule requires any modification, then the user can click the "Edit" button and go to the annual or design day schedule editor dialog box.



### **3.4 Dialog Boxes Serving Schedule Editing**

There are several dialog boxes designed for the purpose of editing schedule in the schedule library. They are annual, weekly, daily load and daily A/C system schedule edit dialog boxes. These dialog boxes are shown in Figure 3.5 to 3.8.

There are some common fields used in these dialog boxes, they are "New", "Save", "Save As" and "Delete" buttons.

#### "New" button:

The user can click this button to add a new schedule to the schedule library. After this button is clicked, the dialog box will clear all fields and let the user describe the new schedule. When the user finish the schedule description, he can click the "Save As" button and give the new schedule a proper name. After the "New" button is clicked, the "Save" button will be disabled. The reason is that the new schedule can not be saved to the library before a proper name has been assigned.

#### "Save" button:

When a specific schedule is selected, user can modify the value in the editing fields. After the modification is finished, the user has to click the "Save" button to save it. Otherwise, the modification will not be saved for that schedule permanently.

#### "Save As" button:

This button is clicked when the user defines a new schedule or want to save an existing schedule in a different name. The user then has to provide a proper name in the new schedule dialog box, and click "OK". The schedule with the new defined name will be saved in the global schedule library.

#### "Delete" button:

This button allows the user to delete a schedule from schedule library. If a lower schedule is currently being used by a higher level schedule in the library, then this lower level schedule can not be deleted directly. A warning message box will show up to stop the delete procedure, if the user tries to delete it.

### 3.4.1 Annual Schedule Edit Dialog Box(Figure 3.5)

Annual Schedule edit dialog box can be used for editing both annual load and A/C system schedule library.

In the annual schedule edit dialog box, the user can modify or delete an existing schedule or create a new in the annual schedule library. The major fields in the annual schedule edit dialog box are described below:

#### Weekly Schedule for different periods of a year:

The user can define a maximum of four different weekly schedule periods in a year. For each weekly schedule period, the user needs to specify a weekly schedule name, beginning and ending date of that period. The time periods during a year cannot be overlapped, but the order of the periods can be defined in any way.

**Annual Load Schedule Edit Window**

Annual Schedule Name :      Annual Schd #4

Weekly Schedule for different periods of a year					
	Weekly Schedule Name:	From		To	
		Month:	Day:	Month:	Day:
Period 1:	Weekly Schd #1	Jan.	1	Mar.	31
Period 2:	Weekly Schd #2	Apr.	1	Jun.	30
Period 3:	Weekly Schd #3	July	1	Sept.	30
Period 4:	Weekly Schd #4	Oct.	1	Dec.	31

**Modify Weekly Schedule**

**Annual Schedule Library**

- Annual Schd #1
- Annual Schd #2
- Annual Schd #3
- Annual Schd #4
- Continue
- zero

**Note: The periods of a year can not be overlapped !!**

New

Save

Save As

Delete

Help

Done

Figure 3.5 Annual Schedule Edit Dialog Box

Modify Weekly Schedule:

If the user wants to modify the weekly schedule which is currently highlighted in the annual schedule edit dialog box, he can click on this button and the program will open the weekly schedule edit dialog box. When the modification is finished, the program will return to this annual schedule edit dialog box and will set the highlight back to the weekly schedule which was highlighted before modification.

**3.4.2 Weekly Schedule Edit Dialog Box(Figure 3.6)**

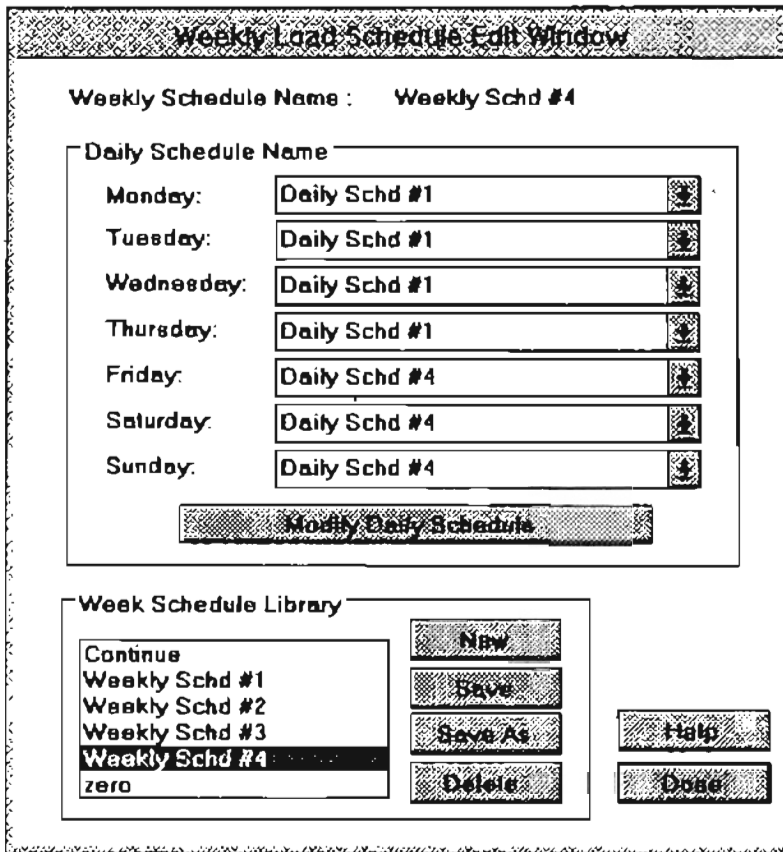


Figure 3.6 Weekly Schedule Edit Dialog Box

Weekly schedule edit dialog box is used for editing both load and A/C system weekly schedule library. The major fields in the weekly schedule edit dialog box are described below:

Daily Schedule Name:

For a weekly schedule, daily schedule name for each weekday needs to be defined. If a load weekly schedule is being edited, daily schedule name will be selected from the daily load schedule library. If a A/C system weekly schedule is being edited, daily schedule name will be selected from the daily A/C system schedule library.

Modify Daily Schedule:

If the user want to modify the daily schedule which is currently highlighted in the weekly schedule edit dialog box, he can click this button to enter load or A/C system daily schedule edit dialog box. When modification is finished, the program will return to this weekly schedule edit dialog box and will set the focus back to the daily schedule which was highlighted before modification.

### **3.4.3 Daily Load Schedule Edit Dialog Box(Figure 3.7)**

For a daily load schedule, the user needs to define the fraction value for each hour which multiples to the peak load of the load components or ventilation. There are 24 scroll bars in the load daily schedule edit dialog box. Whenever the 24 fraction values are defined properly, the user can click on the "Save" button and save the schedule to the global library. The user also can click the "New" button to create a new load daily schedule.

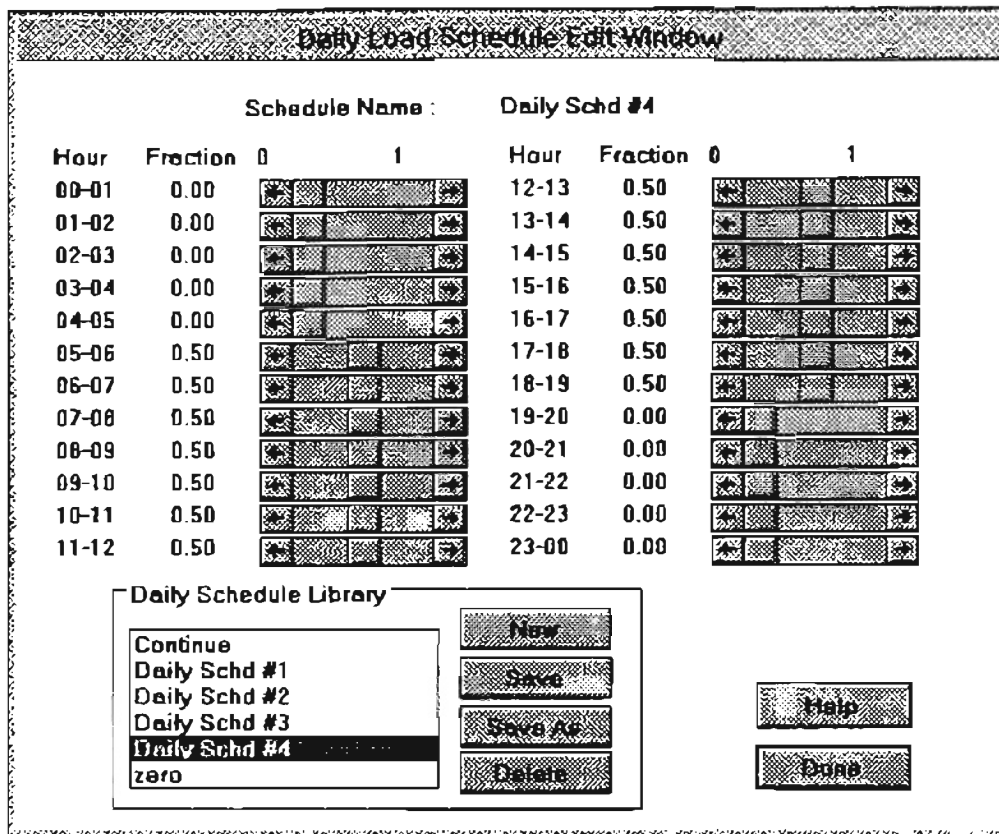


Figure 3.7 Daily Load Schedule Edit Dialog Box

### 3.4.4 System Daily Schedule Edit Dialog Box(Figure 3.8)

For a system daily schedule, the user needs to define the system operation state of a A/C system for 24 hours. There are two different system operation state for each hour, which are "Normal Set" and "Set Back". The user also needs to specify the high and low set point temperatures for both "Normal Set" and "Set Back" operation states, and these values can be specified in the fields "Set Point Temperature" and "Set Back Temperatures". The high and low set point temperatures have to be defined properly by

the user. In other word, the low set point temperature can never be higher than the high set point temperature. Otherwise, a message box will show up to let the user modify the input value.

### ***3.5 Plotting Procedure Modification***

#### **3.5.1 Error Fixing for Original Program's Plot Procedure**

In the original version of the HVAC program, there were several serious errors that showed up during plotting procedure. The phenomenon and fix for these errors are described in the following sections.

##### System memory resource consumed during plotting procedure:

The reason for this is that the program does not delete the object properly after creating it for painting. A painting object has to be deleted immediately after using it, otherwise the system memory will never be freed up even after the application terminates. The new version of the HVAC program can handle this properly, and whenever a plot window is closed, the memory being used will be released immediately.

##### The bit map picture could not show up on the window at correct position:

This is because the position calculation of a bit map was based on absolute window dimension values in the old HVAC program. If the system display setting( like resolution or font) is changed, the previous position calculation will not be able to handle this situation. The solution for this problem is that relative window dimension values be used whenever a bit map position needs to be calculated.

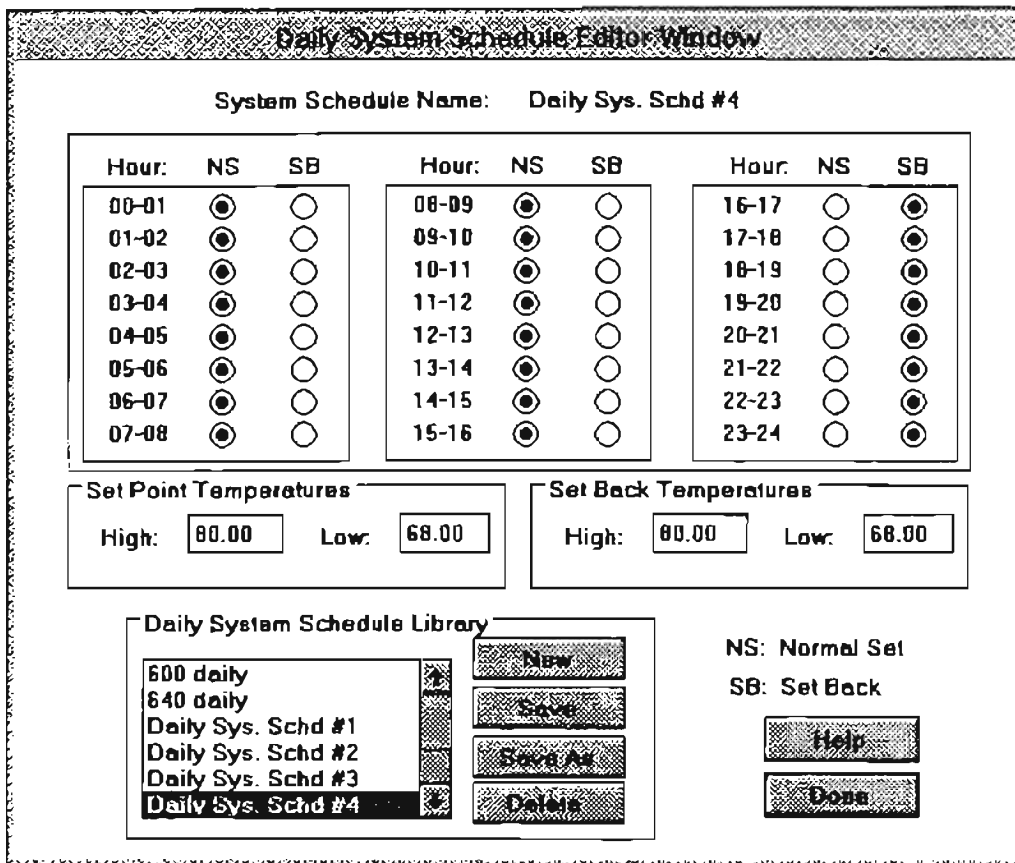


Figure 3.8 System Daily Schedule Edit Dialog Box

### 3.5.2 Plotting Zone Monthly Load Results

In order to show the results of an annual simulation, in the zone window, a plot child window is designed to show the zone monthly results. Monthly total heating and cooling load are displayed in bars with different colors. If the user's mouse pointer points to a particular monthly load bar, the corresponding month and load value of that month will be shown up in the message box on the bottom left corner of the plot window.

This plot window also displays the zone peak heating and cooling loads of that typical simulation year.

### ***3.6 Recommendation on Further User Interface Modification***

The user interface designed in the current version of the HVAC program has met the necessary functionality to let the user complete a building annual energy simulation. And most of the simulation results can be read directly from the interface in a convenient way. Most building description tasks can be done by mouse clicking. In order to make the program have more functionality which can be demanded for a standard Windows™ program, some recommendations are given below for further modification on the HVAC load calculation program's user interface.

#### **Using MDI instead of SDI**

Make the current window to a multiple document interface(MDI) style. The current HVAC window is in single document interface(SDI) style. A building which is currently opened is represented by a icon. If there are several buildings opened at the same time, the switch among these buildings can be done by clicking different building's icons. But when the zone, room or even elements child windows are also opened for some of these buildings, the relationship of these child windows will not be very clear, and leads to making mistakes easily in such a SDI environment. If MDI environment is used instead of SDI, a building is represented as a single document window in the client area, and only one document window is active at any time. Then the logical relationship among building documents will become much more clear. If a building document window is minimized, all related child windows of that specific building will also disappear from the client area.



## Chapter IV

### Validation with BLAST

#### *4.1 Overview*

In order to validate the building energy simulation results calculated by the HVAC program, several validation procedures were performed in this project. Three special test cases were designed to validate the results of both annual and design day building load calculation. They are:

1. A test zone with a single room which includes only one exterior wall, and a constant zone air temperature
2. Load calculation for a real building case which is a two story motel located in Tulsa, Oklahoma
3. BESTEST (Judkoff, et al., 1993) cases involves a more complicated zone. The zone which is located at the top floor includes four exterior walls and a roof. Infiltration and internal equipment loads are also specified. The A/C system served for this zone allows the space air temperature in the zone floating between 68 °F and 80.6 °F. System set back procedure is also performed for these test cases.

The first two validation cases will be discussed in detail in this chapter, and the BESTEST cases will be discussed in chapter V.

## **4.2 Test on a zone with a single exterior wall**

To validate the results carried out by the HVAC program, that uses the transfer function method to perform the building load calculation, the first thing that needs to be focused on is the conduction heat transfer through exterior walls. To eliminate the effects of other load components, the test cases of a zone with a single exterior wall was designed. The test zone is located on the mid-floor of a fictitious building so that there is no heat transfer through the floor and the roof. Furthermore, there are no other building loads in this test zone. Corresponding to a certain design day condition and annual weather data, both design day and annual simulation results calculated by HVAC for Windows™ were compared with the results from BLAST(1991a, 1991b), another building load analysis program which uses heat balance method to perform the building load calculation. BLAST is widely considered to be one of the most accurate building load calculation programs. Empirical validation studies have been reported by Bauman (1983), Carroll (1983), Robertson (1985) and Yuill (1984).

### **4.2.1 Test Building Setup**

A test building which represents equivalent conditions between BLAST and HVAC for Windows is defined as follows:

#### Building's Location:

Tulsa, Oklahoma

longitude: 95.9 degree

latitude: 36.2 degree

Time Zone: 6

#### Design Day Weather Conditions:

July, 21 (Monday)

Out Door Air High Temperature = 98.0 °F

Out Door Air Low Temperature = 74.0 °F

Wet Bulb Temperature = 75.0 °F

Pressure = 400 in. H<sub>2</sub>O

Wind Speed = 788.2 ft/m at direction 0 degree

97.0 percent clear sky

Building Geometry Description:

Floor Area: 15x15 ft<sup>2</sup>

Ceiling Height: 10 ft

Zone Location: Middle floor

Building Components Description:

Exterior Wall: Test Wall Types (Wall types 1,5,11 and 17)

Partition Wall: 3" Batt Insulation with plaster board on both sides

Floor: Midfloor type with light weight

Roof: Midfloor Ceiling without suspended ceiling

Zone Control System Profile Description:

Max. Heat Extraction Capacity: 100000 Btu/hr

Min. Heat Extraction Capacity: -100000(Heating) Btu/hr

Zone Set Point Temperature: 68 °F(constant)

System Throttling Range: 0.05 °F

Annual Simulation Information:

The weather file used for BLAST is "Tultmy.wea", a TMY weather file for Tulsa for a typical year. In HVAC annual simulation, local weather data is extracted from BLAST weather report file, "Tultmy.wot", for the purpose of comparison.

#### 4.2.2 Wall type discussion

Different wall types are used in this single wall test cases. Wall types (1,5,11,17) listed in "Cooling and Heating Load Calculation Manual" (McQuiston and Spitler, 1992) are chosen as sample walls. The layer description of these sample walls is shown in the Tables 4.1 through 4.4.

Table 4.1 Material Distribution for Wall Type 1

Layers	Layer Description	R value( $^{\circ}\text{F}\cdot\text{ft}^2\cdot\text{h}/\text{Btu}$ )
A3(inside)	Steel siding	0
B1	Air space resistance	0.91
B13	4 in. insulation	13.33
A3(outside)	Steel siding	0
Total R Value		14.24
Total U Value		0.0702
Outer Solar Absorptance		0.2
Outer Surface Roughness		Smooth

Table 4.2 Material Distribution for Wall Type 5

Layers	Layer Description	R value( $^{\circ}\text{F}\cdot\text{ft}^2\cdot\text{h}/\text{Btu}$ )
A6(inside)	Finish	0.17
B21	1.36 in. insulation	4.5
C7(outside)	8 in. Lightweight concrete block	2.0
Total R Value		6.67
Total U Value		0.1499
Outer Solar Absorptance		0.65
Outer Surface Roughness		Rough

Table 4.3 Material Distribution for Wall Type 11

Layers	Layer Description	R value( $^{\circ}\text{F}\cdot\text{ft}^2\cdot\text{h}/\text{Btu}$ )
E1(inside)	3/4 in. Plaster or gypsum	0.15
C8	8 in. Heavyweight concrete block	1.11
B6	2 in. Insulation	6.67
A1(outside)	1 in. Stucco	0.21
Total R Value		8.14
Total U Value		0.1229
Outer Solar Absorptance		0.92
Outer Surface Roughness		Smooth

Table 4.4 Material Distribution for Wall Type 17

Layers	Layer Description	R value( $^{\circ}\text{F}\cdot\text{ft}^2\cdot\text{h}/\text{Btu}$ )
A2(inside)	4 in. Face brick	0.43
C2	4 in. Lightweight concrete block	1.51
B15(outside)	6 in. Insulation	20.00
Total R Value		21.94
Total U Value		0.0456
Outer Solar Absorptance		0.5
Outer Surface Roughness		Very Rough

The layers of these wall types described in the above tables do not include the effects of wall's exterior and interior surface combined-coefficients. In HVAC program, all wall and roof's interior surface combined-coefficients are chosen as a constant, equal to  $1.46 \text{ Btu/hr}\cdot\text{ft}^2\cdot^{\circ}\text{F}$ . For Exterior surface, the constant combined-coefficient  $3.0 \text{ Btu/hr}\cdot\text{ft}^2\cdot^{\circ}\text{F}$  is used under all circumstances. In BLAST, the outer surface convective coefficient is a variable that changes with outdoor wind speed and material texture. For comparison

purposes, the exterior surface combined-coefficient is modified during HVAC simulation cases corresponding to different testing conditions.

#### 4.2.3 Exterior Surface Combined Coefficient Setting

To make the test conditions in both BLAST and HVAC simulation as close as possible, the constant value of exterior surface coefficient in the HVAC program was modified depending on the different outer surface material roughness and design outdoor wind speed.

In BLAST program, the ASHRAE(1993) model, which is curve fit formula based on a second order polynomial was used to calculate the exterior surface pure convective coefficient, and the independent variable is outdoor wind speed. The formula has the form(Judkoff, 1993):

$$h_o = a_1 + a_2 \times V + a_3 \times V^2 \quad (4.1)$$

where:

$h_o$ : exterior surface convective coefficient (W/m<sup>2</sup>.K)

$a_1, a_2, a_3$ : curve fit coefficients related to outer surface texture

$V$ : outdoor wind speed (m/s)

The "a" coefficients are shown in the table 4.5(Judkoff, 1993):

The exterior surface convective heat transfer coefficients calculated by Equation 4.1 using design day wind speed is listed in table 4.6, and these values are approximately used as exterior surface combined coefficients in the HVAC annual and design day building load simulations. In the BLAST program, the exterior radiant heat exchange are calculated separately. The results of Equation 4.1 only represents the surface exterior pure convective coefficients. The reason of eliminating the effects of the radiation part is that,

Table 4.5 Coefficients for Calculating Exterior Convective Heat Transfer Coefficient

Material Roughness	$a_1$	$a_2$	$a_3$
Very Rough	11.58	5.894	0.0
Rough	12.49	4.065	0.028
Med. Rough	10.79	4.192	0.0
Med. Smooth	8.23	4.0	-0.057
Smooth	10.22	3.1	0.0
Very Smooth	8.23	3.33	-0.036

when air speed becomes relatively large, the relative effect of the surface exterior radiation heat exchange will diminish. This approximation is suitable for the comparison purposes in this specific project.

Table 4.6 Exterior Combined Coefficient Values for Different Wall Types

Wall Type	Out Surface Roughness	Wind Speed (ft/min)	Ex. Surf Coeff. (Btu/hr. ft <sup>2</sup> °F)
Wall type 1	Smooth	788.2 (4.0 m/s)	3.9834
Wall type 5	Rough	788.2 (4.0 m/s)	5.1418
Wall type 11	Smooth	788.2 (4.0 m/s)	3.9834
Wall type 17	Very Rough	788.2 (4.0 m/s)	6.1910

#### 4.2.4 Validation Procedure

Based on the building description and ambient conditions discussed above, both BLAST and HVAC program are used to execute the design day and annual cooling

load simulation for each exterior wall type. For each wall type, the wall facing angle was also changed (South, North, East and West) so that the effect of solar radiation on the calculated cooling load through the exterior wall can be tested.

Initial Value

- Some explanation for BLAST input:

While using BLAST to perform the test simulation, each layer of the wall is defined as a temporary material. The reason for doing this is to make the comparison condition between BLAST and HVAC as close as possible. A temporary control profile is also defined in the BLAST input to keep the zone space temperature as a constant (68 °F) for both design day and annual simulation period. In BLAST, the floor area should be defined to obtain correct cooling load calculation results based on the heat balance method. Partition wall, mid floor and ceiling are not heat transfer building load components, but heat storage components in BLAST. In BLAST test case input file, the only heat transfer component for the whole zone is an exterior wall. For different wall type tests, the exterior wall's facing angle is modified in the BLAST ".bin" file. The BLAST program is run based on each corresponding .bin file.

- Some explanation for HVAC program input data:

Room parameter definition:

For this specific test case, the only load element defined in the HVAC program is a exterior wall. The partition, floor and other internal heat storage components are represented by the user defined room parameters.

The room parameters defined for these test cases are listed in the table 4.7.



Table 4.7 Room Parameters used by HVAC in the single wall test

inter  
both

Room Parameters	Defined Value
Room Geometry	15 x 15
Room Height	10
# of Exterior Wall	1
Interior Shade	0%
Furniture	Without
Exterior Construction	
Wall Type 1	L.W. with Lt. insulation
Wall Type 5	L.W. with Lt. insulation
Wall Type 11	H.W. with moderate insulation
Wall Type 17	L.W. with moderate insulation
Partition Type	5/8 in. Gyp-Air-5/8 in. Gyp
Room Location	Mid Floor Type
Mid Floor Type	1 in. Wood
Slab Type	Mid Floor Type
Ceiling Type	Without Ceiling
Roof Type	L.W. w/o susp. ceiling
Floor Covering	vinyl tile
Glass Percent	10 %

Exterior Wall Total U Factor:

Exterior Wall total U factor(air to air) used in the HVAC program is chosen as same as the U factor shown in BLAST simulation output file(.bot file). The total U factor in BLAST is calculated based on the wall layer description and surface convective and radiative coefficients. As mentioned previously, the surface exterior convective coefficient is a function of outdoor wind speed and surface texture. The changing of the exterior convective coefficients also affect the surface overall U factor. Moreover, if the effect of

heat storage is eliminated, the U factor is the major variable that causes heat transfer between internal space and ambient . So it is reasonable to use the same U factor in both BLAST and HVAC input data in the test procedures.

#### HVAC summer design day conditions description:

In HVAC, the summer design day is defined by design day's date(month and day), outdoor dry bulb air temperature, mean coincident wet bulb temperature and mean daily temperature range. In BLAST, the design day is chosen from BLAST design day library No. 142, which represents the design day condition of Tulsa, Oklahoma. The high outdoor air DBT is 98 °F and the low outdoor air DBT is 74 °F. In the HVAC summer design day input, the high outdoor DBT of 98 °F and the temperature daily range of 24 °F will represent exactly the same summer outdoor air dry bulb temperature hourly profile as BLAST.

#### **4.2.5 Simulation Results from BLAST and HVAC**

The results of design day cooling load calculation from both BLAST and HVAC are shown in Figures 4.1 through 4.4. The results of annual simulation based on the Tulsa weather data are shown in Figures 4.5 through 4.8.

As shown in the results, the difference between BLAST and HVAC design day and annual simulation are both in acceptable ranges. A detailed discussion of the results is given in section 4.4. But it should be noticed, the exterior surface combined coefficients is modified in HVAC program based on the equation 4.5 for each test case. How does the exterior surface combined coefficient influence the cooling load calculation? There is another simple test introduced to explain this question.

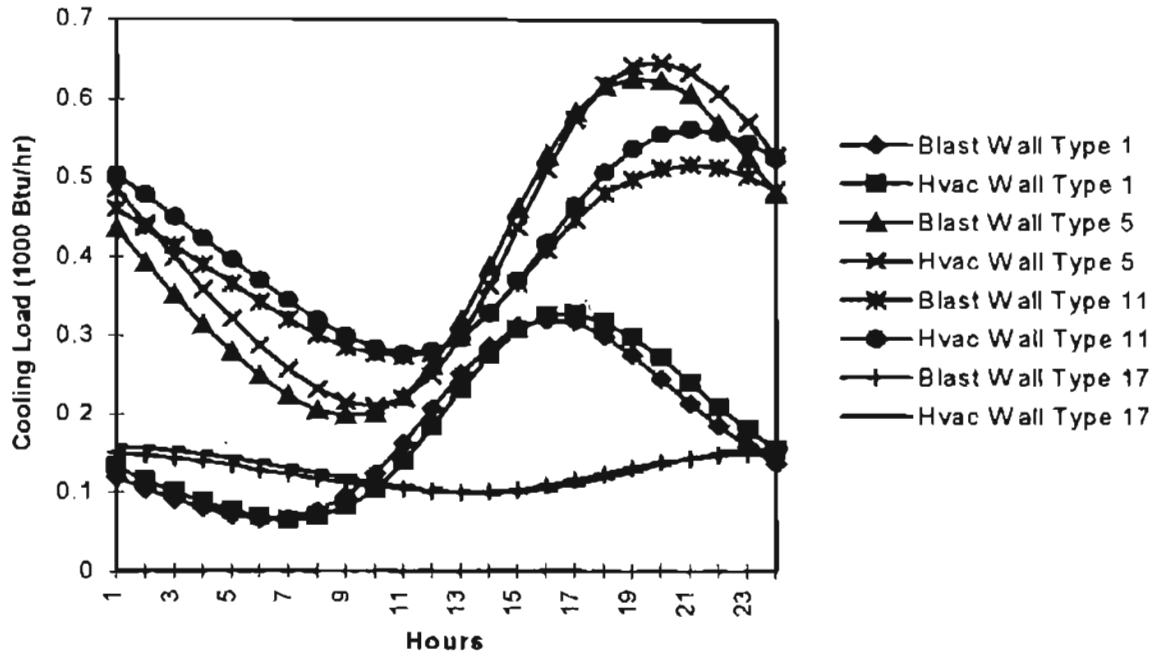


Figure 4.1 South Wall Design Day Comparison for the Single Wall Test

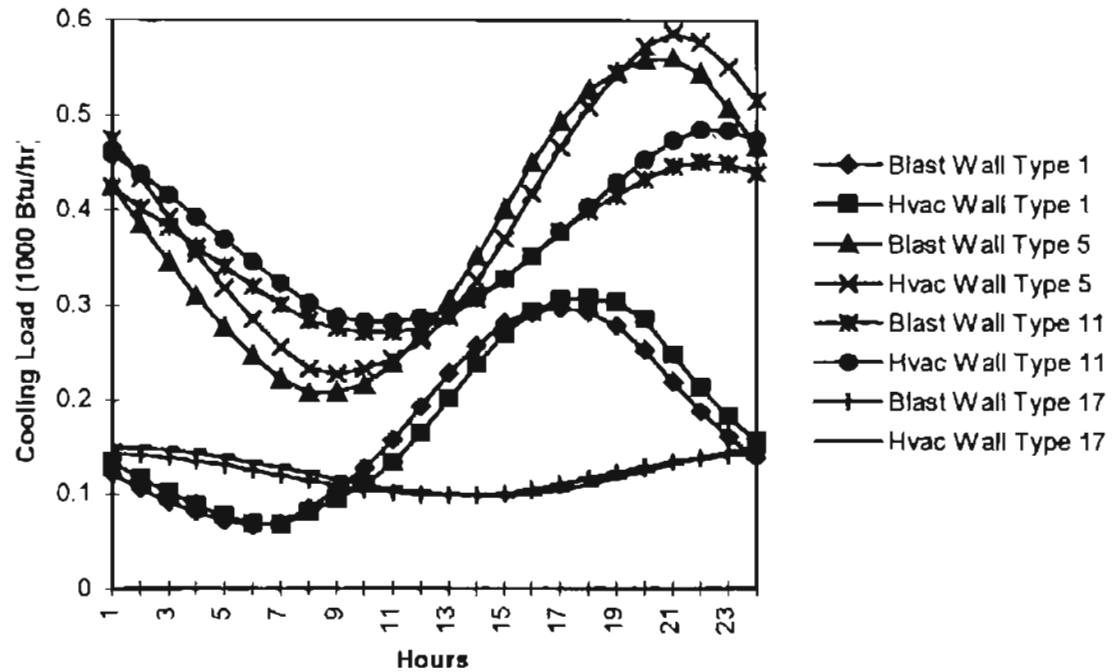


Figure 4.2 North Wall Design Day Comparison for the Single Wall Test

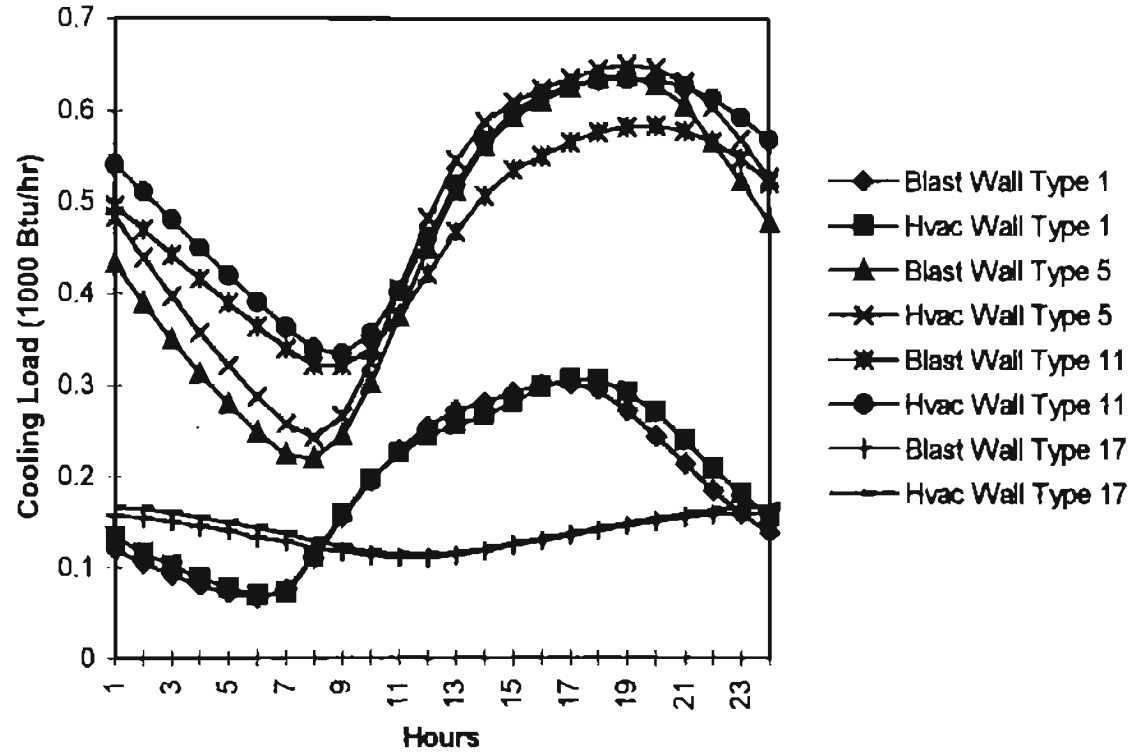


Figure 4.3 East Wall Design Day Comparison for the Single Wall Test

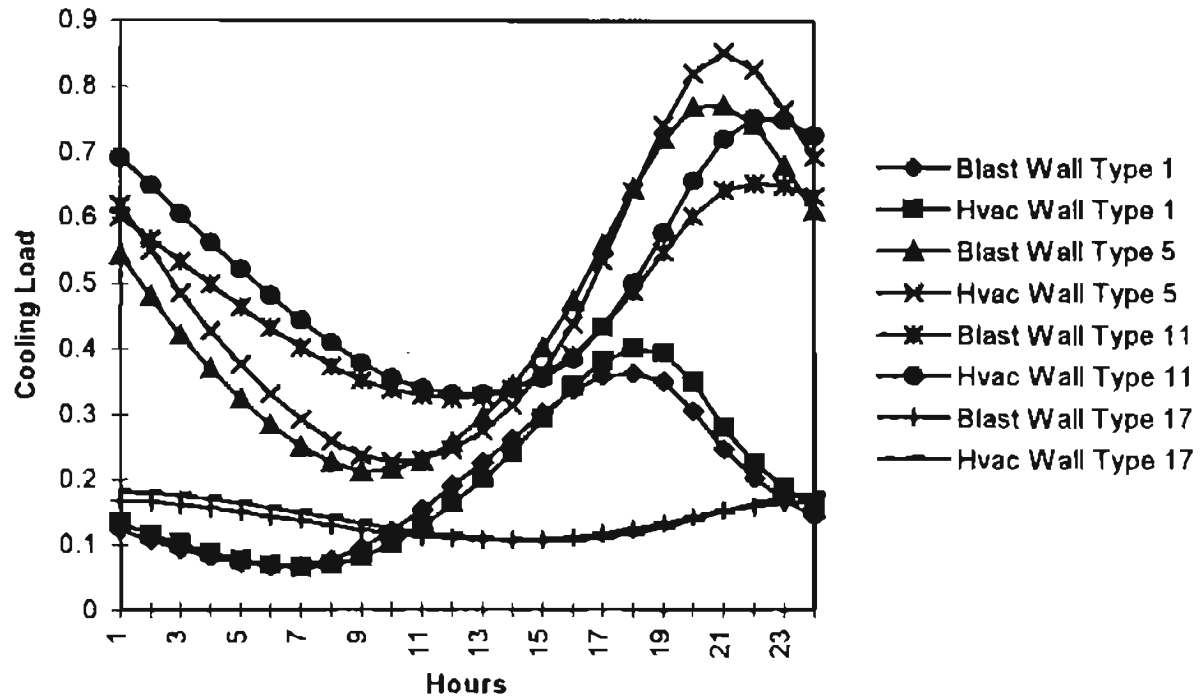
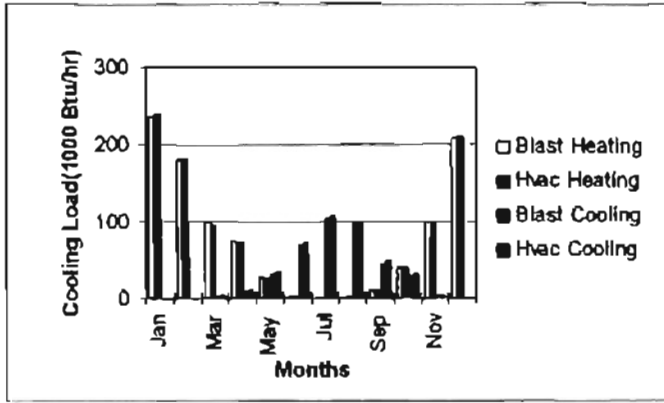
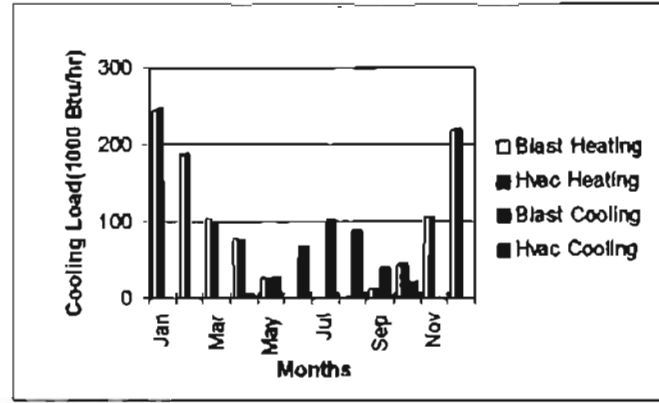


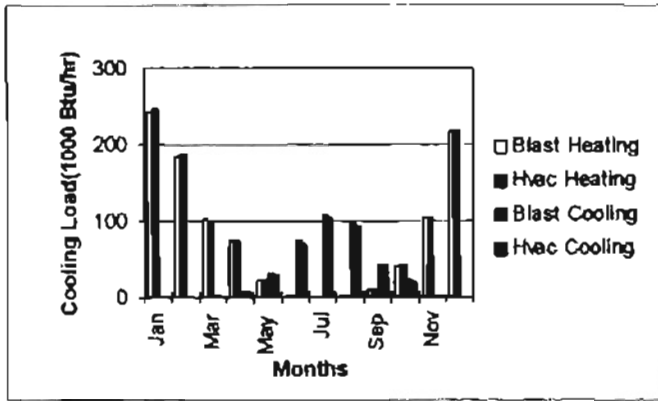
Figure 4.4 West Wall Design Day Comparison for the Single Wall Test



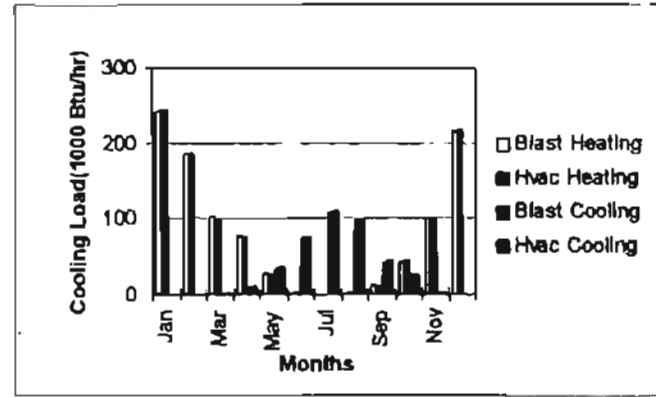
South Wall



North Wall

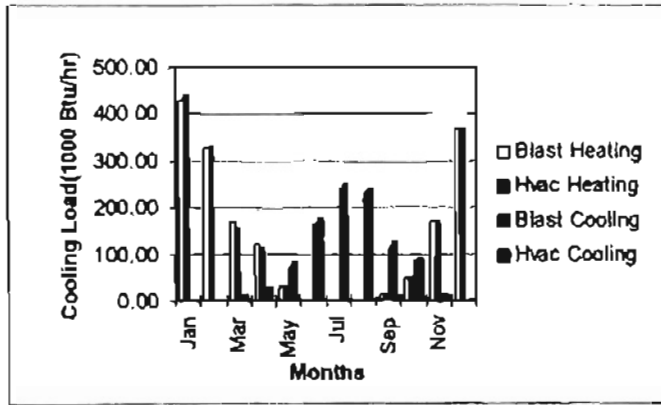


East Wall

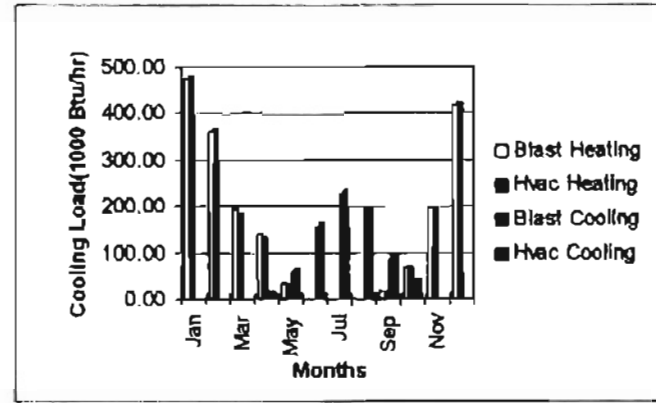


West Wall

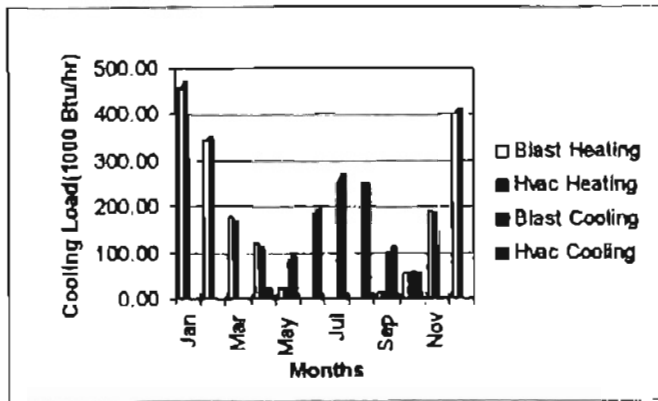
Figure 4.5 Annual Simulation Comparison on Wall Type 1



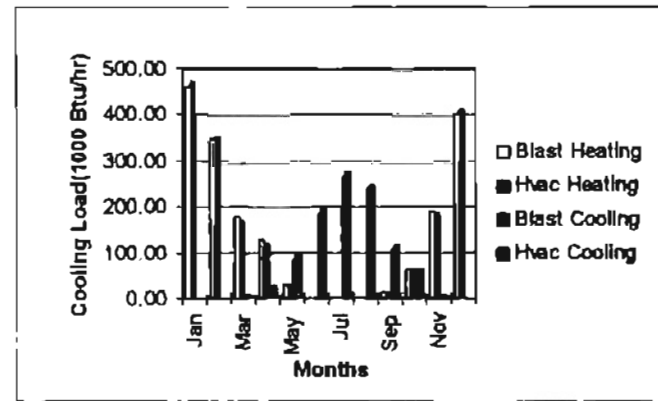
South Wall



North Wall



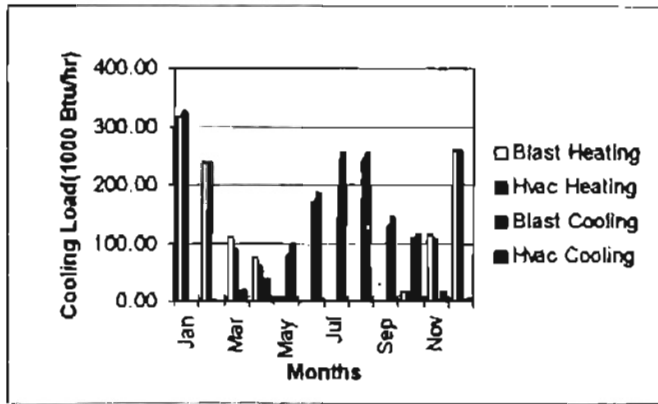
East Wall



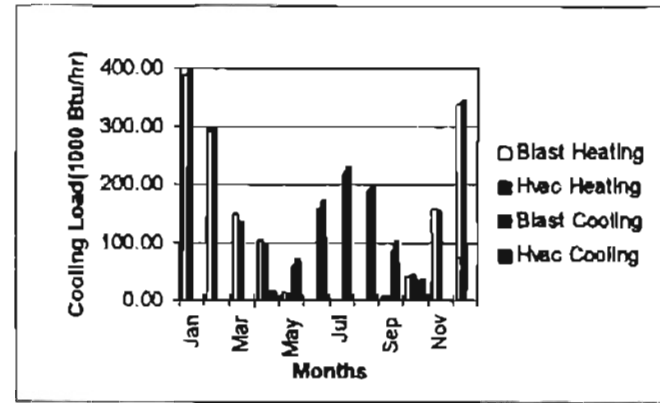
West Wall

Figure 4.6 Annual Simulation Comparison on Wall Type 5

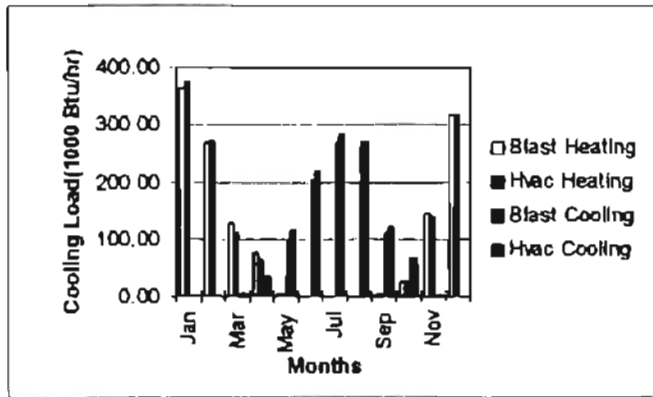




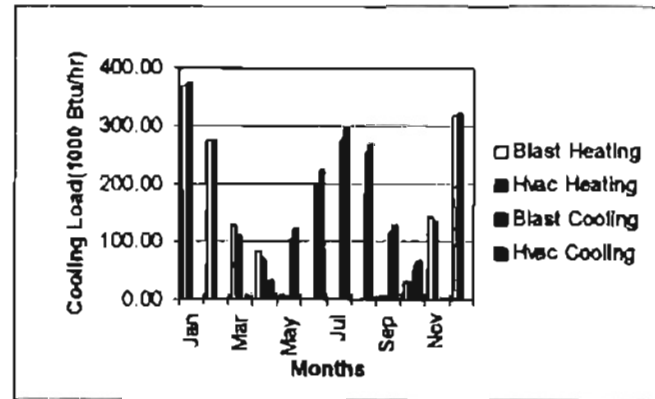
South Wall



North Wall

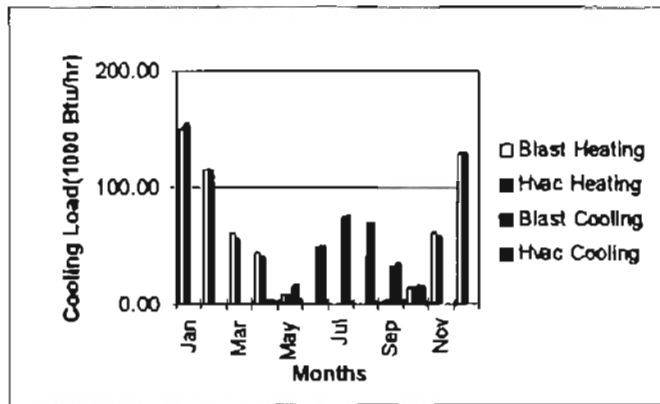


East Wall

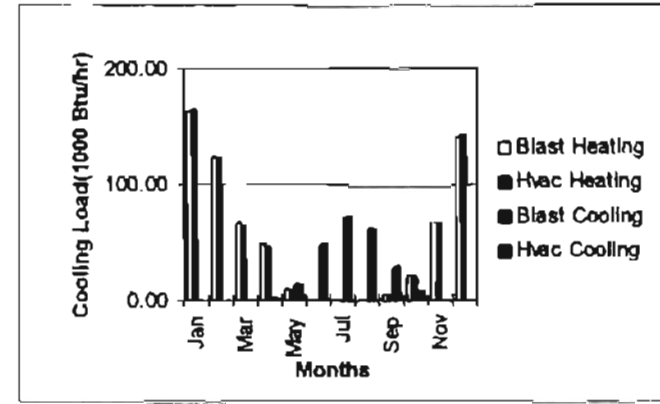


West Wall

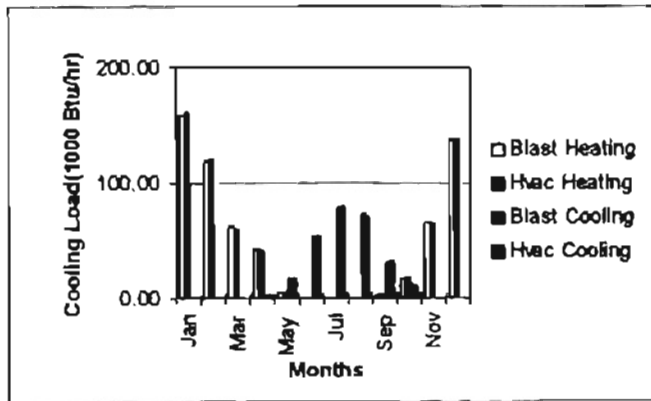
Figure 4.7 Annual Simulation Comparison on Wall Type 11



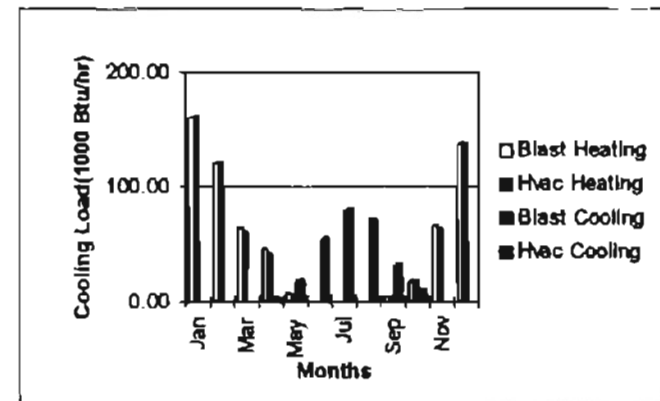
South Wall



North Wall



East Wall



West Wall

Figure 4.8 Annual Simulation Comparison on Wall Type 17

#### 4.2.6 Some Extra Tests on Exterior Surface Coefficients and Window's effects

- Exterior Surface Coefficients Effects:

From the test cases with a zone having a single exterior wall, a special case, "Wall type 1, facing South", was chosen to test the effects of exterior surface combined coefficient. In this test, the exterior surface coefficient is changed from 2 to 7 Btu/hr.ft<sup>2</sup>.°F. The design day cooling load calculation results carried out by the HVAC program are shown in Figure 4.9. From the results of this simple test, it is clearly shown that the peak cooling load reduced when the exterior surface combined coefficient ( $h_o$ ) becomes larger. This phenomenon can be explained by the Equation 1.5. When the value of  $h_o$  becomes larger, the sol-air temperature will become smaller. Furthermore, the sol-air temperature is an important factor that determines the conduction heat gain through the exterior wall.

- Window Effects:

In addition to the conduction heat transfer through exterior wall, another major part of the heat gain due to building exterior surface is the heat gain through window. In order to test the capability to model the thermal process of heat gain through window of the HVAC program, The following test was carried out.

The previous test case, " Wall type 5, facing South", was modified to have a window on the 15 x 10 ft<sup>2</sup> south wall. The dimension of the window is 6 by 4 feet. Design day and Annual conditions are as same as before. The results of annual and design day were obtained from both BLAST and the HVAC program.

The comparison results are shown in Figure 4.10. The shading coefficient approach over predicts the transmitted heat transfer through window. It is desirable to develop a more detailed window heat transfer simulation model. Further discussion can be seen in Chapter VI, "Conclusions and Recommendations".

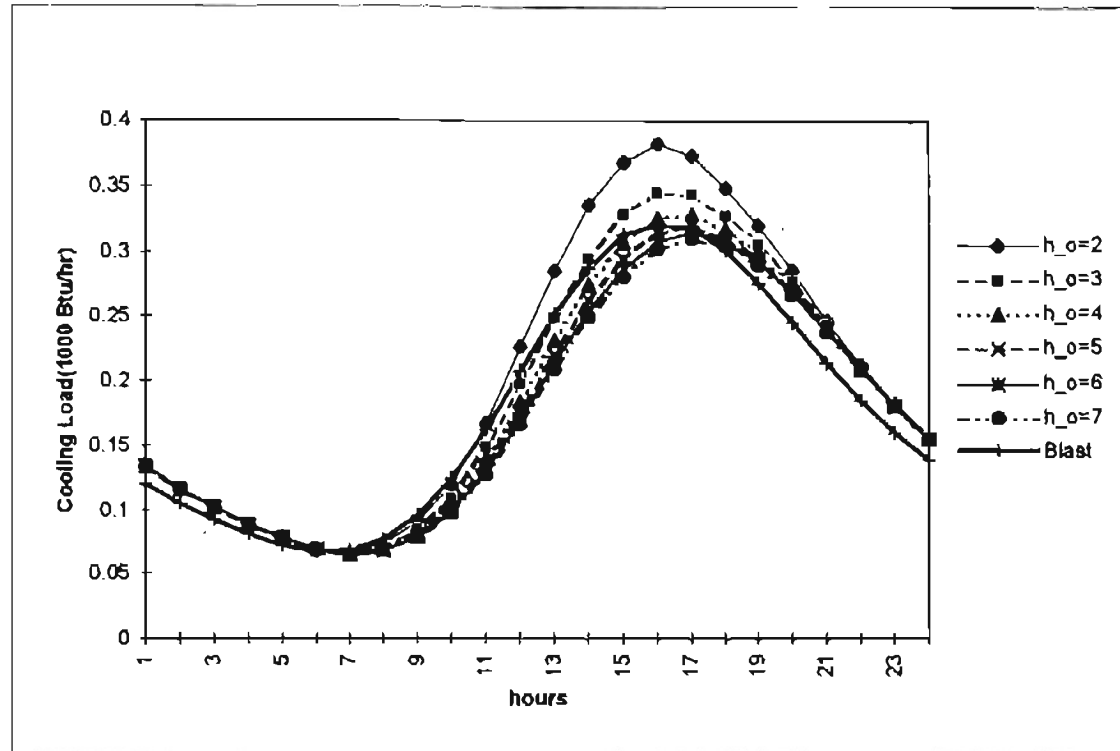


Figure 4.9 Cooling Loads Affected by Exterior Surface Coefficient(Wall Type 1, South)

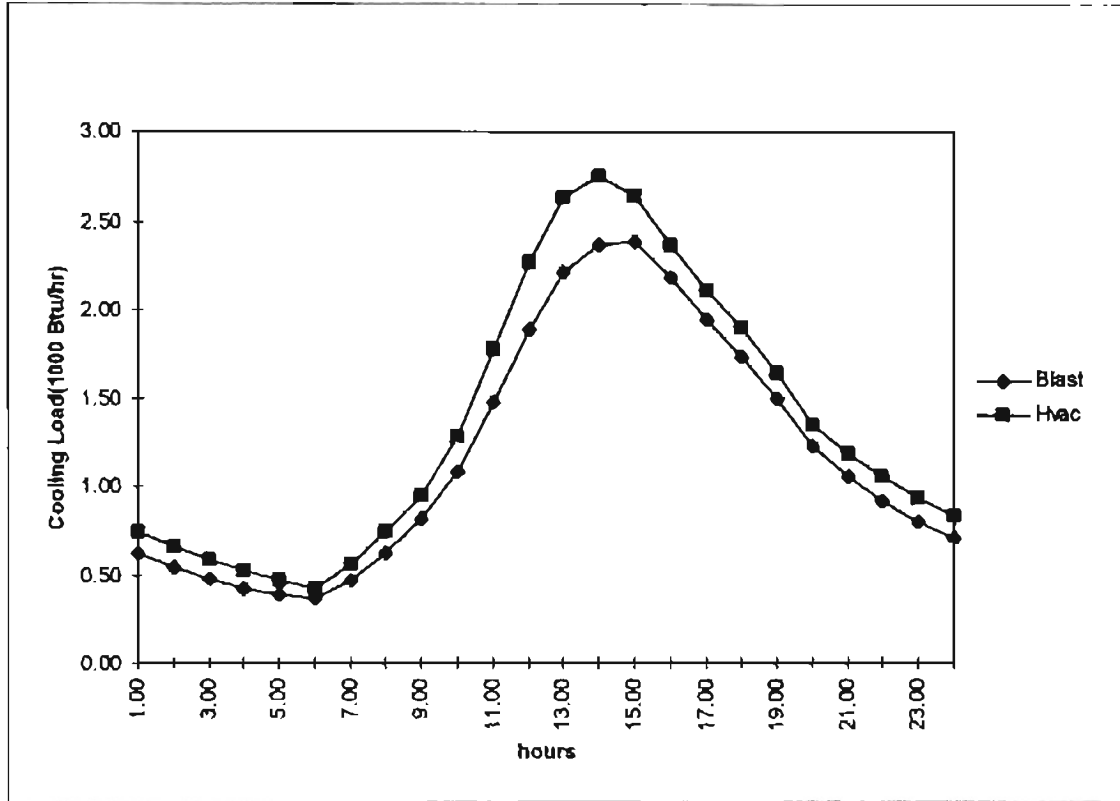


Figure 4.10 Wall Type 5, South Window Design Day Comparison

### **4.3 Test of a Load Calculation on a Real Building (Motel )**

This section discussed on a load calculation comparison between BLAST(1992) and the HVAC for Windows on a realistic building - a two story motel.

For a real building load calculation, the situation would become more complicated than the test performed on a single zone. All kinds of different load components, like lights, people, electric equipment, ventilation and interzone partitions will be involved as parts of space cooling load. Furthermore, some of these loads may be combined with specific schedules according to specific simulation time periods. Also, for the first floor of building, the heat transfer due to floor has to be considered. For the special comparison purposes desired in this project, which was intended to compare the simulation results between BLAST and HVAC, the building description input for each program can only be defined as close as possible, and it may not be possible to represent the building exactly the same in both programs. And the results of the comparison can only provide a basic idea of how the HVAC program can be applied to a real complicated commercial building.

#### **4.3.1 Motel Plan View**

The building's first floor and second floor's plan views of the motel are shown in figure 4.11 and 4.12. The building general design information is described in the following section.

#### **4.3.2 Building General Design Information**

##### Building General Information:

- Location Name: Tulsa, Oklahoma

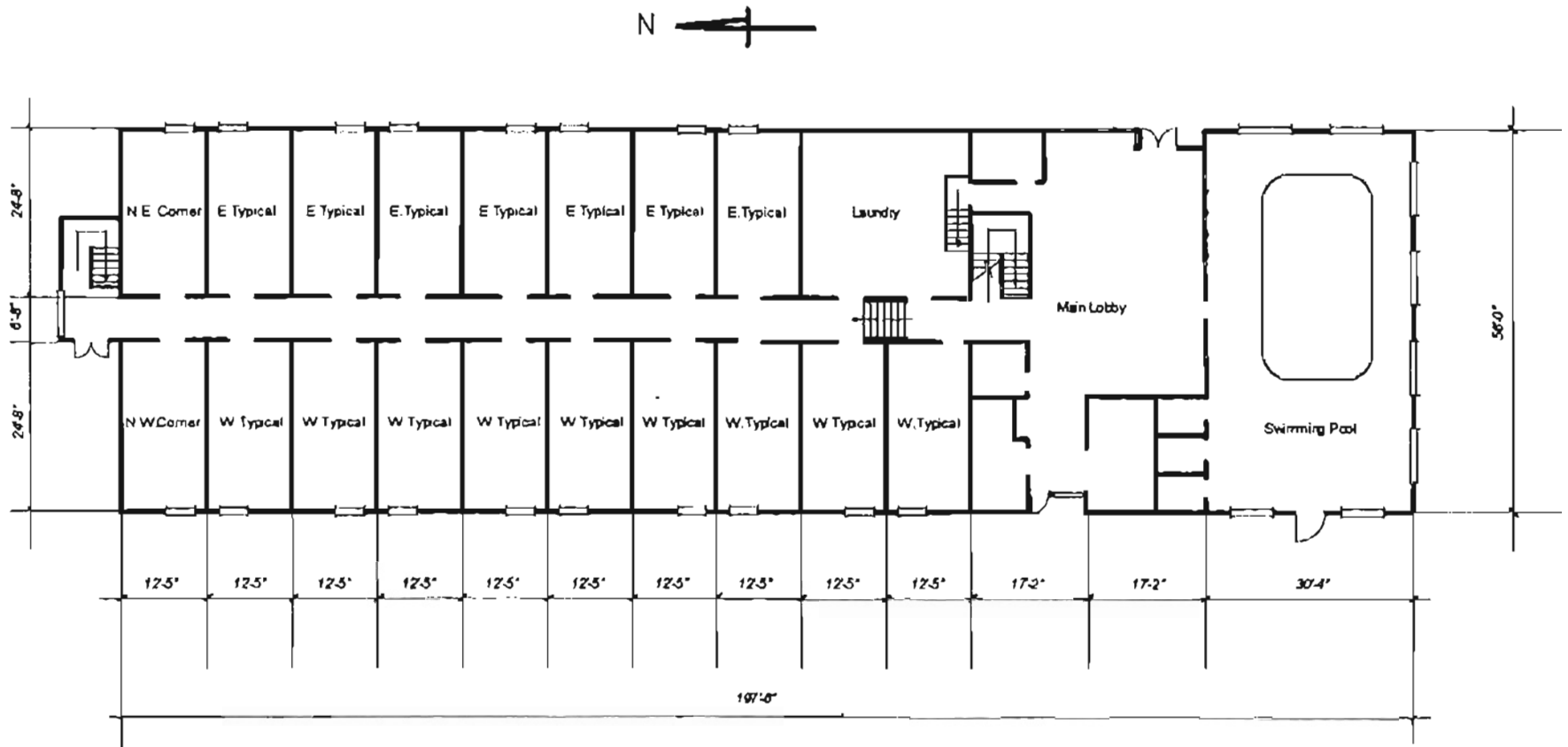


Figure 4.11 Motel First Floor Plan View

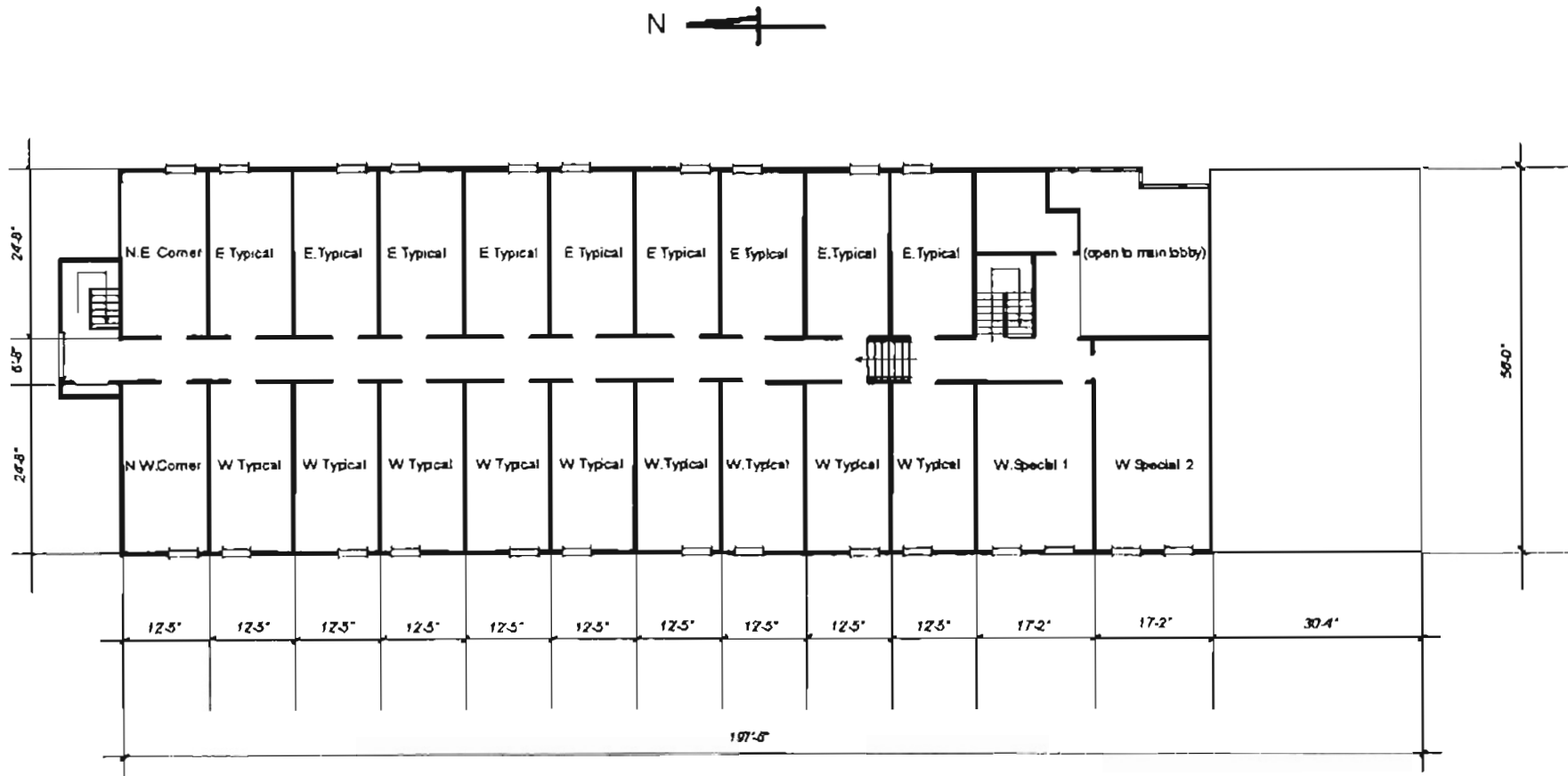


Figure 4.12 Motel Second Floor Plan View



- Latitude: 36°12'
- Longitude: 95°54'
- Time Zone: 6

Summer Design Day Conditions:

- Month: 7
- Day: 21
- Design Day Outdoor Dry Bulb Temperature: 98.00°F
- Design Day Outdoor Wet Bulb Temperature: 74.00°F
- Mean Daily Range: 24.00°F

Building Construction Description:

- Exterior Wall - Wood frame construction with overall U factor (including surface conductance) of 0.108.
- Roof - shingled, pitched roof, attic airspace, with overall U factor of 0.045
- Windows - Double pane, with shading coefficient of 0.88 and overall U factor of 0.67

In order to perform the cooling load calculation on the motel, the building needs to be divided into several representing zones, and each zone will be controlled by a single A/C system and have a same system control profile. The zone description of the motel can be found in Table 4.8.

Table 4.8 Motel Zones Information Summary

Zone No.	Zone Name	Zone Multiplier	Floor Area [sq.ft.]	Height [ft.]	Total Window Area [ft.]	System Control Annual Schedule Name	System Max. Cooling Capacity [Btu/hr]	System Max. Heating Capacity [Btu/hr]	System Throttling Range [°F]	Ventilation ODA [cfm]
1	NW Corner 1st Fl.	1	348	8	26.88	motel room control	100000	100000	0.1	30
2	West Typical 1 st Fl.	9	348	8	26.88	motel room control	100000	100000	0.1	30
3	NE Corner 1st Fl.	1	348	8	26.88	motel room control	100000	100000	0.1	30
4	East Typical 1st Fl.	7	348	8	26.88	motel room control	100000	100000	0.1	30
5	NW Corner 2nd Fl.	1	348	8	26.88	motel room control	100000	100000	0.1	30
6	West Typical 2nd Fl.	9	348	8	26.88	motel room control	100000	100000	0.1	30
7	NE Corner 2nd Fl.	1	348	8	26.88	motel room control	100000	100000	0.1	30
8	East Typical 2nd Fl.	9	348	8	26.88	motel room control	100000	100000	0.1	30
9	Special 2nd Fl.	2	538	8	53.76	motel room control	100000	100000	0.1	30
10	Laundry	1	696	8	0	laundry control	100000	100000	1.0	160
11	Main Lobby	1	1926	8	287.24	Lobby's Control	100000	100000	2.0	300
12	Swimming Pool	1	1702	10	220.5	swim control	1000000	1000000	1.0	1700

### 4.3.3 Motel Annual Simulation Results

After the building description files have been created carefully for both BLAST and the HVAC program, annual load simulations are executed. The annual load simulations are based on the weather data of a Tulsa's typical year. From the annual simulation results carried out by BLAST and the HVAC program, the monthly cooling and heating loads for each zone of the motel can be collected. In this project, only the results of system sensible loads are compared between BLAST and the HVAC.

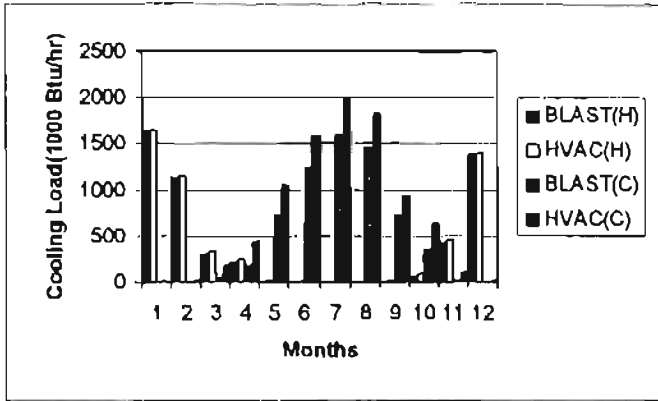
The motel input building description file for BLAST( ".bin" file) is listed in the Appendix A. The motel input building description file for the HVAC program( ".ipt" file) is listed in the Appendix B.

The comparison results of monthly cooling and heating loads are shown in Figure 4.13(A) through 4.13(C).

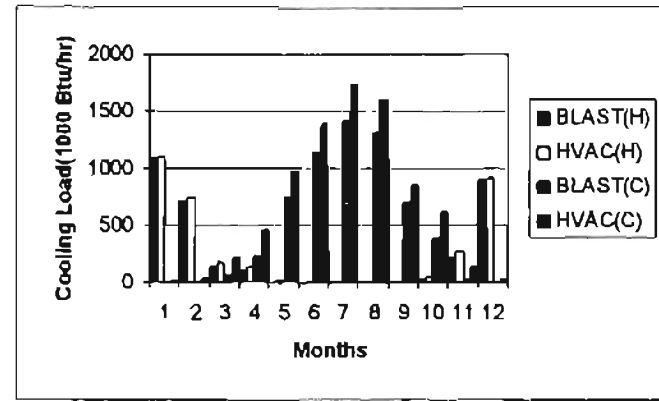
The annual total cooling and heating loads results of both BLAST and the HVAC program are listed in Table 4.9.

Table 4.9 Motel Annual Total Cooling and Heating Loads

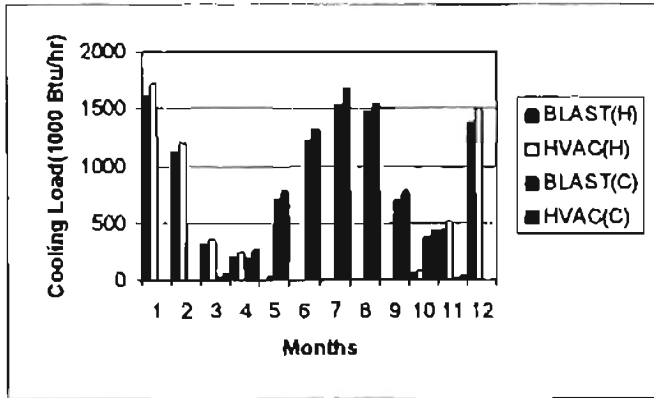
Zone Name	Annual Total Cooling Load( 1000 Btu)		Annual Total Heating Load( 1000 Btu)	
	BLAST	HVAC	BLAST	HVAC
NW Corner 1st Fl.	6346	8803	5139	5384
West Typical 1 st Fl.	6009	8028	3152	3395
NE Corner 1st Fl.	6208	6900	5127	5657
East Typical 1st Fl.	5880	6095	3149	3647
NW Corner 2nd Fl.	8068	10292	6672	7178
West Typical 2nd Fl.	7669	9454	4534	5119
NE Corner 2nd Fl.	7799	7646	6559	6381
East Typical 2nd Fl.	7443	7210	4461	5286
Special 2nd Fl.	12277	15831	7245	7761
Laundry	7938	10126	4084	3622
Main Lobby	69216	82536	42945	51635
Swimming Pool	17632	24910	323552	321227



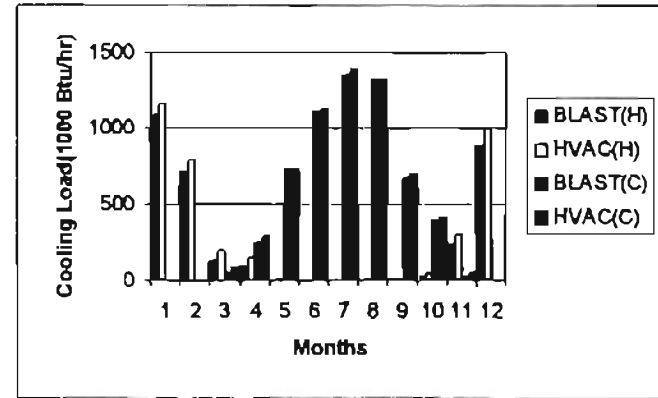
1 N.W. Corner Zone



1 W. Typical Zone

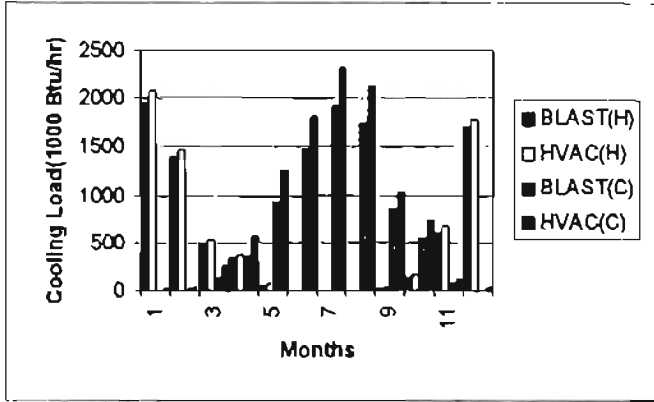


1 N.E. Corner Zone

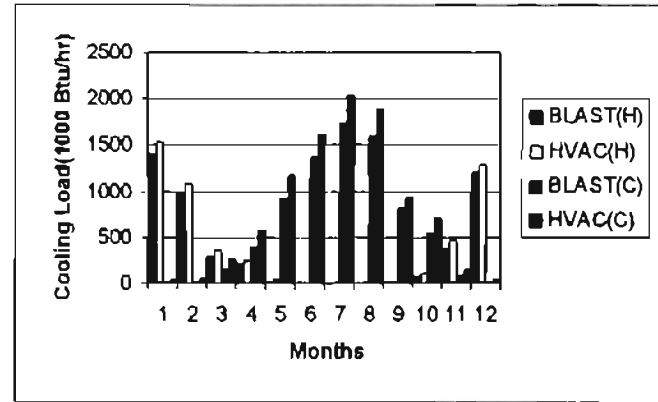


1 E. Typical Zone

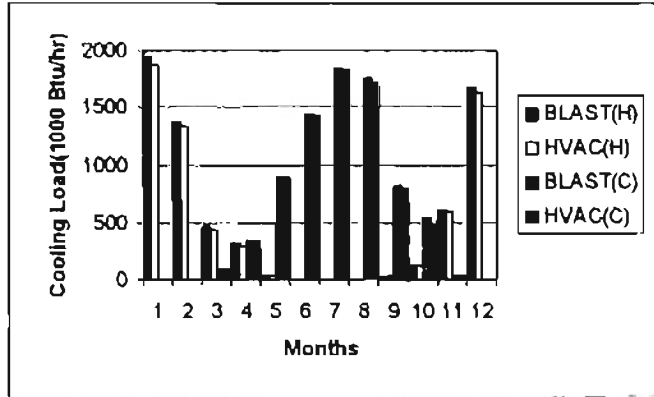
Figure 4.13(A) Motel Monthly Cooling and Heating Load Comparison Between BLAST and the HVAC Program(Part A)



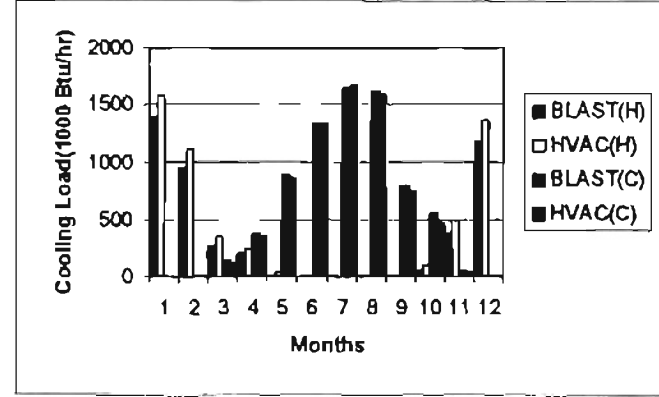
2 N.W. Corner Zone



2 W. Typical Zone

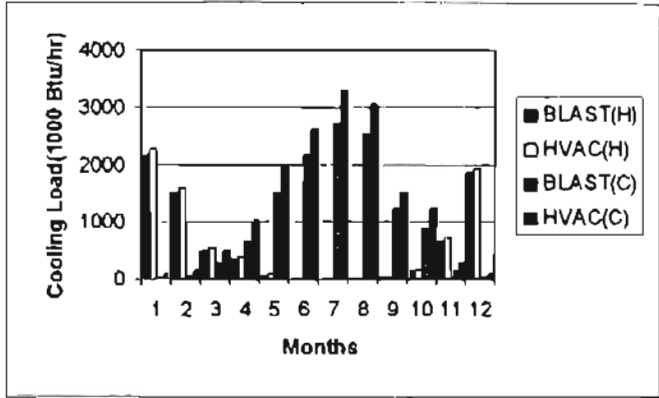


2 N.E. Corner Zone

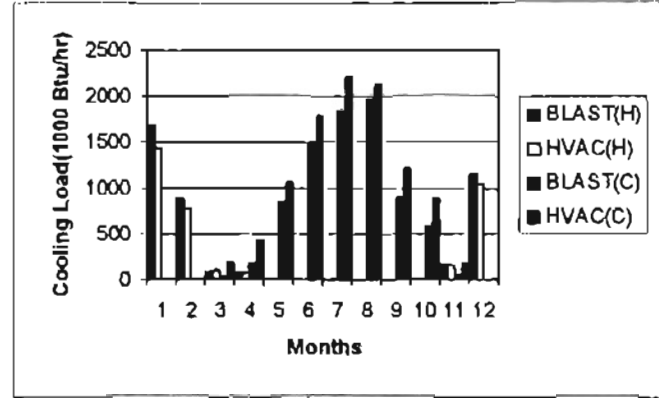


2 E. Typical Zone

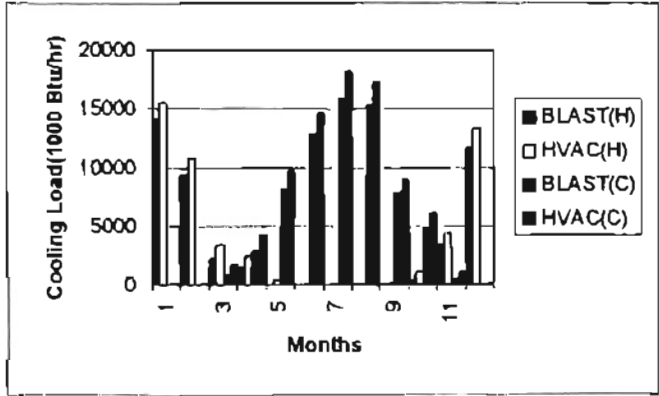
Figure 4.13(B) Motel Monthly Cooling and Heating Load Comparison Between BLAST and the HVAC Program(Part B)



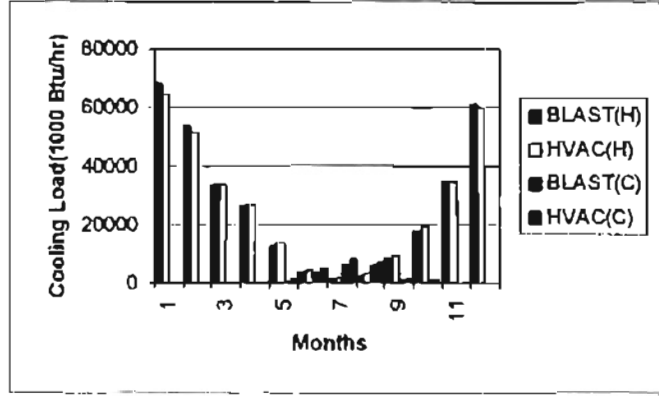
2 Special Zone



Laundry Zone



Main Lobby



Swimming Room

Figure 4.13(C) Motel Monthly Cooling and Heating Load Comparison Between BLAST and the HVAC Program(Part C)

The building annual total cooling and heating loads for the motel are listed in Table 4.10.

Table 4.10 Motel Annual Total Cooling and Heating Loads

Annual Total Cooling Load(1000 Btu)		Annual Total Heating Load(1000 Btu)	
BLAST	HVAC	BLAST	HVAC
379039	447794	539959	566357

#### **4.4 Discussion**

In this chapter, BLAST is used as a reference program to validate the simulation results carried out by the HVAC program. The test begins with the most fundamental case which is a room with a single exterior wall. Furthermore, the effects of surface exterior coefficients and window are also tested to evaluate the simulation capability of the HVAC program. At the end of this test procedure, load calculation on a relatively complicated real building - motel is executed by both BLAST and the HVAC program. All comparison results are illustrated in either chart or table formats.

From the comparison results carried out by the single zone test, the following conclusion can be achieved. For the design day calculation, if there is no window on the exterior wall, the single zone test results will only represent the conduction heat transfer through the exterior wall. No matter what the facing angle of an exterior wall is, the difference in the peak cooling load of the summer design day between BLAST and HVAC is kept within 16 %. The largest difference occurred in the case of "West wall, wall type 11". For wall type 1, the agreement between BLAST and the HVAC program are relatively better than other cases. As described by Sowell(1992), according to the group method used in the ASHRAE Research Project 472 to keep representative wall group and roof group in a acceptable number, there is an inherent error of positive 20 % in the

amplitude and one hour in time delay by using derived transfer function coefficients. This inherent error can be seen clearly from the comparison results of the single zone tests. In all cases, the hourly cooling load results calculated by the HVAC program are greater than that from BLAST and the biggest difference is smaller than 20 percent. This is acceptable for most purposes and will give a conservative result.

For the results of the single zone annual simulation, because the design day wind speed is used to calculate the approximate exterior surface combined coefficient in the HVAC program, but real hourly wind speed is used in BLAST, the comparison results will become not as predictable as in the design day calculation. But, in the annual simulation, the average outdoor wind speed still can be considered as same as the summer design day because higher and lower hourly outdoor wind speed will compensate with each other during the entire year and the macroscopic results are still considered comparable. From the annual simulation comparison results shown in Figures 4.5 through 4.8, for total annual cooling load, the biggest difference is also under 13 percent; for total annual heating load, the biggest difference is under 4 percent.

Another test on the exterior surface combined coefficient shows that, for the summer design day calculation, when solar radiation is in effect, the hourly cooling load will be reduced by increasing the value of the coefficient. This is because when a solar flux is incident on an exterior wall, the exterior surface temperature will rise and become higher than the ambient air. As the value of exterior surface coefficient increases due to a higher outdoor wind speed, the convective heat transfer between exterior surface and ambient air will be increased. Therefore, there will be less heat conducted to the indoor space through the wall, and the cooling load will be decreased correspondingly. The phenomenon can also be explained by observing Equation 2.21 which is used to calculate the sol-air temperature. This also implies that it is desirable to modify the exterior surface combined coefficient in the HVAC program to vary with surface roughness and wind speed.

When a south window is added in the case " South wall, wall type 5", a relatively large disagreement between BLAST and the HVAC program is emerged. Actually, a south window is defined as similarly as possible in both BLAST and the HVAC program.



In BLAST, the window material is defined as glass type with specified R value and shading coefficient. In the HVAC program, the window R value and shading coefficient are chosen as same as in BLAST. Because the case "South wall, wall type 5" without window has been tested previously, the big difference in the results on the window case is mainly due to the effect of the existing of the window. For all test cases in this project, include the test cases shown in next chapter, all results show that, the heat gain caused by window calculated by the HVAC program are about 10 to 20 percent greater than the results calculated by BLAST. This indicate that the simplified method( Shading Coefficient Method ) in window heat transfer calculation does not have sufficient accuracy and can be improve in future study.

The primary purpose of the test case for the motel is to figure out if the HVAC program suitable to a real building annual load simulation. From the previous results obtained from the single zone test, one can tell that the results of conduction heat transfer through exterior walls( also roofs) have a good accuracy for both design day and annual simulation. Furthermore, the methodology of calculating other building load components, such as infiltration, lights, people, equipment, and ventilation, is relatively straight forward and similar in both BLAST and the HVAC program. In this special test case, the exterior surface combined coefficient is set to be  $3.0 \text{ Btu/hr-ft}^2\text{-F}$  as the real value the current HVAC program actually used. Under this condition the results calculated by the HVAC program are expected larger than the case with using modified exterior surface combined coefficient.

In the motel simulation, another factor can influence the calculation results is floor heat transfer. Because the HVAC program cannot take the floor heat transfer into account, during the BLAST building description procedure, the monthly ground temperatures are set approximately to be close to the zone space air temperature. This definition will make the heat transfer due to floor as small as possible during the entire simulation period in BLAST and the factor of floor heat transfer can be neglected in the results comparison. However, it would be highly desirable to include floor heat transfer in the annual energy analysis.

From the motel simulation comparison results shown in Figures 4.20a through 4.20c, it can be observed that the monthly total heating loads have a very good agreement between BLAST and the HVAC program for all zones. The HVAC monthly total cooling loads are bigger than BLAST in the range of 15 - 40 percent. The building annual total heating and cooling loads comparison is listed in Table 4.10. The building total heating load of HVAC is about 5 percent higher than that of BLAST. The building total cooling load of HVAC is about 18 percent higher than that of BLAST.

The comparison results between BLAST and the HVAC program shown in this chapter indicates that the HVAC program has the capability to simulate any complicated commercial building. The results carried out by the HVAC program are generally greater than that carried out by BLAST. Some new features, including floor heat transfer, modified exterior surface combined coefficient calculation model, and improved window heat transfer model, can be considered adding to the HVAC program to improve the program accuracy and capability.

## **Chapter V**

### **Validation by Building Energy Simulation Test (BESTEST)**

#### ***5.1 Overview***

The validation procedure of the "Building Energy Simulation Test"(BESTEST) (1993) is to make an equivalent building description for the program being tested and other programs which are considered to be state-of-the-art programs and widely used in the field of HVAC engineering design and consulting routines. Fourteen cases are presented in the BESTEST procedure, and 10 of them are chosen to used in this project for the purpose of the HVAC program validation. They are the 600 and 900 series which consist of qualification tests. The 600 Series represents a zone with lightweight envelope construction and the 900 Series represents a zone with heavyweight construction.

#### ***5.2 Test Building and Input Data Description***

##### **5.2.1 Building Construction Information**

The test zone in both the 600 and 900 series is a zone built up with four exterior walls, one roof and a large window with double pane glass on the south wall. It is a zone located on the top story of a fictitious building. Figure 5.1 and Figure 5.2 show the plan view and elevation view of this "fictitious" zone, respectively. There is no heat transfer through the interzone floor for this top story test zone.

The 600 test series building component's description is listed in Tables 5.1 through 5.3, while the 900 test series building component's description is listed in Tables 5.4 through 5.6.

In all cases, the window plays an important role in building envelope heat transfer because of its relatively large size. The characteristic values of the window defined by the BESTEST for all test cases are listed in Table 5.7.

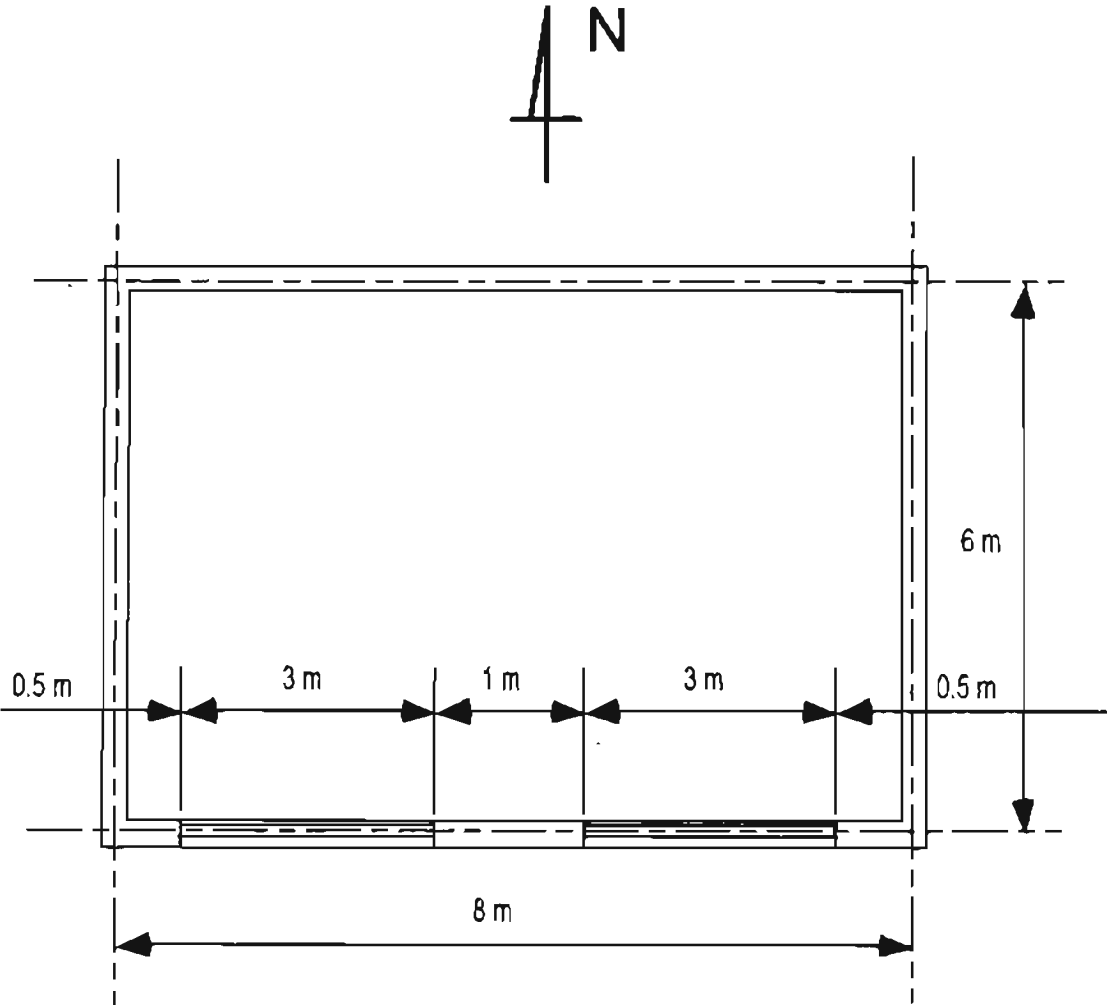


Figure 5 1 BESTEST Zone Plan View

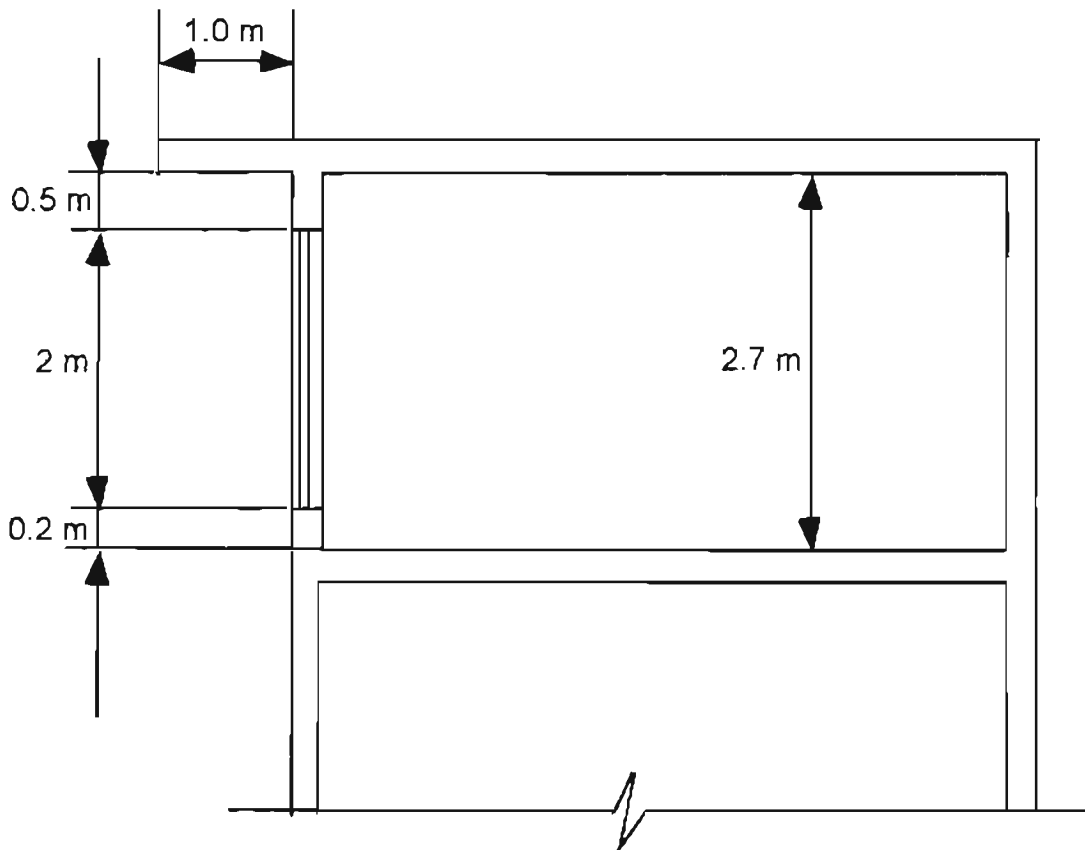


Figure 5.2 BESTEST Zone Elevation View

Table 5.1 Case 600s' Exterior Wall Material Description (inside to outside)

Name	k	Thickness	U	R	Density	Cp
	Btu/h*ft*F	ft	Btu/h*ft2*F	h*ft2*F/Btu	lb./ft3	Btu/lb*F
Int. Surf. Coefficient			1.461	0.685		
Plasterboard	0.093	0.039	2.350	0.426	59.307	0.201
Fiberglass quilt	0.023	0.217	0.107	9.363	0.749	0.201
Wood Siding	0.081	0.030	2.741	0.365	33.087	0.215
Ext. Surf. Coefficient			5.163	0.194		
Total air-air U value	0.091 Btu/h*ft2*F					
Total surf-surf U value	0.098 Btu/h*ft2*F					

Table 5.2 Case 600's Roof Material Description(inside to outside)

Name	k	Thickness	U	R	Density	Cp
	Btu/h*ft*F	ft	Btu/h*ft2*F	h*ft2*F/Btu	lb./ft3	Btu/lb*F
Int Surf. Coefficient			1.461	0.685		
Plasterboard	0.093	0.033	2.820	0.355	59.307	0.201
Fiberglass quilt	0.023	0.367	0.063	15.854	0.749	0.201
Roofdeck	0.081	0.062	1.299	0.775	33.087	0.215
Ext. Surf Coefficient			5.163	0.194		
Total air-air U value	0.056 Btu/h*ft2*F					
Total surf-surf U value	0.059 Btu/h*ft2*F					

Table 5.3 Case 600's Floor Material (inside to outside)

Name	k	Thickness	U	R	Density	Cp
	Btu/h·ft·F	ft	Btu/h·ft <sup>2</sup> ·F	h·ft <sup>2</sup> ·F/Btu	lb./ft <sup>3</sup>	Btu/lb·F
Int. Surf. Coefficient			1.461	0.684		
Timber flooring	0.081	0.082	0.987	1.013	40.578	0.287
Fiberglass quilt	0.023	3.291	0.007	142.287	0.000	0.000
Total air-air U value	0.007 Btu/h·ft <sup>2</sup> ·F					
Total surf-surf U value	0.007 Btu/h·ft <sup>2</sup> ·F					

Table 5.4 Case 900's Exterior Wall Material(inside to outside)

Name	k	Thickness	U	R	Density	Cp
	Btu/h·ft·F	ft	Btu/h·ft <sup>2</sup> ·F	h·ft <sup>2</sup> ·F/Btu	lb./ft <sup>3</sup>	Btu/lb·F
Int. Surf. Coefficient			1.461	0.685		
Plasterboard	0.295	0.328	0.899	1.113	87.399	0.239
Fiberglass quilt	0.023	0.202	0.115	8.722	0.624	0.335
Wood Siding	0.081	0.030	2.741	0.365	33.087	0.215
Ext. Surf. Coefficient			5.163	0.194		
Total air-air U value	0.090 Btu/h·ft <sup>2</sup> ·F					
Total surf-surf U value	0.098 Btu/h·ft <sup>2</sup> ·F					

Table 5.5 Case 900's Roof Material(inside to outside)

Name	k	Thickness	U	R	Density	Cp
	Btu/h*ft°F	ft	Btu/h*ft²°F	h*ft²°F/Btu	lb./ft³	Btu/lb°F
Int. Surf. Coefficient			1.461	0.684		
Plasterboard	0.093	0.033	2.820	0.355	59.307	0.201
Fiberglass quilt	0.023	0.367	0.063	15.854	0.749	0.201
Roofdeck	0.081	0.062	1.299	0.770	33.087	0.215
Ext. Surf. Coefficient			5.163	0.194		
Total air-air U value	0.056 Btu/h*ft²°F					
Total surf-surf U value	0.059 Btu/h*ft²°F					

Table 5.6 Case 900's Floor Material(inside to outside)

Name	k	Thickness	U	R	Density	Cp
	Btu/h*ft°F	ft	Btu/h*ft²°F	h*ft²°F/Btu	lb./ft³	Btu/lb°F
Int. Surf. Coefficient			1.461	0.684		
Concrete Slab	0.653	0.262	2.489	0.402	87.399	0.239
Fiberglass quilt	0.023	3.304	0.007	142.855	0.000	0.000
Total air-air U value	0.007 Btu/h*ft²°F					
Total surf-surf U value	0.007 Btu/h*ft²°F					



Table 5.7 BESTEST Window's Characteristics

Extinction Coefficient	0.0196 / mm
Number of Panes	2
Pane Thickness(standard 1/8" glass under IP system)	3.175 mm
Air Gap Thickness	13 mm
Index of Refraction	1.526
Normal Direct Beam Transmittance Through 1 Pane In Air	0.86156
Conductivity of Glass	1.06 W/m.K
Conductance of Each Glass Pane	333 W/m <sup>2</sup> .K
Combined Radiative and Convective Coefficient of Air Gap	6.297 W/m <sup>2</sup> .K
Exterior Combined Surface Coefficient	21.00 W/m <sup>2</sup> .K
Interior Combined Surface Coefficient	8.29 W/m <sup>2</sup> .K
U-Value from Interior Air to Ambient Air	3.0 W/m <sup>2</sup> .K
Density of Glass	2500 kg/m <sup>3</sup>
Specific Heat of Glass	750 J/kg.K
Curtains, Blinds, Frames, etc. inside the window	None

## 5.2.2 Cases Description

### 5.2.2.1 Infiltration

The Infiltration load in the BESTEST test zone is defined as 0.5 air change per hour.

### 5.2.2.2 Internal Equipment Heat Gain

The power of the internal heat source is assumed to be a constant value, 200 W, and the radiative and convective portion are 60 % and 40 %, respectively. This load represents the pure heat gain of the space from the internal equipment. The equipment has a continuous running schedule.

### 5.2.2.3 Exterior Combined Surface Coefficient

From 2300 pm to 0700 am:

if the space temperature is less than 10 °C(50 °F), system heating will be turned on;

From 0700 to 2300 pm:

if the space temperature is less than 20 °C(68 °F), system heating will be turned on;

For all hours:

if the space temperature is greater than 27 °C(80.6 °F), system cooling will be turned on;

#### 5.2.2.8 Loads Schedule

There are two kinds of schedule loads presented in the BESTEST cases, they are internal equipment and infiltration heat gain . But the schedule of these loads are all treated as continuous, i.e. they will be turned on continuously during the entire simulation period. So in HVAC simulations, a continuous schedule is assigned to these loads.

#### 5.2.2.9 Cases Specification Table

All BESTEST cases performed in this project are summarized in the table 5.8.

### 5.2.3 **HVAC Input Data for BESTEST Cases**

To describe the test zone in the HVAC user's interface environment is pretty straight forward, except some special input field which are specified in detail in following sections.

#### 5.2.3.1 Room Parameter's Description

Room parameters for the test series 600 and 900 are summarized in Table 5.9:

Table 5.8 BESTEST Case Summary Information

1	2	3	4	5	6	7	8	9
Case No.	Set Pt. °C	Mass	Equip. W	Infil. ACH	ABS	Glass m <sup>2</sup>	Window Orient.	Overhang
600	20,27	Light	200	0.5	0.6	12	S	without
610	20,27	Light	200	0.5	0.6	12	S	with
620	20,27	Light	200	0.5	0.6	6,6	E,W	without
630	20,27	Light	200	0.5	0.6	6,6	E,W	with
640	S.B.	Light	200	0.5	0.6	12	S	without
900	20,27	Heavy	200	0.5	0.6	12	S	without
910	20,27	Heavy	200	0.5	0.6	12	S	with
920	20,27	Heavy	200	0.5	0.6	6,6	E,W	without
930	20,27	Heavy	200	0.5	0.6	6,6	E,W	with
940	S.B.	Heavy	200	0.5	0.6	12	S	without

**Note:** S.B.: System SETBACK control profile in affect; ABS: Exterior Solar Absorbance;

### 5.2.3.2 Wall Type Description

When the transfer function method is used, the wall type has to be carefully selected to calculate the exterior wall conduction heat transfer. If the exact matching wall material cannot be found in the wall material library, a material which has the closest thermal properties from the library should be used instead.

For case 600s, according to the wall layer description listed in Table 5.1, the outermost layer of the exterior wall is plasterboard, which has a heat capacity of  $0.039 \times 59.307 \times 0.201 = 0.495 \text{ Btu}/\text{ft}^2\text{F}$ , and the material that can be chosen from the library is "A3", " Steel Siding ", which has a heat capacity of  $0.24 \text{ Btu}/\text{ft}^2\text{F}$ . Similarly, B12 - 3 in. Insulation is chosen for "Fiberglass quilt" and "A3" for Wood Siding. The dominant wall material is "Steel Siding" and the secondary principle material is "3/4 in. Plaster or Gypsum". The Mass location is "Mass Integral". After these variables are specified inside the HVAC program, the wall type is calculated and described as "Wall Type 1".

The definition of wall layer for the BESTEST are summarized in Table 5.10.

Table 5.9 Room parameters for BESTEST cases

Name of Parameter	Cases 600s ( Light )	Cases 900s ( Heavy )
Room Geometry	15 ft x 15 ft	15 ft x 15 ft
Room Height	10 ft	10 ft
# of Exterior Walls	4	4
Room Location	Top Floor	Top Floor
Interior Shade	0 %	0 %
Furniture	Without	Without
Exterior Wall Construction	L.W. with moderate insu	H.W. with moderate insu
Partition Type	5/8 in. Gyp-Air-5/8 in. Gyp	5/8 in. Gyp-Air-5/8 in. Gyp
Mid Floor Type	1 in. wood	8 in. Concrete
Slab Type	Mid floor type	Mid floor type
Ceiling Type	Without ceiling	Without ceiling
Roof Type	L.W. w/o suspended ceiling	L.W. w/o suspended ceiling
Floor Covering	Vinyl Tile	Vinyl Tile
Glass Percent	10	10

Table 5.10 BESTEST Wall and Roof Layer Summary Information

	Case 600	Case 900
Layer Distribution(inside to outside)	E0,E1,B4,A3,A0	E0,C4,B4,E1,A0
Principle Matenal	Steel Siding	4 in. Common Brick
Secondary Matenal	3/4 in. Plaster Board	3/4 in Plaster Board
Mass Location	Mass Integral	Mass In
Actual U Factor	0.091 Btu/h*ft <sup>2</sup> *F	0.090 Btu/h*ft <sup>2</sup> *F

### 5.2.3.3 Roof Type Description

Similar to the wall type selection, the layer distribution of the roof for both 600 and 900 cases is defined as layers of - E0,E2,B12,B7,A0, "Mass Integral", with principle material of 1 in. wood, and without suspended ceiling. Roof type of 2 is obtained from the HVAC program.

## **5.3 Annual simulation results**

The BESTEST input building description file for the HVAC program ( ".ipt" file) is listed in the Appendix C.

There are several sets of comparison results that can be obtained from the BESTEST procedure. They are annual total cooling load, annual total heating load, peak heating and cooling load and there occurring times. The annual heating and cooling load comparison results for low mass cases (Case 600s) are shown in figure 5.3 and 5.4, the annual heating and cooling load comparison results for heavy mass cases (Case 900s) are shown in figure 5.5 and 5.6. The results of sensitivity test are shown in Figure 5.7 through 5.12. In these tests, the sensitivity of the program to various phenomena is examined by taking the difference between two different cases. For example, in Fig. 5.7, the difference in heating load between cases 630 and 620 is plotted. The only difference between the two cases is that case 630 has an overhang. In this case, HVAC is shown not to be very sensitive to the addition of an overhang, when compared to the other programs.

As mentioned in the BESTEST, to pass a test case, the simulation results of testing program must show "reasonable agreement with the reference programs for both the absolute results and the sensitive results" (Judkoff, 1993). When a disagreement show up during a specific test case, the user need to follow the diagnostic procedure provided by the BESTEST. The BESTEST results on the HVAC program shown in this section are the final results of this project, which means that the problems found during the BESTEST procedure have already been fixed. The problem tracing method in the BESTEST will be discussed in the following section.

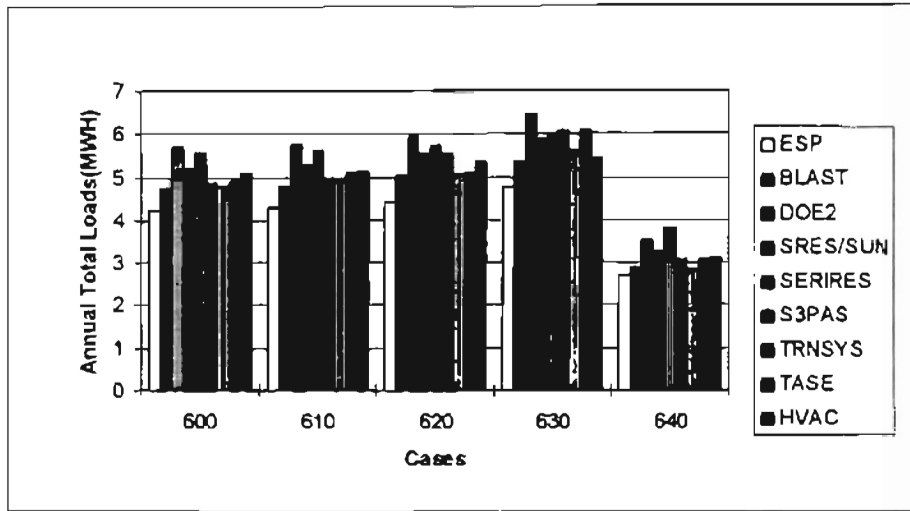


Figure 5.3 BESTEST Low Mass Cases Annual Heating Load Comparison

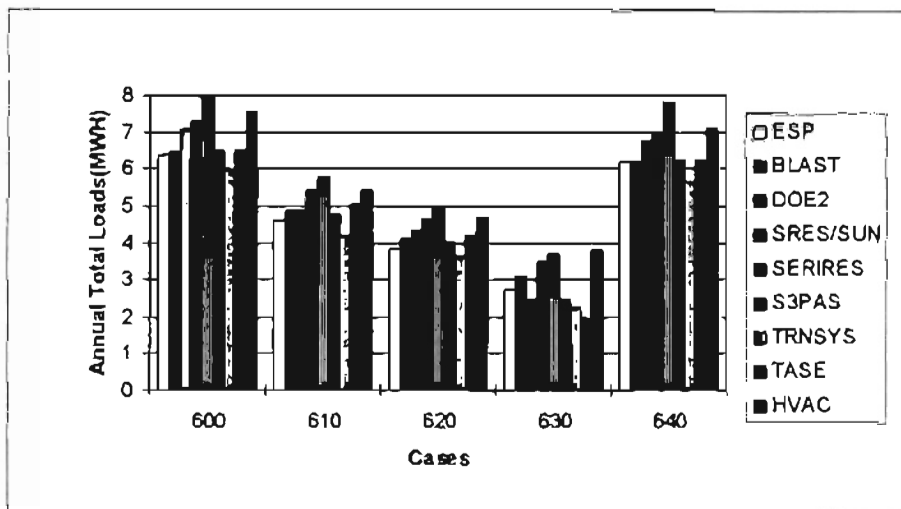


Figure 5.4 BESTEST Low Mass Cases Annual Cooling Load Comparison

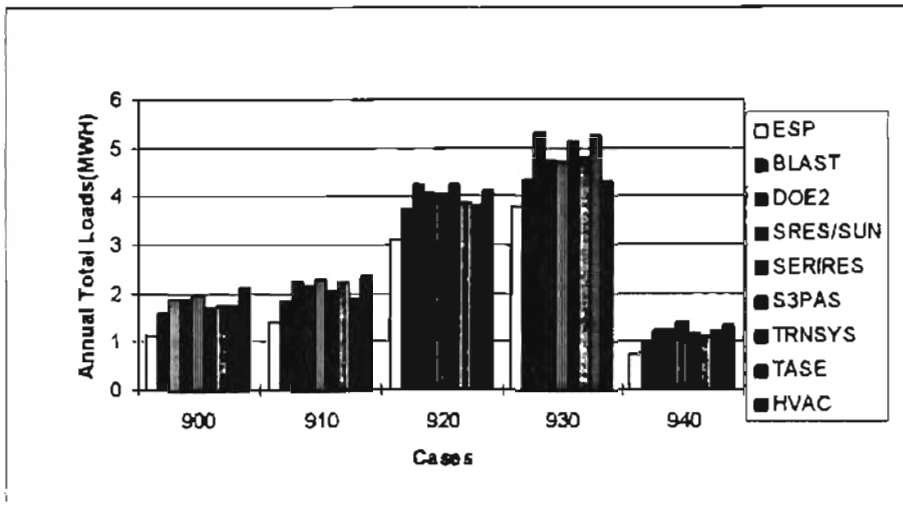


Figure 5.5 BESTEST Hi Mass Cases Annual Heating Load Comparison

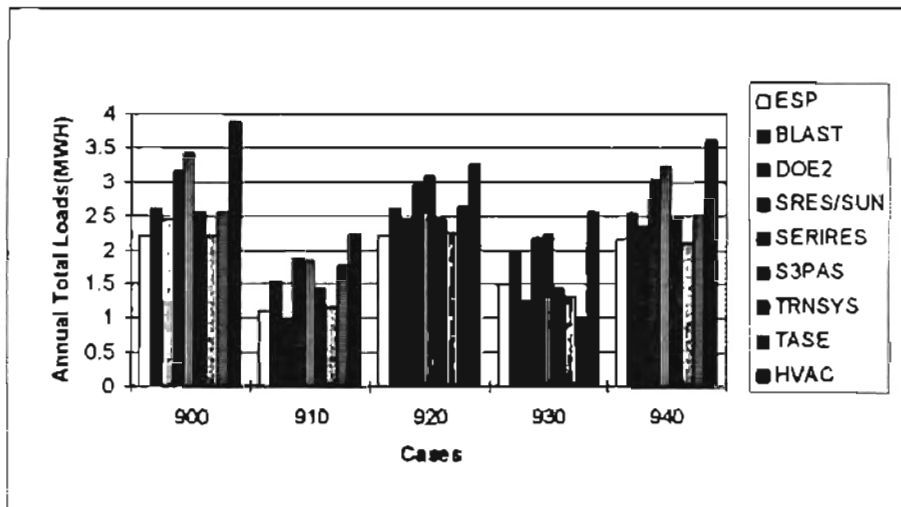


Figure 5.6 BESTEST Hi Mass Cases Annual Cooling Load Comparison

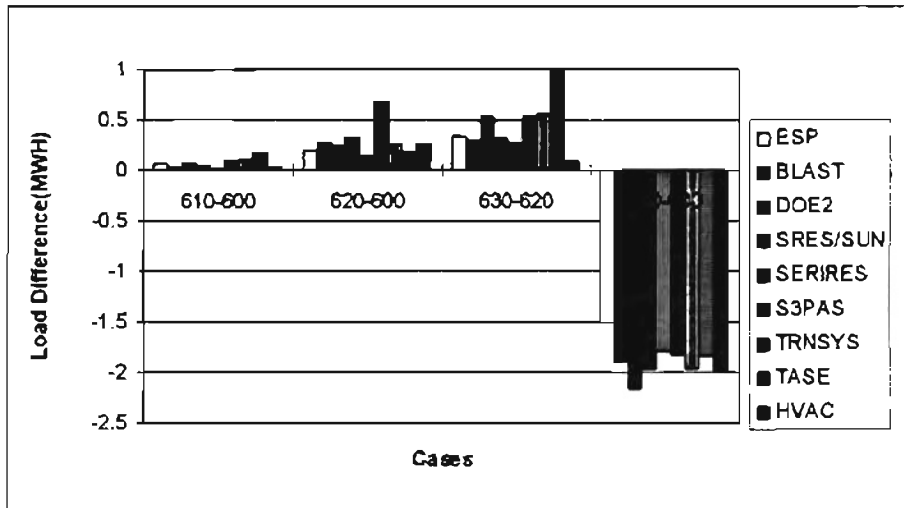


Figure 5.7 BESTEST Low Mass Cases Heating Load Qualification tests Results

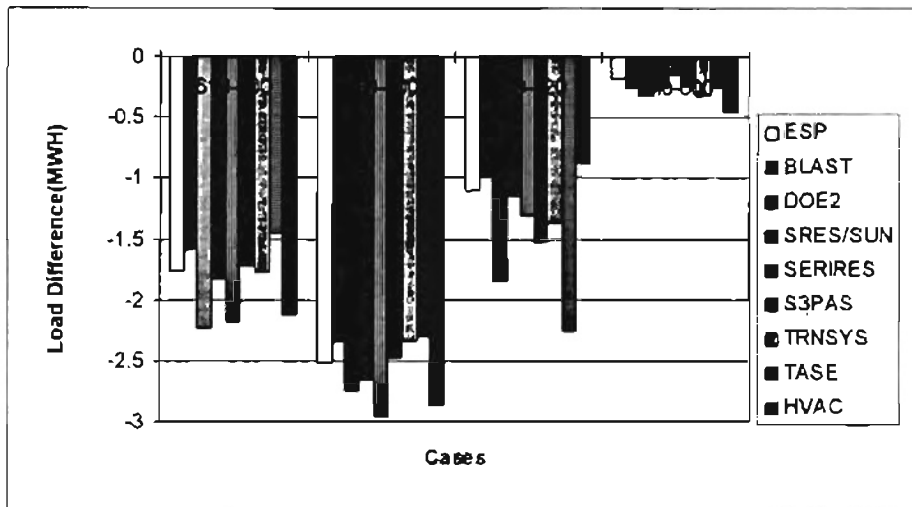


Figure 5.8 BESTEST Low Mass Cases Cooling Load Qualification tests Results



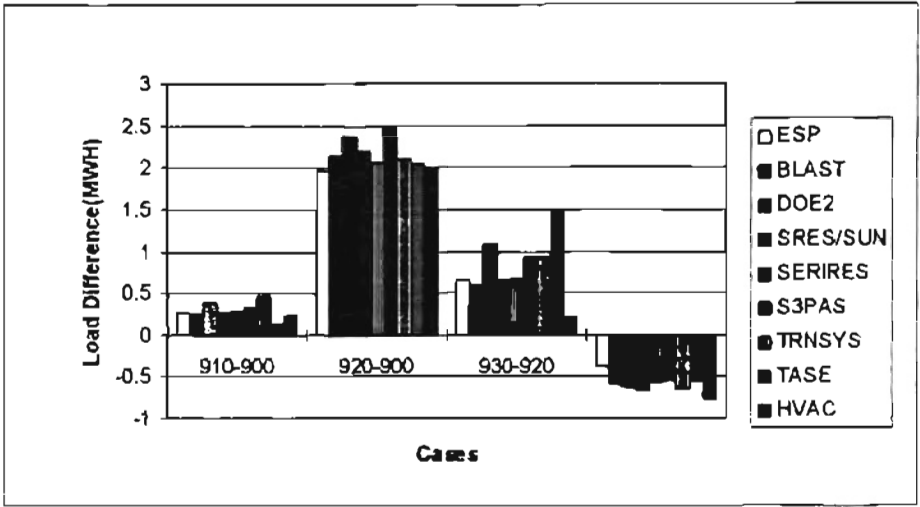


figure 5.9 BESTEST Hi Mass Cases Heating Load Qualification tests Results

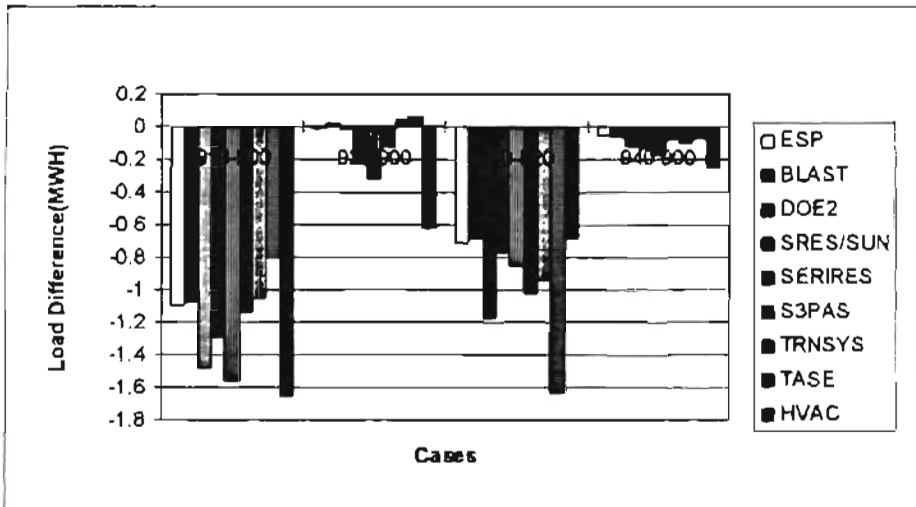


figure 5.10 BESTEST Hi Mass Cases Cooling Load Qualification tests Results

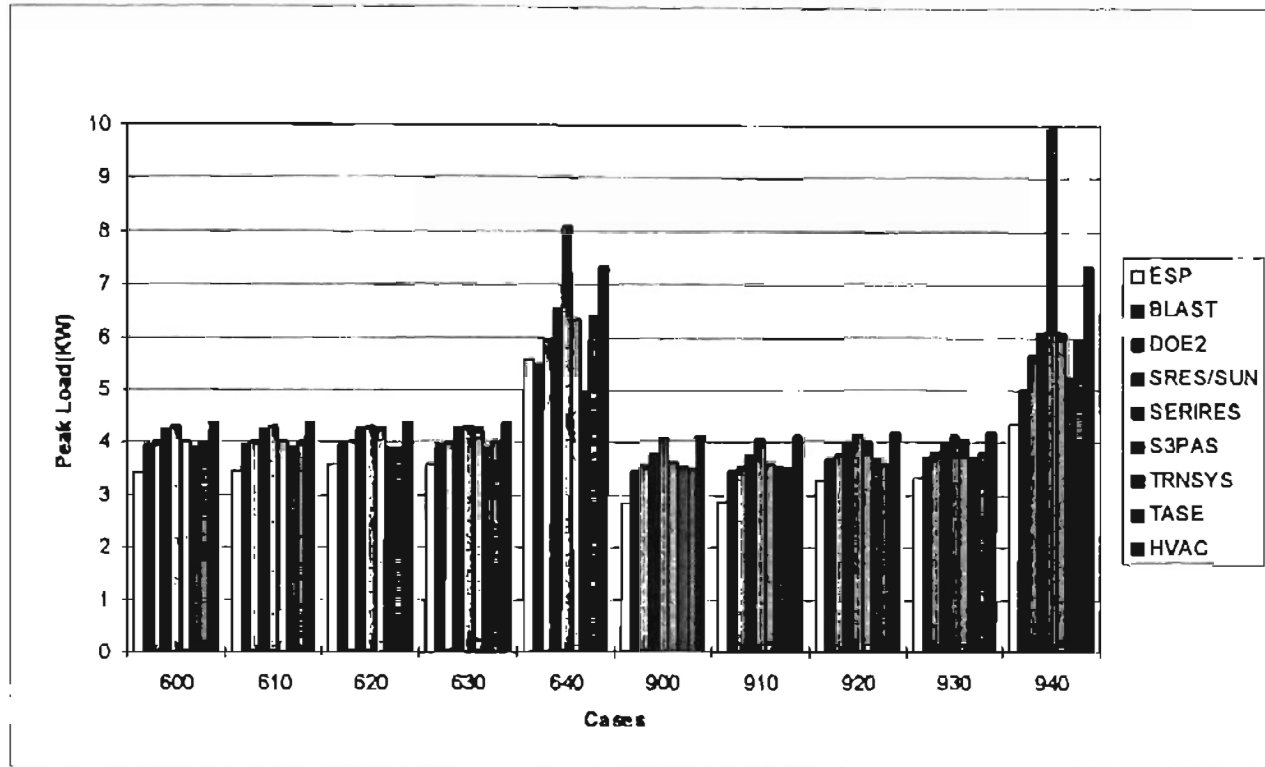


Figure 5.11 BESTEST Heating Peak Load Comparison

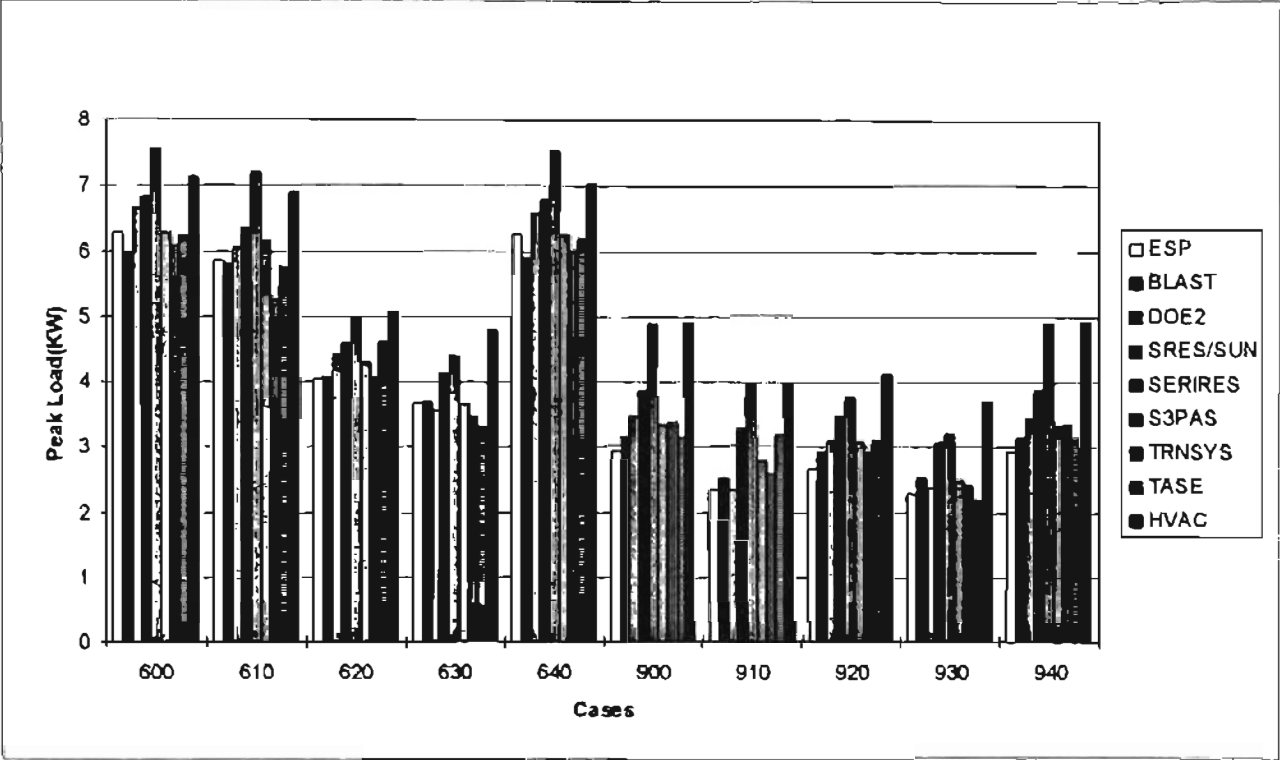


Figure 5.12 BESTEST Cooling Peak Load Comparison

## **5.4 Discussion**

The BESTEST is specially designed for both software developer to trace the potential problem and software end user to validate the commercial software accuracy. In this specific project, the BESTEST is applied to determine if the annual simulation results carried out the HVAC program is acceptable. Furthermore, when problems are encountered, the diagnostic procedure provided by the BESTEST become especially useful to trace the problem and check the implemented technical methodology in the HVAC program.

In this project, the BESTEST begin with the base test - case 600 for a light mass construction. At first, the comparison results were not satisfied for some unclear reason. According to the procedure provided by the BESTEST diagnostic diagram, cases 195 to 320 were executed to find the reason of the major disagreement in the annual simulation results.

In the BESTEST diagnostic procedure, case 195 especially tests the conduction heat transfer of the building exterior construction. In this case, there is no window on any exterior walls. Also, the components of internal heat gain, infiltration are eliminated. Furthermore, the BANGBANG is used as the system control strategy, which holds the space air temperature as a constant value of 20°C(68°F). Under these conditions, the annual simulation was executed by the HVAC program, and the results showed that the simulation results of the HVAC program has a good agreement with other programs presented in the BESTEST.

After the most basic test - case 195 has been done, the diagnostic procedure was move on to other diagnostic test cases. Among the test cases, the case 200 test the surface convection heat transfer problem; the case 230 test the infiltration problem; the case 240 tests the internal heat gain problem; the case 250 test the solar absorptance of exterior walls. The cases 210 through 220 were skipped for the reason that the HVAC program does not have the capability to simulate the interior and exterior surface IR radiation.

From the diagnostic case 270, the heat transfer through window becomes important. As discussed in the previous chapter, the algorithm of solar radiation through

window in the HVAC program makes the cooling load results higher than other programs (like BLAST). This phenomenon also appeared in the case 270. The case 290 through 310 test the affects of changing the window orientation and adding extra window exterior shading.

The results for all test cases mentioned above have an agreement with the results from other reference programs in the BESTEST in a reasonable range. The HVAC program was then considered passing these diagnostic tests. The test then moved on the case 320. The difference between the case 320 and other previous test cases is that the case 320 uses a DEADBAND system control profile which lets the room space air temperature float between 20 and 27°C (68 and 80.6°F). And this case is designed specially to test the capability of the program to deal with the thermostat DEADBAND.

The annual simulation results by the HVAC program showed a major disagreement in the annual total heating load. The problem on thermostat DEADBAND calculation in the HVAC program was noticed at this point. In order to find out the reason of the problem, detailed information was extracted during the annual simulation procedure of the HVAC program.

The BLAST program was employed to check the hourly cooling load results of the HVAC program. By using the transfer function method, the system heat extraction rate calculated by the HVAC program has an equivalent meaning with the cooling load results in the BLAST output file. For this reason, the hourly data of system heat extraction rate from the HVAC program and the hourly data of cooling loads from BLAST have been compared for the checking purposes. Because the difference between case 320 and 270 indicates the effects of the thermostat DEADBAND, the hourly loads calculation results are also extracted from both BLAST and the HVAC program for comparison. Figure 5.13 and 5.14 show the comparison between case 320 (DEADBAND) and 270 (BANGBANG) for BLAST and the HVAC program, respectively.

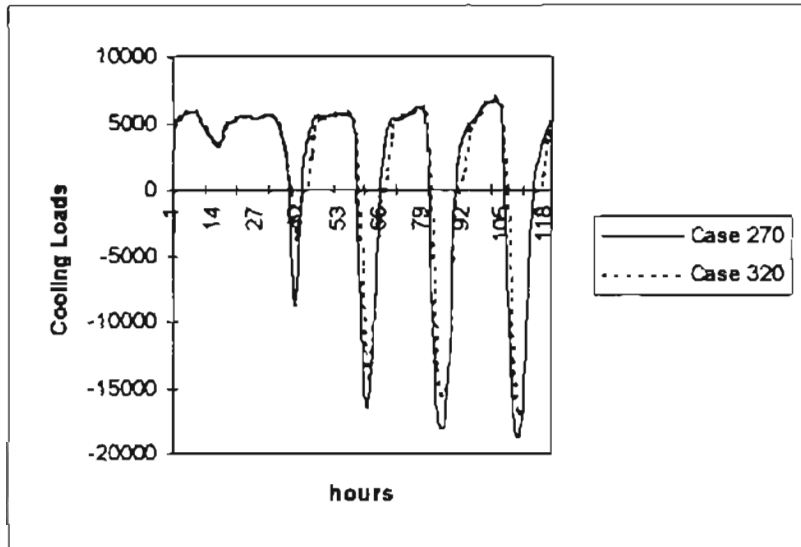


Figure 5.13 BLAST Results Comparison Between BESTEST cases 270 and 320

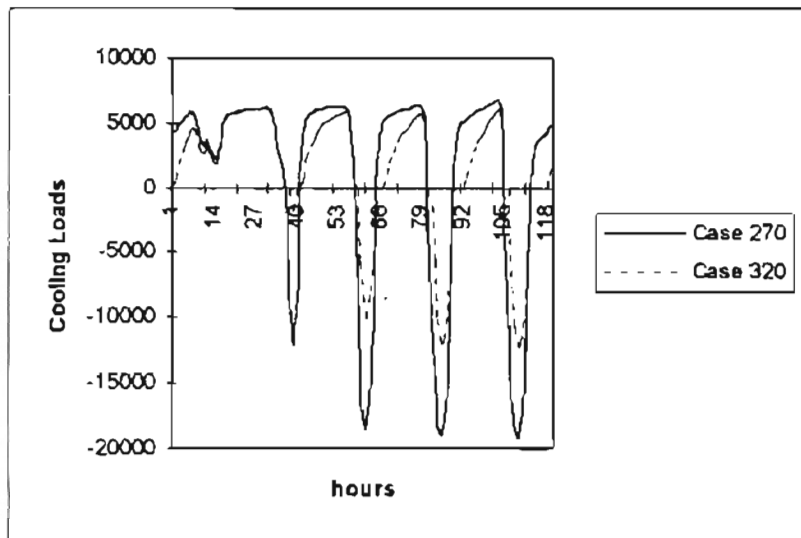


Figure 5.14 HVAC Results Comparison Between BESTEST cases 270 and 320

Figure 5.13 and 5.14 indicate that the HVAC program appears to have a higher heat storage thermal mass during DEADBAND system control strategy. According to the load calculation procedure in the transfer function method, when DEADBAND system control strategy is in effect, the part of cooling load which will be converted to the system heat extraction rate will be determined by the coefficients of space air transfer function. Furthermore, these coefficients are determined by the zone construction type. As mention before, in the previous version of the HVAC program, there are three different types of zone construction defined, which are “Light”, “Medium” and “Heavy” construction. From the test results, it is shown that even the “Light” construction type cannot represent the low mass cases in the BESTEST test properly. For this reason, it is considered that it is necessary to add an extra building construction type to the heat extraction rate calculation procedure.

As discussed in Barakat paper(1987)(See literature review in Chapter 1), for houses with wood frame construction, the mass level is much smaller than the mass range covered in ASHRAE(1993). Also, Barakat provides a set of space air transfer function coefficients for wood frame housed based on experimental results. This extra set of space air transfer function coefficients are implemented into the HVAC program. The results published here for low mass cases are the results after the implementation.

After the case 600 passed the BESTEST (after implementing the “Extra Light” construction option), the comparison results of the test case followed showed a reasonable agreements with other reference programs.

BESTEST also highlighted the sensitivity of the program to certain inputs which were found to be erroneous. At the beginning of the high mass test, there was an input error in the HVAC program building description procedure. The error was a wrong wall type is define for the exterior wall. The error lead to the results that both annual total heat and cooling load were much higher than the results carried out by other reference programs. This problem is shown even during the very basic case - case 900 of the high mass test procedure. As mention in the chapter 4, the definition of exterior wall type is very important in the transfer function method, because it determines the amplitude and time delay of conduction heat transfer through exterior walls. If these value cannot be

defined properly, all following procedure will use wrong information for further calculation on cooling loads and system heat extraction rate. After this input error was noticed and fixed, the annual simulation results of the high mass BESTEST case can also show the agreement with other reference programs.

Room parameters affect the conversion procedure from space heat gain to space cooling load. During the BESTEST procedure, it is shown clearly that some room parameters can influence the simulation results dramatically. These room parameters include: Exterior wall construction, interior shading and zone location. When other parameters are fixed, the zone location is the most sensitive parameter that influence the cooling load calculation results. Because the test case described in the BESTEST represent a zone with a exposed roof and a floor above a conditioned space, the zone location for BESTEST should be "Top Story". The value of interior shading is chosen as 0 percent because there is no curtain behind the window(s).

From the results of previous chapter, especially section 4.2.6, it is shown that the simplified window transmitting heat transfer calculation procedure can make a considerable disagreement between the HVAC program and BLAST. In BESTEST cases, the window's size is relatively large and the major part of the heat gain is due to window transmitting heat transfer. This makes the cooling load results calculated by the HVAC program larger than other programs for all cases, especially for high mass cases. The proportion of heat gain due to window become larger in high mass cases than that in low mass cases because the amplitude of exterior wall conduction heat gain in high mass cases reduced. Comparing with the annual simulation results from other reference program, the total annual cooling load calculated by the HVAC program is high but still can be used to indicate the system annual energy consumption for engineering analysis purposes. Also, the future improvement on window calculation model is expected for the HVAC program.

From the Figures 5.7 through 5.10, which show the sensitivity test results, the sensitivity of the HVAC program to each building or system description variety can be detected. For low mass and high mass cases, each differential value between two cases can indicate the sensitivity of the program to a certain case. Table 5 11 list the test purposes of each differential value.



Table 5.11 BESTEST Sensitivity Test Purposes

Differential Value	Test Purpose
610 - 600	Test South Window Overhang
620 - 600	Test East and West Solar Transmittance and incidence
630 - 620	Test East and West Window Overhang
640 - 600	Test Night Setback System Control
910 - 900	Test South Window Overhang with Mass Interaction
920 - 900	Test East and West Transmittance with Mass Interaction
930 - 920	Test East and West Shading with Mass Interaction
940 - 900	Test Setback with Mass Interaction

As illustrated in Figure 5.7 and 5.9, for annual heating load calculation results, the HVAC program has good agreement with other reference programs in most of the sensitivity test cases, except the “630 - 620” and “930 - 920” cases, which test the east and west shading devices. But it should be noticed that the absolute value of the difference between these cases are already very small. It is harder to reach a better agreement than other sensitivity test cases. Furthermore, as discussed by Judkoff (1993), even among the results of BESTEST reference programs, the disagreements in the annual cooling load predictions for the east and west shading device cases is large. In the HVAC program, the heating load actually takes the negative value of the cooling load. And because the large size of the windows in the BESTEST cases, the time of the shading device in effect almost always occurs during the period when cooling load is positive. Therefore, it is reasonable that the total annual heat load cannot be affected a lot by adding shading devices.

For high mass case, the sensitivity test results on change window orientation of the HVAC program is shown considerably higher than other program. It can be seen that the disagreement among other reference program are large and the results seem unpredictable.

All this phenomenon indicates that an improved window solar radiation heat transfer model needs to be developed.

## Chapter VI

### Conclusions and Recommendations

The procedure of annual energy analysis has been implemented in the HVAC for Windows™ program. The annual simulation results calculated by the HVAC program have been validated by the testing procedures discussed in the previous two chapters. In this chapter, the conclusions and some recommendations will be presented.

#### 6.1 Conclusions

From the comparison results in chapter IV and V, it is clearly shown that the HVAC program can successfully perform an annual load simulation on realistic buildings. To execute the annual simulation, the solar radiation calculation procedure was modified from the previous version of the HVAC program. Local annual hourly weather data is used in the building annual energy simulation.

In order to simulate a more complicated A/C system control profile for a year, the heat extraction rate calculation procedure is modified in the new version of the HVAC program. The zone space air temperature is allowed to float between high and low set point temperatures which are defined by the user. System set back period can also be modeled in the new version of HVAC program.

Unlike the design day calculation, the schedule for different time periods need to be assigned to each schedule load for an annual simulation. In the new version of the HVAC program, the user can define daily, weekly and annual schedules to an element in a

GUI environment. The system control profile can also be scheduled for an annual simulation.

Simulation result validation procedures have also been carried out in this project. The validation procedure began with a very fundamental test - a single wall test and proceeded to a very complicated real building test. The validation results are discussed in previous chapters.

The validation results in this project indicates that, for general engineering energy analysis purpose, the new version of the HVAC program can be used to simulate any kinds of commercial building with acceptable accuracy. Using the BESTEST procedure, the HVAC program was compared to other detailed energy analysis programs. Generally, the results compared well, with a few discrepancies. The thermal process of conduction heat transfer, heat gain through window, system thermostat DEADBAND and etc. can be successfully simulated by using the HVAC program. Furthermore, from the HVAC program, information of monthly loads, loads for each zone, peak loads of zones and even hourly load for an entire year can be obtained from the annual simulation. This feature is especially useful when these data is required for other HVAC application, such as GLHEPRO (Spitler, 1996) program. Further study is expected for the transfer function method on window heat gain calculation to improve the simulation accuracy of the HVAC program. Some recommendations are suggested in the following section.

## **6.2 Recommendations**

1) Using transfer function method, the floor is considered as a energy storage component. The variation of the ground temperature for different season has no effects on the load calculation procedure. If there is no other heat transfer component existing in a zone, the calculated cooling load will be carried out as zero. For a design day cooling load calculation, to ignore the heat transfer from the floor is acceptable. But for an annual simulation, the error introduced from this simplification will become significant, especially for a heating season and an interior zone calculation. It is recommended that heat transfer

component for floor be added. It can be similar to the partition element, and the ground temperature could be defined for every month during an annual simulation.

2) The calculation model of exterior surface combined coefficient needs to be improved. There are several convection coefficient calculation models available currently. For the transfer function method, a constant exterior combined coefficient is used. This will lead to a small error if the outdoor wind speed becomes large. A model which can relate the surface coefficient with the outdoor wind speed and surface roughness can be implemented to the HVAC program in the future to eliminate this error.

3) An improved calculation model of window heat transfer needs to be developed for the transfer function method. Currently, the shading coefficient is employed to simplify the radiation transmitted through the window. The shading coefficient approach ignores incidence angle dependence and assumes a constant fraction of the absorbed solar radiation is convected into the space. Furthermore, the value of the shading coefficient strongly affects the results. From the stand point of this project, it is recommended that a more detailed window heat transfer model be implemented to improve the accuracy of annual load simulation.

4) The current version of the HVAC program does not have the capability to model actual humidity fluctuations in the space. A constant zone design relative humidity ratio is used for an entire year simulation. The error of the latent load calculation results can become considerably large during the heating season. It is recommended that a model of a coil be added which can account for condensation under actual operating conditions.

5) An more detailed model to simulate the shading device which affects the beam radiation through window is recommended. Form the results of the BESTEST, even among the state of the art load calculation program, a weak agreement occurred in modeling window shading device. More empirical study is required to verify the analysis simulation results.

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## **Appendixes**

## **Appendix A**

### **BLAST Input File for the Motel Load Simulation**

```

REGIN INPUT:
RUN CONTROL:
NEW ZONES,
NEW AIR SYSTEMS,
PLANT,
REPORTS (ZONE LOADS, ZONE),
UNITS (IN=ENGLISH, OUT=ENGLISH):
TEMPORARY MATERIALS:
WALLINSU
  = (L=0.1820, K=0.0250, D=5.7, CP=0.200, ABS=0.75,
    TABS=0.900, ROUGH);
ROOFINSU
  = (L=0.1500, K=0.0250, D=5.7, CP=0.200, ABS=0.75,
    TABS=0.900, ROUGH);
MGLASS
  = (R=0.610, SC=0.00, VERY SMOOTH, GLASS);
FLOORINSU
  = (R=00.000, ABS=0.75, TABS=0.900, ROUGH);
MIZPART
  = (R=1.500, ABS=0.75, TABS=0.900, ROUGH);
END:
TEMPORARY WALLS:
MPARTI
  = (PL4 ,
    IN2 ,
    PL4);
MHWALL
  = (PL3 ,
    PL4 ,
    WALLINSU ,
    PL4);
MIZ
  = (MGLASS);
END:
TEMPORARY ROOFS:
CROOF
  = (WD2 ,
    IN2 ,
    E4 ,
    PL4);
MROOF
  = (PL4 ,
    E4 ,
    ROOFINSU ,
    E5);
END:
TEMPORARY FLOORS:
MFLOR
  = (DIRT 12 IN ,
    CO1);
CFLOOR
  = (PL4 ,
    E4 ,
    IN2 ,
    WD2);
INSUFLOOR
  = (DIRT 12 IN ,
    FLOORINSU ,
    CO1);
END:
TEMPORARY WINDOWS:
MWINDOW

```

```

= (MGLASS);
END:
TEMPORARY SCHEDULE (ROOM LIGHT):
MONDAY THRU FRIDAY=(0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,
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SATURDAY=(0.00,0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,
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SPECIAL3=(0.00,0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,
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SPECIAL4=(0.00,0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,0.00,
0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,0.00);
END:
TEMPORARY SCHEDULE (ROOM PEOPLE):
MONDAY THRU FRIDAY=(1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,0.00,0.00,
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SPECIAL1=(1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,0.00,0.00,
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SPECIAL2=(1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,0.00,0.00,
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END:
TEMPORARY SCHEDULE (ROOM TV):
MONDAY THRU FRIDAY=(0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,
0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,0.00),
SATURDAY=(0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,
0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,0.00),
SUNDAY=(0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,
0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,0.00),
HOLIDAY=(0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,
0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,0.00),
SPECIAL1=(0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,
0.00,0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,0.00),
SPECIAL2=(0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,
0.00,0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,0.00),
SPECIAL3=(0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,
0.00,0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,0.00),
SPECIAL4=(0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,
0.00,0.00,0.00,0.00,0.00,0.00,0.00,1.00,1.00,1.00,0.00,0.00);
END:
TEMPORARY SCHEDULE (CONTINUOUS):
MONDAY THRU FRIDAY=(1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,
1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00),
SATURDAY=(1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,
1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00),
SUNDAY=(1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,
1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00);

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FACING(180.00)  
 TILTED(180.00)  
 MFLOOR (28.00 BY 12.50):  
 CEILINGS :  
 STARTING AT(0.00, 0.00, 9.00)  
 FACING(180.00)  
 TILTED(0.00)  
 CROOF (28.00 BY 12.50):  
 PEOPLE=2,ROOM PEOPLE ,  
 AT ACTIVITY LEVEL 0.35,100.00 PERCENT RADIANT,  
 FROM 01JAN THRU 31DEC:  
 LIGHTS=0.78,ROOM LIGHT ,  
 0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,  
 0.00 PERCENT VISIBLE, 0.00 PERCENT REPLACEABLE,  
 FROM 01JAN THRU 31DEC:  
 CONTROLS=ROOM CONTROL ,  
 3412000.0 HEATING, 3412000.0 COOLING,  
 0.00 PERCENT HRT,  
 FROM 01JAN THRU 31DEC:  
 ELECTRIC EQUIPMENT=0.68,ROOM TV ,  
 100.00 PERCENT RADIANT, 0.00 PERCENT LATENT, 0.00 PERCENT LOST,  
 FROM 01JAN THRU 31DEC:  
 INFILTRATION=53.13,ROOM VENT ,  
 WITH COEFFICIENTS (1.000000, 0.000000, 0.000000, 0.000000),  
 FROM 01JAN THRU 31DEC:  
 END ZONE:  
 ZONE 2 "1W.typical " :  
 ORIGIN:(0.00, -24.84, 0.00):  
 NORTH AXIS=0.00:  
 EXTERIOR WALLS :  
 STARTING AT(0.00, 12.42, 0.00)  
 FACING(270.00)  
 TILTED(90.00)  
 MWALL (12.42 BY 8.00)  
 WITH WINDOWS OF TYPE  
 MWINDOW (5.38 BY 5.00)  
 REVEAL(0.00)  
 AT (0.01, 0.01):  
 PARTITIONS :  
 STARTING AT(0.00, 0.00, 0.00)  
 FACING(190.00)  
 TILTED(90.00)  
 MPARTI (24.70 BY 8.00),  
 STARTING AT(24.70, 0.00, 0.00)  
 FACING(90.00)  
 TILTED(90.00)  
 MPARTI (9.00 BY 8.00),  
 STARTING AT(24.70, 12.42, 0.00)  
 FACING(0.00)  
 TILTED(90.00)  
 MPARTI (24.70 BY 8.00):  
 SLAB ON GRADE FLOORS :  
 STARTING AT(0.00, 12.42, 0.00)  
 FACING(190.00)  
 TILTED(180.00)  
 MFLOOR (28.00 BY 12.42):  
 CEILINGS :  
 STARTING AT(0.00, 0.00, 9.00)  
 FACING(180.00)  
 TILTED(0.00)  
 CROOF (28.00 BY 12.42):  
 PEOPLE=2,ROOM PEOPLE ,  
 AT ACTIVITY LEVEL 0.35,100.00 PERCENT RADIANT,  
 FROM 01JAN THRU 31DEC:  
 LIGHTS=0.78,ROOM LIGHT ,  
 0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,  
 0.00 PERCENT VISIBLE, 0.00 PERCENT REPLACEABLE,  
 FROM 01JAN THRU 31DEC:  
 CONTROLS=ROOM CONTROL ,  
 3412000.0 HEATING, 3412000.0 COOLING,  
 0.00 PERCENT HRT.

AT ACTIVITY LEVEL 0.35,100.00 PERCENT RADIANT,  
 FROM 01JAN THRU 31DEC:  
 LIGHTS=0.78,ROOM LIGHT ,  
 0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,  
 0.00 PERCENT VISIBLE, 0.00 PERCENT REPLACEABLE,  
 FROM 01JAN THRU 31DEC:  
 CONTROLS=ROOM CONTROL ,  
 3412000.0 HEATING, 3412000.0 COOLING,  
 0.00 PERCENT HRT,  
 FROM 01JAN THRU 31DEC:  
 ELECTRIC EQUIPMENT=0.68,ROOM TV ,  
 100.00 PERCENT RADIANT, 0.00 PERCENT LATENT, 0.00 PERCENT LOST,  
 FROM 01JAN THRU 31DEC:  
 INFILTRATION=53.13,ROOM VENT ,  
 WITH COEFFICIENTS (1.000000, 0.000000, 0.000000, 0.000000),  
 FROM 01JAN THRU 31DEC:  
 END ZONE:  
 ZONE 3 "1N.E.Corner " :  
 ORIGIN:(28.00, -12.42, 0.00):  
 NORTH AXIS=0.00:  
 EXTERIOR WALLS :  
 STARTING AT(28.00, 0.00, 0.00)  
 FACING(90.00)  
 TILTED(90.00)  
 MWALL (12.42 BY 8.00)  
 WITH WINDOWS OF TYPE  
 MWINDOW (5.38 BY 5.00)  
 REVEAL(0.00)  
 AT (0.01, 0.01),  
 STARTING AT(28.00, 12.42, 0.00)  
 FACING(0.00)  
 TILTED(90.00)  
 MWALL (28.00 BY 8.00):  
 PARTITIONS :  
 STARTING AT(3.30, 0.00, 0.00)  
 FACING(180.00)  
 TILTED(90.00)  
 MPARTI (24.70 BY 8.00),  
 STARTING AT(3.30, 9.00, 0.00)  
 FACING(270.00)  
 TILTED(90.00)  
 MPARTI (9.00 BY 8.00):  
 SLAB ON GRADE FLOORS :  
 STARTING AT(0.00, 12.42, 0.00)  
 FACING(180.00)  
 TILTED(180.00)  
 MFLOOR (28.00 BY 12.42):  
 CEILINGS :  
 STARTING AT(0.00, 0.00, 9.00)  
 FACING(180.00)  
 TILTED(0.00)  
 CROOF (28.00 BY 12.42):  
 PEOPLE=2,ROOM PEOPLE ,  
 AT ACTIVITY LEVEL 0.35,100.00 PERCENT RADIANT,  
 FROM 01JAN THRU 31DEC:  
 LIGHTS=0.78,ROOM LIGHT ,  
 0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,  
 0.00 PERCENT VISIBLE, 0.00 PERCENT REPLACEABLE,  
 FROM 01JAN THRU 31DEC:  
 CONTROLS=ROOM CONTROL ,  
 3412000.0 HEATING, 3412000.0 COOLING,  
 0.00 PERCENT HRT.

FROM 01JAN THRU 31DEC;  
ELECTRIC EQUIPMENT=0.68,ROOM TV ,  
100.00 PERCENT RADIANT, 0.00 PERCENT LATENT, 0.00 PERCENT LOST,  
FROM 01JAN THRU 31DEC;  
INFILTRATION=53.13,ROOM VENT ,  
WITH COEFFICIENTS (1.000000, 0.000000, 0.000000, 0.000000),  
FROM 01JAN THRU 31DEC;

END ZONE;

ZONE 4 "IE.Typical ":

ORIGIN:(29.00, -24.84, 0.00);

NORTH AXIS=0.00;

EXTERIOR WALLS :

STARTING AT(28.00, 0.00, 0.00)

FACING(90.00)

TILTED(90.00)

MWALL (12.42 BY 8.00)

WITH WINDOWS OF TYPE

MWINDOW (5.30 BY 5.00)

REVEAL(0.00)

AT (0.01, 0.01);

PARTITIONS :

STARTING AT(3.30, 0.00, 0.00)

FACING(180.00)

TILTED(90.00)

MPART) (24.70 BY 8.00),

STARTING AT(3.30, 9.00, 0.00)

FACING(270.00)

TILTED(90.00)

MPART) (9.00 BY 8.00),

STARTING AT(28.00, 12.42, 0.00)

FACING(0.00)

TILTED(90.00)

MPART) (24.70 BY 8.00);

SLAB ON GRADE FLOORS :

STARTING AT(0.00, 12.42, 0.00)

FACING(180.00)

TILTED(180.00)

MFLOOR (28.00 BY 12.42);

CEILING :

STARTING AT(0.00, 0.00, 8.00)

FACING(180.00)

TILTED(0.00)

CROOF (28.00 BY 12.42);

PEOPLE=2,ROOM PEOPLE ,

AT ACTIVITY LEVEL 0.35,100.00 PERCENT RADIANT,

FROM 01JAN THRU 31DEC;

LIGHTS=0.78,ROOM LIGHT ,

0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,

0.00 PERCENT VISIBLE, 0.00 PERCENT REFLECTABLE,

FROM 01JAN THRU 31DEC;

CONTROLS=ROOM CONTROL ,

3412000.0 HEATING, 3412000.0 COOLING,

0.00 PERCENT HRT,

FROM 01JAN THRU 31DEC;

ELECTRIC EQUIPMENT=0.68,ROOM TV ,

100.00 PERCENT RADIANT, 0.00 PERCENT LATENT, 0.00 PERCENT LOST,

FROM 01JAN THRU 31DEC;

INFILTRATION=53.13,ROOM VENT ,

WITH COEFFICIENTS (1.000000, 0.000000, 0.000000, 0.000000),

FROM 01JAN THRU 31DEC;

END ZONE;

ZONE 5 "IW.Typical ":

ORIGIN:(0.00, -37.26, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 2 EXCEPT;

END ZONE;

ZONE 6 "IW.Typical ":

ORIGIN:(0.00, -49.68, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 2 EXCEPT;

END ZONE;

ZONE 7 "IW.Typical ":

ORIGIN:(0.00, -62.10, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 2 EXCEPT;

END ZONE;

ZONE 8 "IW.Typical ":

ORIGIN:(0.00, -74.52, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 2 EXCEPT;

END ZONE;

ZONE 9 "IW.Typical ":

ORIGIN:(0.00, -86.94, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 2 EXCEPT;

END ZONE;

ZONE 10 "IW.Typical ":

ORIGIN:(0.00, -99.36, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 2 EXCEPT;

END ZONE;

ZONE 11 "IW.Typical ":

ORIGIN:(0.00, -111.78, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 2 EXCEPT;

END ZONE;

ZONE 12 "IW.Typical ":

ORIGIN:(0.00, -124.20, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 2 EXCEPT;

END ZONE;

ZONE 13 "IE.Typical ":

ORIGIN:(28.00, -37.26, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 4 EXCEPT;

END ZONE;

ZONE 14 "IE.Typical ":

ORIGIN:(28.00, -49.68, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 4 EXCEPT;

END ZONE;

ZONE 15 "IE.Typical ":

ORIGIN:(28.00, -62.10, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 4 EXCEPT;

END ZONE;

ZONE 16 "IE.Typical ":

ORIGIN:(28.00, -74.52, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 4 EXCEPT;

END ZONE;

ZONE 17 "IE.Typical ":

ORIGIN:(28.00, -86.94, 0.00);

NORTH AXIS=0.00;

SAME AS ZONE 4 EXCEPT:  
 END ZONE;  
 ZONE 18 "IE. Typical ":  
 ORIGIN:(28.00, -99.16, 0.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 4 EXCEPT:  
 END ZONE;  
 ZONE 19 "laundry ":  
 ORIGIN:(28.00, -124.20, 0.00);  
 NORTH AXIS=0.00;  
 EXTERIOR WALLS :  
 STARTING AT(28.00, 0.00, 0.00)  
 FACING(90.00)  
 TILTED(90.00)  
 MWALL (24.84 BY 8.00);  
 PARTITIONS :  
 STARTING AT(28.00, 24.84, 0.00)  
 FACING(0.00)  
 TILTED(90.00)  
 MPART1 (24.70 BY 8.00),  
 STARTING AT(3.30, 24.84, 0.00)  
 FACING(270.00)  
 TILTED(90.00)  
 MPART1 (24.84 BY 9.00),  
 STARTING AT(3.30, 0.00, 0.00)  
 FACING(180.00)  
 TILTED(90.00)  
 MPART1 (24.70 BY 8.00);  
 SLAB ON GRADE FLOORS :  
 STARTING AT(0.00, 24.84, 0.00)  
 FACING(180.00)  
 TILTED(180.00)  
 MFLOOR (28.00 BY 24.84);  
 CEILINGS :  
 STARTING AT(0.00, 0.00, 8.00)  
 FACING(180.00)  
 TILTED(0.00)  
 CROOF (28.00 BY 24.84);  
 PEOPLE=5, LAUNDRY MACHINE ,  
 AT ACTIVITY LEVEL 0.65, 100.00 PERCENT RADIANT,  
 FROM 01JAN THRU 31DEC;  
 LIGHTS=1.90, LAUNDRY MACHINE ,  
 0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,  
 0.00 PERCENT VISIBLE, 0.00 PERCENT REPLACEABLE,  
 FROM 01JAN THRU 31DEC;  
 ELECTRIC EQUIPMENT=7.17, LAUNDRY MACHINE ,  
 100.00 PERCENT RADIANT, 0.00 PERCENT LATENT, 0.00 PERCENT LOST,  
 FROM 01JAN THRU 31DEC;  
 CONTROLS=LAUNDRY CONTROL ,  
 3412000.0 HEATING, 3412000.0 COOLING,  
 0.00 PERCENT MRT,  
 FROM 01JAN THRU 31DEC;  
 INFILTRATION=299.00, LAUNDRY VENT ,  
 WITH COEFFICIENTS (1.000000, 0.000000, 0.000000, 0.000000),  
 FROM 01JAN THRU 31DEC;  
 END ZONE;  
 ZONE 20 "Lobby ":  
 ORIGIN:(0.00, -152.33, 0.00);  
 NORTH AXIS=0.00;  
 EXTERIOR WALLS :  
 STARTING AT(0.00, 34.33, 0.00)  
 FACING(270.00)

TILTED(90.00)  
 MWALL (34.33 BY 8.00)  
 WITH WINDOWS OF TYPE  
 MWINDOW (9.09 BY 7.00)  
 REVEAL(0.00)  
 AT (0.01, 0.01),  
 STARTING AT(56.00, 0.00, 0.00)  
 FACING(90.00)  
 TILTED(90.00)  
 MWALL (34.33 BY 8.00)  
 WITH WINDOWS OF TYPE  
 MWINDOW (29.47 BY 7.60)  
 REVEAL(0.00)  
 AT (0.01, 0.01);  
 PARTITIONS :  
 STARTING AT(0.00, 0.00, 0.00)  
 FACING(180.00)  
 TILTED(90.00)  
 MPART1 (56.00 BY 8.00),  
 STARTING AT(56.00, 34.33, 0.00)  
 FACING(0.00)  
 TILTED(90.00)  
 MPART1 (56.00 BY 8.00);  
 SLAB ON GRADE FLOORS :  
 STARTING AT(0.00, 34.33, 0.00)  
 FACING(180.00)  
 TILTED(180.00)  
 MFLOOR (56.00 BY 34.33);  
 ROOFS :  
 STARTING AT(56.00, 0.00, 8.00)  
 FACING(90.00)  
 TILTED(15.00)  
 MROOF (34.33 BY 29.00);  
 CEILINGS :  
 STARTING AT(0.00, 0.00, 8.00)  
 FACING(180.00)  
 TILTED(0.00)  
 CROOF (28.00 BY 34.33);  
 PEOPLE=15, LOBBY PEOPLE ,  
 AT ACTIVITY LEVEL 0.45, 100.00 PERCENT RADIANT,  
 FROM 01JAN THRU 31DEC;  
 LIGHTS=3.29, CONTINUOUS ,  
 0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,  
 0.00 PERCENT VISIBLE, 0.00 PERCENT REPLACEABLE,  
 FROM 01JAN THRU 31DEC;  
 CONTROLS=ROOM CONTROL ,  
 3412000.0 HEATING, 3412000.0 COOLING,  
 0.00 PERCENT MRT,  
 FROM 01JAN THRU 31DEC;  
 ELECTRIC EQUIPMENT=2.00, CONTINUOUS ,  
 100.00 PERCENT RADIANT, 0.00 PERCENT LATENT, 0.00 PERCENT LOST,  
 FROM 01JAN THRU 31DEC;  
 INFILTRATION=557.00, CONTINUOUS ,  
 WITH COEFFICIENTS (1.000000, 0.000000, 0.000000, 0.000000),  
 FROM 01JAN THRU 31DEC;  
 END ZONE;  
 ZONE 21 "2nd W. Corridor ":  
 ORIGIN:(0.00, -124.42, 8.00);  
 NORTH AXIS=0.00;  
 EXTERIOR WALLS :  
 STARTING AT(0.00, 12.42, 0.00)  
 FACING(270.00)



TILTED(90.00)  
 MWALL (12.42 BY 8.00)  
 WITH WINDOWS OF TYPE  
 MWINDOW (5.38 BY 5.00)  
 REVEAL(0.00)  
 AT (0.01, 0.01),  
 STARTING AT(24.00, 12.42, 0.00)  
 FACING(0.00)  
 TILTED(90.00)  
 MWALL (28.00 BY 8.00);  
 PARTITIONS :  
 STARTING AT(0.00, 0.00, 0.00)  
 FACING(180.00)  
 TILTED(90.00)  
 MPARTI (24.70 BY 8.00),  
 STARTING AT(24.70, 0.00, 0.00)  
 FACING(90.00)  
 TILTED(90.00)  
 MPARTI (9.00 BY 9.00);  
 FLOORS :  
 STARTING AT(0.00, 12.42, 0.00)  
 FACING(180.00)  
 TILTED(180.00)  
 CFLOOR (28.00 BY 12.42);  
 ROOFS :  
 STARTING AT(0.00, 12.42, 8.00)  
 FACING(270.00)  
 TILTED(15.00)  
 MROOF (12.42 BY 28.00);  
 PEOPLE=2,ROOM PEOPLE ,  
 AT ACTIVITY LEVEL 0.35,100.00 PERCENT RADIANT,  
 FROM 01JAN THRU 31DEC;  
 LIGHTS=0.78,ROOM LIGHT ,  
 0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,  
 0.00 PERCENT VISIBLE, 0.00 PERCENT REPLACEABLE,  
 FROM 01JAN THRU 31DEC;  
 CONTROLS=ROOM CONTROL ,  
 3412000.0 HEATING, 3412000.0 COOLING,  
 0.00 PERCENT HRT,  
 FROM 01JAN THRU 31DEC;  
 ELECTRIC EQUIPMENT=0.68,ROOM TV ,  
 100.00 PERCENT RADIANT, 0.00 PERCENT LATENT, 0.00 PERCENT LOST,  
 FROM 01JAN THRU 31DEC;  
 INFILTRATION=53.13,ROOM VENT ,  
 WITH COEFFICIENTS (1.000000, 0.000000, 0.000000, 0.000000),  
 FROM 01JAN THRU 31DEC;  
 END ZONE;  
 ZONE 23 "2W.Typical " :  
 ORIGIN:(0.00, 24.94, 8.00);  
 NORTH AXIS 1.00;  
 EXTERIOR WALLS :  
 STARTING AT(0.00, 12.42, 0.00)  
 FACING(270.00)  
 TILTED(90.00)  
 MWALL (12.42 BY 8.00)  
 WITH WINDOWS OF TYPE  
 MWINDOW (5.38 BY 5.00)  
 REVEAL(0.00)  
 AT (0.01, 0.01);  
 PARTITIONS :  
 STARTING AT(0.00, 0.00, 0.00)  
 FACING(180.00)

TILTED(90.00)  
 MPARTI (24.70 BY 8.00),  
 STARTING AT(24.70, 0.00, 0.00)  
 FACING(90.00)  
 TILTED(90.00)  
 MPARTI (9.00 BY 8.00),  
 STARTING AT(24.70, 12.42, 0.00)  
 FACING(0.00)  
 TILTED(90.00)  
 MPARTI (24.70 BY 8.00);  
 FLOORS :  
 STARTING AT(0.00, 12.42, 0.00)  
 FACING(180.00)  
 TILTED(180.00)  
 CFLOOR (28.00 BY 12.42);  
 ROOFS :  
 STARTING AT(0.00, 12.42, 8.00)  
 FACING(270.00)  
 TILTED(15.00)  
 MROOF (12.42 BY 28.00);  
 PEOPLE=2,ROOM PEOPLE ,  
 AT ACTIVITY LEVEL 0.35,100.00 PERCENT RADIANT,  
 FROM 01JAN THRU 31DEC;  
 LIGHTS=0.78,ROOM LIGHT ,  
 0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,  
 0.00 PERCENT VISIBLE, 0.00 PERCENT REPLACEABLE,  
 FROM 01JAN THRU 31DEC;  
 CONTROLS=ROOM CONTROL ,  
 3412000.0 HEATING, 3412000.0 COOLING,  
 0.00 PERCENT HRT,  
 FROM 01JAN THRU 31DEC;  
 ELECTRIC EQUIPMENT=0.68,ROOM TV ,  
 100.00 PERCENT RADIANT, 0.00 PERCENT LATENT, 0.00 PERCENT LOST,  
 FROM 01JAN THRU 31DEC;  
 INFILTRATION=53.13,ROOM VENT ,  
 WITH COEFFICIENTS (1.000000, 0.000000, 0.000000, 0.000000),  
 FROM 01JAN THRU 31DEC;  
 END ZONE;  
 ZONE 23 "2W.Typical " :  
 ORIGIN:(0.00, -37.26, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 22 EXCEPT;  
 END ZONE;  
 ZONE 24 "2W.Typical " :  
 ORIGIN:(0.00, -49.68, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 22 EXCEPT;  
 END ZONE;  
 ZONE 25 "2W.Typical " :  
 ORIGIN:(0.00, -62.10, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 22 EXCEPT;  
 END ZONE;  
 ZONE 26 "2W.Typical " :  
 ORIGIN:(0.00, -74.52, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 22 EXCEPT;  
 END ZONE;  
 ZONE 27 "2W.Typical " :  
 ORIGIN:(0.00, -86.94, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 22 EXCEPT;

END ZONE:  
 ZONE 28 "2W.Typical " :  
 ORIGIN:(0.00, -99.36, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 22 EXCEPT:  
 END ZONE:  
 ZONE 29 "2W.Typical " :  
 ORIGIN:(0.00, -111.71, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 22 EXCEPT:  
 END ZONE:  
 ZONE 30 "2W.Typical " :  
 ORIGIN:(0.00, -124.20, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 22 EXCEPT:  
 END ZONE:  
 ZONE 31 "2N.E.Typical " :  
 ORIGIN:(28.00, -12.42, 8.00);  
 NORTH AXIS=0.00;  
 EXTERIOR WALLS :  
 STARTING AT(28.00, 0.00, 0.00)  
 FACING(90.00)  
 TILTED(90.00)  
 MWALL (12.42 BY 8.00)  
 WITH WINDOWS OF TYPE  
 MWINDOW (5.39 BY 5.00)  
 REVEAL(0.00)  
 AT (0.01, 0.01);  
 STARTING AT(29.00, 12.42, 0.00)  
 FACING(0.00)  
 TILTED(90.00)  
 MWALL (28.00 BY 8.00);  
 PARTITIONS :  
 STARTING AT(3.30, 0.00, 0.00)  
 FACING(180.00)  
 TILTED(90.00)  
 MPARTI (24.70 BY 8.00);  
 STARTING AT(3.30, 9.00, 0.00)  
 FACING(270.00)  
 TILTED(90.00)  
 MPARTI (9.00 BY 8.00);  
 FLOORS :  
 STARTING AT(0.00, 12.42, 0.00)  
 FACING(180.00)  
 TILTED(180.00)  
 CFLOOR (28.00 BY 12.42);  
 ROOFS :  
 STARTING AT(29.00, 0.00, 8.00)  
 FACING(90.00)  
 TILTED(15.00)  
 HROOF (12.42 BY 28.00);  
 PEOPLE=2,ROOM PEOPLE ,  
 AT ACTIVITY LEVEL 0.35,100.00 PERCENT RADIANT,  
 FROM 01JAN THRU 31DEC;  
 LIGHTS=0.78,ROOM LIGHT ,  
 0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,  
 0.00 PERCENT VISIBLE, 0.00 PERCENT REPLACEABLE,  
 FROM 01JAN THRU 31DEC;  
 CONTROLS=ROOM CONTROL ,  
 3412000.0 HEATING, 3412000.0 COOLING,  
 0.00 PERCENT MRT,  
 FROM 01JAN THRU 31DEC;

ELECTRIC EQUIPMENT=0.68,ROOM TV ,  
 100.00 PERCENT RADIANT, 0.00 PERCENT LATENT, 0.00 PERCENT LOST,  
 FROM 01JAN THRU 31DEC;  
 INFILTRATION=53.13,ROOM VENT ,  
 WITH COEFFICIENTS (1.000000, 0.000000, 0.000000, 0.000000),  
 FROM 01JAN THRU 31DEC;  
 END ZONE:  
 ZONE 32 "2E.Typical " :  
 ORIGIN:(28.00, 24.84, 8.00);  
 NORTH AXIS=0.00;  
 EXTERIOR WALLS :  
 STARTING AT(28.00, 0.00, 0.00)  
 FACING(90.00)  
 TILTED(90.00)  
 MWALL (12.42 BY 8.00)  
 WITH WINDOWS OF TYPE  
 MWINDOW (5.39 BY 5.00)  
 REVEAL(0.00)  
 AT (0.01, 0.01);  
 PARTITIONS :  
 STARTING AT(3.30, 9.00, 0.00)  
 FACING(270.00)  
 TILTED(90.00)  
 MPARTI (9.00 BY 8.00);  
 STARTING AT(3.30, 0.00, 0.00)  
 FACING(180.00)  
 TILTED(90.00)  
 MPARTI (24.70 BY 8.00);  
 STARTING AT(28.00, 12.42, 0.00)  
 FACING(0.00)  
 TILTED(90.00)  
 MPARTI (24.70 BY 8.00);  
 FLOORS :  
 STARTING AT(0.00, 12.42, 0.00)  
 FACING(180.00)  
 TILTED(180.00)  
 CFLOOR (28.00 BY 12.42);  
 ROOFS :  
 STARTING AT(29.00, 0.00, 8.00)  
 FACING(90.00)  
 TILTED(15.00)  
 HROOF (12.42 BY 28.00);  
 PEOPLE=2,ROOM PEOPLE ,  
 AT ACTIVITY LEVEL 0.35,100.00 PERCENT RADIANT,  
 FROM 01JAN THRU 31DEC;  
 LIGHTS=0.78,ROOM LIGHT ,  
 0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,  
 0.00 PERCENT VISIBLE, 0.00 PERCENT REPLACEABLE,  
 FROM 01JAN THRU 31DEC;  
 CONTROLS=ROOM CONTROL ,  
 3412000.0 HEATING, 3412000.0 COOLING,  
 0.00 PERCENT MRT,  
 FROM 01JAN THRU 31DEC;  
 ELECTRIC EQUIPMENT=0.68,ROOM TV ,  
 100.00 PERCENT RADIANT, 0.00 PERCENT LATENT, 0.00 PERCENT LOST,  
 FROM 01JAN THRU 31DEC;  
 INFILTRATION=53.13,ROOM VENT ,  
 WITH COEFFICIENTS (1.000000, 0.000000, 0.000000, 0.000000),  
 FROM 01JAN THRU 31DEC;  
 END ZONE:  
 ZONE 33 "2E.Typical " :  
 ORIGIN:(28.00, -37.26, 8.00);

NORTH AXIS=0.00;  
 SAME AS ZONE 32 EXCEPT:  
 END ZONE;  
 ZONE 34 "2E.Typical ":  
 ORIGIN:(28.00, -49.68, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 32 EXCEPT:  
 END ZONE;  
 ZONE 35 "2E.Typical ":  
 ORIGIN:(28.00, -62.10, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 32 EXCEPT:  
 END ZONE;  
 ZONE 36 "2E.Typical ":  
 ORIGIN:(28.00, -74.52, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 32 EXCEPT:  
 END ZONE;  
 ZONE 37 "2E.Typical ":  
 ORIGIN:(28.00, -86.94, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 32 EXCEPT:  
 END ZONE;  
 ZONE 38 "2E.Typical ":  
 ORIGIN:(28.00, -99.36, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 32 EXCEPT:  
 END ZONE;  
 ZONE 39 "2E.Typical ":  
 ORIGIN:(28.00, -111.78, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 32 EXCEPT:  
 END ZONE;  
 ZONE 40 "2E.Typical ":  
 ORIGIN:(28.00, -124.20, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 32 EXCEPT:  
 END ZONE;  
 ZONE 41 "2 Special ":  
 ORIGIN:(0.00, -141.37, 8.00);  
 NORTH AXIS=0.00;  
 EXTERIOR WALLS :  
 STARTING AT(0.00, 17.17, 0.00)  
 FACING(270.00)  
 TILTED(90.00)  
 MWALL (17.17 BY 8.00)  
 WITH WINDOWS OF TYPE  
 MWINDOW (7.68 BY 7.00)  
 REVEAL(0.00)  
 AT (0.01, 0.01);  
 PARTITIONS :  
 STARTING AT(0.00, 0.00, 0.00)  
 FACING(180.00)  
 TILTED(90.00)  
 MPARTI (24.70 BY 8.00),  
 STARTING AT(24.70, 0.00, 0.00)  
 FACING(90.00)  
 TILTED(90.00)  
 MPARTI (24.70 BY 8.00),  
 STARTING AT(24.70, 17.17, 0.00)  
 FACING(10.00)  
 TILTED(90.00)

MPARTI (24.70 BY 8.00);  
 FLOORS :  
 STARTING AT(0.00, 17.17, 0.00)  
 FACING(180.00)  
 TILTED(180.00)  
 CFLOOR (31.50 BY 17.17);  
 ROOFS :  
 STARTING AT(0.00, 17.17, 8.00)  
 FACING(270.00)  
 TILTED(0.00)  
 MROOF (17.17 BY 31.50);  
 PEOPLE=2, ROOM PEOPLE ,  
 AT ACTIVITY LEVEL 0.35, 100.00 PERCENT RADIANT,  
 FROM 01JAN THRU 31DEC;  
 LIGHTS=0.78, ROOM LIGHT ,  
 0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,  
 0.00 PERCENT VISIBLE, 0.00 PERCENT REPLACEABLE,  
 FROM 01JAN THRU 31DEC;  
 CONTROLS=ROOM CONTROL ,  
 3412000.0 HEATING, 3412000.0 COOLING,  
 0.00 PERCENT NAT,  
 FROM 01JAN THRU 31DEC;  
 ELECTRIC EQUIPMENT=0.68, ROOM TV ,  
 100.00 PERCENT RADIANT, 0.00 PERCENT LATENT, 0.00 PERCENT LOST,  
 FROM 01JAN THRU 31DEC;  
 INFILTRATION=66.00, VENT SPEC2 ,  
 WITH COEFFICIENTS (1.000000, 0.000000, 0.000000, 0.000000),  
 FROM 01JAN THRU 31DEC;  
 END ZONE;  
 ZONE 42 "2 Special ":  
 ORIGIN:(0.00, -158.54, 8.00);  
 NORTH AXIS=0.00;  
 SAME AS ZONE 41 EXCEPT:  
 END ZONE;  
 ZONE 43 "swim room ":  
 ORIGIN:(0.00, -188.87, 0.00);  
 NORTH AXIS=0.00;  
 EXTERIOR WALLS :  
 STARTING AT(0.00, 34.33, 0.00)  
 FACING(270.00)  
 TILTED(90.00)  
 MWALL (30.33 BY 10.00)  
 WITH WINDOWS OF TYPE  
 MWINDOW (10.89 BY 9.00)  
 REVEAL(0.00)  
 AT (0.01, 0.01).  
 STARTING AT(0.00, 0.00, 0.00)  
 FACING(180.00)  
 TILTED(90.00)  
 MWALL (56.00 BY 10.00)  
 WITH WINDOWS OF TYPE  
 MWINDOW (26.67 BY 7.50)  
 REVEAL(0.00)  
 AT (0.01, 0.01),  
 STARTING AT(56.00, 0.00, 0.00)  
 FACING(90.00)  
 TILTED(90.00)  
 MWALL (30.33 BY 10.00)  
 WITH WINDOWS OF TYPE  
 MWINDOW (10.89 BY 9.00)  
 REVEAL(0.00)  
 AT (0.01, 0.01);

PARTITIONS :  
 STARTING AT(56.00, 30.33, 0.00)  
 FACING(0.00)  
 TILTED(90.00)  
 MPART1 (56.00 BY 10.00):  
 SLAB ON GRADE FLOORS :  
 STARTING AT(0.00, 30.33, 0.00)  
 FACING(180.00)  
 TILTED(180.00)  
 MFLOOR (56.00 BY 30.33):  
 ROOFS :  
 STARTING AT(0.00, 30.33, 0.00)  
 FACING(270.00)  
 TILTED(15.00)  
 MROOF (30.33 BY 29.00),  
 STARTING AT(56.00, 0.00, 0.00)  
 FACING(90.00)  
 TILTED(15.00)  
 MROOF (30.33 BY 29.00):  
 PEOPLE=30, SWIM PEOPLE ,  
 AT ACTIVITY LEVEL 0.70, 100.00 PERCENT RADIANT,  
 FROM 01JAN THRU 31DEC;  
 LIGHTS=2.90, CONTINUOUS ,  
 0.00 PERCENT RETURN AIR, 100.00 PERCENT RADIANT,  
 0.00 PERCENT VISIBLE, 0.00 PERCENT REPLACEABLE,  
 FROM 01JAN THRU 31DEC;  
 CONTROLS=SWIM CONTROL ,  
 3412000.0 HEATING, 3412000.0 COOLING,  
 0.00 PERCENT MRT,  
 FROM 01JAN THRU 31DEC;  
 INFILTRATION=1700.00, CONTINUOUS ,  
 WITH COEFFICIENTS (1.000000, 0.000000, 0.000000, 0.000000),  
 FROM 01JAN THRU 31DEC:  
 END ZONE:  
 END BUILDING DESCRIPTION:  
 END INPUT:

**Appendix B**

**HVAC Input File for the Motel Load Simulation**

>>> The Input Data of Building MTL

----- Building Information -----

Building's name: MTL
Building's Location: Tulsa, Oklahoma
Latitude: 36.20
Longitude: 95.90
Building's Time Zone: 7
Time: Clock Time
Atm. Pressure: 14.70

Summer Design Conditions:

Month: 7
Day: 21
Design Dry Bulb Temp.: 98.00
Mean Coincident WBF: 74.00
Mean Daily Range: 24.00

Winter Design Conditions:

Design Dry Bulb Temp.: 13.00
Relative Humidity: 60.00
Average Air Temp.: 49.30
Ground Amplitude: 18.00

----- Zone Information -----

Zone Name: 1N.E. Corb.
Zone Multiplier: 1
Summer Indoor Design DBT: 68.00
Summer Indoor Design WBF: 70.00
Winter Indoor Design DBT: 0.00
Winter Indoor Design WBF: 0.00
Summer Indoor R. Humidity: 50.00
Winter Indoor R. Humidity: 30.00
Room Construction Type: Extreme Light
Max. System C. Capacity: 100000.00
Max. System H. Capacity: -100000.00
System Air Flow Rate: 0.00
Outdoor Air Flow Rate: 0.00
System Throttling Range: 0.10
System Annual Schd. Name: motel room control
System Design Schd. Name: motel room
Ventilating Ann. Schd. Name: room people
Ventilating Des. Schd. Name: room people

----- Room Information -----

Room Name: Room
Room Multiplier: 1
Floor Sur. Area: 347.70
Room Ceiling Height: 9.00
Room Parameters:
Room Geometry: 15 ft x 15 ft
Room Height: 9 ft
# of Exterior Wall: 2
Interior Shade: 50 %
Furniture: With
Exterior Construction: L.W. with Lt. insln.
Partition Type: 5/8 in. Gyp-Air-5/8 in. Gyp
Room Location: Bottom Floor
Mid Floor Type: 1 in. Wood
Slab Type: 4 in. slab on 12 in. soil
Ceiling Type: Without Ceiling
Roof Type: L.W. w/c susp. ceiling
Floor Covering: vinyl tile
Glass Percent: 10 %

----- People Information -----

People's Name: people
People Peak Gain: 716.00
Peak Occupancy: 2
Sensible Heat Gain: 250.00
Latent Heat Gain: 105.00
Radiant Fraction: 0.700
Convective Fraction: 0.300
Annual Schd. Name: room people
Design Day Schd. Name: room people

----- Light Information -----

Light's Name: Light
Light's Peak Gain: 783.497
Radiant Fraction: 0.590

Convective Fraction: 0.410
Annual Schd. Name: room light
Design Day Schd. Name: room light

----- Equipment Information -----

Equipment's Name: Equipment (TV)
Equipment Peak Gain: 682.00
Sensible Heat Gain: 682.00
Latent Heat Gain: 0.00
Equipment Multiplier: 1
Radiant Fraction: 0.700
Convective Fraction: 0.300
Annual Schd. Name: room TV
Design Day Schd. Name: room TV

----- Infiltration Information -----

Infiltration's Name: Infiltration
Air Change/Hour: 0.50
Annual Schd. Name: continuous
Design Day Schd. Name: continuous

----- Wall Information -----

Wall's Name: East
Facing Direction: 90.00
Tilt Angle: 90.00
Wall Type: 2
Actual U Factor: 0.11
Surface Absorptance: 0.78
Surface Area: 99.36
Material Descriptions:
Resistance
A0 : Outside Surface
A3 : Steel Siding
B12 : 3 in. Insulation
E0 : Inside Surface
Resistance
E2 : 1/2 in. Slag or Stone
Mass Location: Mass Integral
Principle Material: A1,A3,A6, or E1 1 in. Stucco, Steel
Secondary Material: E1 3/4 in. Plaster or Gypsum

>>----- Window for This Surface -----<<<

Glass's Name: window
Window Width: 6.40
Window Height: 4.20
Glass Shading Coefficient: 4.88
Glass U Factor: 0.6700

----- Wall Information -----

Wall's Name: North
Facing Direction: 0.00
Tilt Angle: 90.00
Wall Type: 2
Actual U Factor: 0.11
Surface Absorptance: 0.78
Surface Area: 224.00
Material Descriptions:
Resistance
A0 : Outside Surface
A3 : Steel Siding
B12 : 3 in. Insulation
E0 : Inside Surface
Resistance
E2 : 1/2 in. Slag or Stone
Mass Location: Mass Integral
Principle Material: A1,A3,A6, or E1 1 in. Stucco, Steel
Secondary Material: E1 3/4 in. Plaster or Gypsum
\*\*\* No Window Defined For This Surface \*\*\*

----- Infiltration Information -----

Infiltration's Name: VENT  
 Air Change/Hour: 0.65  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

Infiltration's Name: Infiltration  
 Air Change/Hour: 0.50  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

----- Zone Information -----

Zone Name: 1E. Typ.  
 Zone Multiplier: 7  
 Summer Indoor Design DBT: 68.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Extreme Light  
 Max. System C. Capacity: 100000.00  
 Max. System H. Capacity: -100000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.10  
 System Annual Schd. Name: motel room control  
 System Design Schd. Name: motel room  
 Ventilating Ann. Schd. Name: room people  
 Ventilating Des. Schd. Name: room people

-----Infiltration Information----

Infiltration's Name: VENT  
 Air Change/Hour: 0.65  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

-----Wall Information-----

Wall's Name: East  
 Facing Direction: 90.00  
 Tilt Angle: 90.00  
 Wall Type: 2  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.79  
 Surface Area: 99.36  
 Material Descriptions:  
 Resistance  
 A0 : Outside Surface  
 A1 : Steel Siding  
 B12 : 3 in. Insulation  
 E0 : Inside Surface

-----Room Information-----

Room Name: Room  
 Room Multiplier: 1  
 Floor Sur. Area: 347.70  
 Room Ceiling Height: 8.00  
 Room Parameters:  
 Room Geometry : 15 ft x 15 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 1  
 Interior Shade : 50 %  
 Furniture : With  
 Exterior Construction : L.W. with Lt. insla.  
 Partition Type : 5/8 in. Gyp-Air-5/8 in. Gyp  
 Room Location : Bottom Floor  
 Mid Floor Type : 1 in. Wood  
 Slab Type : 4 in. slab on 12 in. soil  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : vinyl tile  
 Glass Percent : 10 %

Resistance  
 E2 : 1/2 in. Slab or Stone  
 Mass Location: Mass Integral  
 Principle Material: A1,A3,A6,or E1 1 in. Stucco,Steel  
 Secondary Material: E1 3/4 in. Plaster or Gypsum

>>>>>Window for This Surface<<<<

Glass's Name: window  
 Window Width: 6.40  
 Window Height: 4.20  
 Glass Shading Coefficient: 0.89  
 Glass U Factor: 0.6700

-----Light Information-----

Light's Name: Light  
 Light's Peak Gain: 783.457  
 Radiant Fraction: 0.59  
 Convective Fraction: 0.410  
 Annual Schd. Name: room light  
 Design Day Schd. Name: room light

----- Zone Information -----

Zone Name: 2W. Typ.  
 Zone Multiplier: 9  
 Summer Indoor Design DBT: 68.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Extreme Light  
 Max. System C. Capacity: 100000.00  
 Max. System H. Capacity: -100000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.10  
 System Annual Schd. Name: motel room control  
 System Design Schd. Name: motel room  
 Ventilating Ann. Schd. Name: room people  
 Ventilating Des. Schd. Name: room people

-----People Information-----

People's Name: people  
 People Peak Gain: 710.00  
 Peak Occupancy: 2  
 Sensible Heat Gain: 250.00  
 Latent Heat Gain: 105.00  
 Radiant Fraction: 0.70  
 Convective Fraction: 0.300  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

-----Room Information-----

Room Name: Room  
 Room Multiplier: 1  
 Floor Sur. Area: 347.70  
 Room Ceiling Height: 8.00  
 Room Parameters:  
 Room Geometry : 15 ft x 15 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 1  
 Interior Shade : 50 %  
 Furniture : With  
 Exterior Construction : L.W. with Lt. insla.  
 Partition Type : 5/8 in. Gyp-Air-5/8 in. Gyp  
 Room Location : Top Floor  
 Mid Floor Type : 1 in. Wood  
 Slab Type : 4 in. slab on 12 in. soil  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : vinyl tile  
 Glass Percent : 10 %

-----Equipment Information-----

Equipment's Name: Equipment (TV)  
 Equipment Peak Gain: 682.00  
 Sensible Heat Gain: 682.00  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: room TV  
 Design Day Schd. Name: room TV

-----Infiltration Information----

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-----People Information-----
People's Name:           people
People Peak Gain:       710.00
Peak Occupancy:         2
Sensible Heat Gain:    250.00
Latent Heat Gain:      105.00
Radiant Fraction:      0.700
Convective Fraction:   0.300
Annual Schd. Name:     room people
Design Day Schd. Name: room people

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-----Light Information-----
Light's Name:           Light
Light's Peak Gain:     783.497
Radiant Fraction:      0.590
Convective Fraction:   0.410
Annual Schd. Name:     room light
Design Day Schd. Name: room light

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```

-----Equipment Information-----
Equipment's Name:      Equipment (TV)
Equipment Peak Gain:   682.00
Sensible Heat Gain:    682.00
Latent Heat Gain:      0.00
Equipment Multiplier: 1
Radiant Fraction:      0.700
Convective Fraction:   0.300
Annual Schd. Name:     room TV
Design Day Schd. Name: room TV

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-----Infiltration Information-----
Infiltration's Name:   Infiltration
Air Change/Hour:       0.50
Annual Schd. Name:     continuous
Design Day Schd. Name: continuous

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-----Roof Information-----
Roof's Name:           Roof
Facing Direction:      270.00
Tilt Angle:            15.00
Roof Type:             1
Actual U Factor:       0.01
Surface Absorptance:   0.78
Surface Area:          360.18
Material Descriptions:
Mass Location:         ## Undefined ##
Principle Material:    ## Undefined ##
Suspended Ceiling:    ## Undefined ##
*** No Window Defined For This Surface ***

```

```

-----Infiltration Information-----
Infiltration's Name:   VENT
Air Change/Hour:       0.65
Annual Schd. Name:     room people
Design Day Schd. Name: room people

```

```

-----Wall Information-----
Wall's Name:           West
Facing Direction:      270.00
Tilt Angle:            90.00
Wall Type:             2
Actual U Factor:       0.11
Surface Absorptance:   0.78
Surface Area:          99.36
Material Descriptions:
Resistance             A0 : Outside Surface
Resistance             A3 : Steel Siding
Resistance             B12 : 3 in. Insulation
Resistance             E0 : Inside Surface
Resistance

```

```

E2 : 1/2 in. Slag Stone
Mass Location:         Mass Integral
Principle Material:    A1,A3,A6,or E1 1 in. Stucco,Steel
Secondary Material:    E1 3/4 in. Plaster or Gypsum

```

```

>>>>-----Window for This Surface-----<<<<
Glass's Name:          window
Window Width:          6.40
Window Height:         4.20
Glass Shading Coefficient: 0.88
Glass U Factor:        0.6700

```

```

-----Zone Information-----
Zone Name:             2N.W. Corn
Zone Multiplier:       1
Summer Indoor Design DBT: 65.00
Summer Indoor Design WBT: 70.00
Winter Indoor Design DBT: 0.00
Winter Indoor Design WBT: 0.00
Summer Indoor R. Humidity: 50.00
Winter Indoor R. Humidity: 30.00
Room Construction Type: Extreme Light
Max. System C. Capacity: 100000.00
Max. System H. Capacity: -100000.00
System Air Flow Rate: 0.00
Outdoor Air Flow Rate: 0.00
System Throttling Range: 0.10
System Annual Schd. Name: motel room control
System Design Schd. Name: motel room
Ventilating Ann. Schd. Name: room people
Ventilating Des. Schd. Name: room people

```

```

-----Room Information-----
Room Name:             Room
Room Multiplier:       1
Floor Sur. Area:       347.70
Room Ceiling Height:   8.00
Room Parameters:
Room Geometry          : 15 ft x 15 ft
Room Height            : 8 ft
# of Exterior Wall     : 2
Interior Shade         : 50 %
Furniture              : With
Exterior Construction : L.W. with Lt. insln.
Partition Type         : 5/8 in. Gyp-Air-5/8 in. Gyp
Room Location          : Top Floor
Mid Floor Type         : 1 in. Wood
Slab Type              : 4 in. Slab on 10 in. Ins.
Ceiling Type           : Without Ceiling
Roof Type              : L.W. w/5 Susp. Ceiling
Floor Covering         : Vinyl Tile
Glass Percent          : 10 %

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-----People Information-----
People's Name:         people
People Peak Gain:     710.00
Peak Occupancy:       2
Sensible Heat Gain:   250.00
Latent Heat Gain:     105.00
Radiant Fraction:     0.700
Convective Fraction:  0.300
Annual Schd. Name:    room people
Design Day Schd. Name: room people

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-----Light Information-----
Light's Name:          Light
Light's Peak Gain:     783.497
Radiant Fraction:      0.590
Convective Fraction:   0.410
Annual Schd. Name:     room light
Design Day Schd. Name: room light

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-----Equipment Information-----
Equipment's Name:      Equipment (TV)
Equipment Peak Gain:   682.00

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Sensible Heat Gain: 682.00  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: room TV  
 Design Day Schd. Name: room TV

Resistance  
 B12 : 3 in. Insulation  
 E0 : Inside Surface  
 E2 : 1/2 in. Slag or  
 Stone  
 Mass Location: Mass Integral  
 Principle Material: A1,A3,A6,or E1 1 in.  
 Stucco,Steel  
 Secondary Material: E1 3/4 in. Plaster or  
 Gypsum  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Infiltration Information-----

Infiltration's Name: Infiltration  
 Air Change/Hour: 0.50  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Zone Information-----

Zone Name: 7N.E. Corn  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 68.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Extreme Light  
 Max. System C. Capacity: 100000.00  
 Max. System H. Capacity: -100000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.10  
 System Annual Schd. Name: motel room control  
 System Design Schd. Name: motel room  
 Ventilating Ann. Schd. Name: room people  
 Ventilating Des. Schd. Name: room people

-----Roof Information-----

Roof's Name: Roof  
 Facing Direction: 270.00  
 Tilt Angle: 15.00  
 Roof Type: 1  
 Actual U Factor: 0.05  
 Surface Absorptance: 0.78  
 Surface Area: 360.18  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Suspended Ceiling: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Room Information-----

Room Name: Room  
 Room Multiplier: 1  
 Floor Sur. Area: 347.70  
 Room Ceiling Height: 8.00  
 Room Parameters:  
 Room Geometry : 15 ft x 15 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 2  
 Interior Shade : 50 %  
 Furniture : With  
 Exterior Construction : L.W. with Lt. insin.  
 Partition Type : 5/8 in. Gyp-Air-5' in. Gyp  
 Room Location : Top Floor  
 Mid Floor Type : 1 in. Wood  
 Slab Type : 4 in. slab on 12 in. con.  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : vinyl tile  
 Glass Percent : 10 %

-----Infiltration Information-----

Infiltration's Name: VENT  
 Air Change/Hour: 0.65  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

-----Light Information-----

Light's Name: Light  
 Light's Peak Gain: 783.457  
 Radiant Fraction: 0.550  
 Convective Fraction: 0.450  
 Annual Schd. Name: room light  
 Design Day Schd. Name: room light

-----Wall Information-----

Wall's Name: West  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 2  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.78  
 Surface Area: 99.36  
 Material Descriptions:  
 A0 : Outside Surface  
 Resistance  
 A3 : Steel Siding  
 B12 : 3 in. Insulation  
 E0 : Inside Surface  
 Resistance  
 E2 : 1/2 in. Slag or  
 Stone  
 Mass Location: Mass Integral  
 Principle Material: A1,A3,A6,or E1 1 in.  
 Stucco,Steel  
 Secondary Material: E1 3/4 in. Plaster or  
 Gypsum

-----Equipment Information-----

Equipment's Name: Equipment (TV)  
 Equipment Peak Gain: 682.00  
 Sensible Heat Gain: 682.00  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: room TV  
 Design Day Schd. Name: room TV

>>-----Window for This Surface-----<<

Glass's Name: Window  
 Window Width: 6.40  
 Window Height: 4.20  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.6700

-----Wall Information-----

Wall's Name: North  
 Facing Direction: 0.00  
 Tilt Angle: 90.00  
 Wall Type: 2  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.78  
 Surface Area: 271.07  
 Material Descriptions:  
 A0 : Outside Surface  
 Resistance  
 A3 : Steel Siding

-----People Information-----

People's Name: people  
 People Peak Gain: 710.00  
 Peak Occupancy: 2  
 Sensible Heat Gain: 250.00  
 Latent Heat Gain: 105.00  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300

Annual Schd. Name: room people  
Design Day Schd. Name: room people

Mass Location: Mass Integral  
Principle Material: A1,A3,A6, or E1 1 in.  
Stucco,Steel  
Secondary Material: E1 3/4 in. Plaster or  
Gypsum  
\*\*\* No Window Defined For This Surface \*\*\*

-----Infiltration Information-----

Infiltration's Name: Infiltration  
Air Change/Hour: 0.50  
Annual Schd. Name: continuous  
Design Day Schd. Name: continuous

----- Zone Information -----

Zone Name: 2E, Typ.  
Zone Multiplier: 9  
Summer Indoor Design DBT: 68.00  
Summer Indoor Design WB7: 70.00  
Winter Indoor Design DBT: 0.00  
Winter Indoor Design WB7: 0.00  
Summer Indoor R. Humidity: 50.00  
Winter Indoor R. Humidity: 30.00  
Room Construction Type: Extreme Light  
Max. System C. Capacity: 100000.00  
Max. System H. Capacity: -100000.00  
System Air Flow Rate: 0.00  
Outdoor Air Flow Rate: 0.00  
System Throttling Range: 0.10  
System Annual Schd. Name: motel room control  
System Design Schd. Name: motel room  
Ventilating Ann. Schd. Name: room people  
Ventilating Des. Schd. Name: room people

-----Roof Information-----

Roof's Name: Roof  
Facing Direction: 90.00  
Tilt Angle: 15.00  
Roof Type: 1  
Actual U Factor: 0.05  
Surface Absorptance: 0.78  
Surface Area: 360.18  
Material Descriptions:  
Mass Location: ## Undefined ##  
Principle Material: ## Undefined ##  
Suspended Ceiling: ## Undefined ##  
\*\*\* No Window Defined For This Surface \*\*\*

-----Infiltration Information-----

Infiltration's Name: VENT  
Air Change/Hour: 0.65  
Annual Schd. Name: room people  
Design Day Schd. Name: room people

-----Room Information-----

Room Name: Room  
Room Multiplier: 1  
Floor Sur. Area: 347.70  
Room Ceiling Height: 8.00  
Room Parameters:  
Room Geometry : 15 ft x 15 ft  
Room Height : 8 ft  
# of Exterior Wall : 1  
Interior Shade : 50 ft  
Furniture : With  
Exterior Construction : L.W. with Lt. insin.  
Partition Type : 5/8 in. Gyp-Air 1/4 in. Gyp  
Room Location : Top Floor  
Mid Floor Type : 1 in. Wood  
Slab Type : 4 in. slab on 12 in. soil  
Ceiling Type : Without Ceiling  
Roof Type : L.W. w/o susp. ceiling  
Floor Covering : Vinyl tile  
Glass Percent : 10 %

-----Wall Information-----

Wall's Name: East  
Facing Direction: 90.00  
Tilt Angle: 90.00  
Wall Type: 2  
Actual U Factor: 0.11  
Surface Absorptance: 0.78  
Surface Area: 95.36  
Material Descriptions:  
Resistance  
A0 : Outside Surface  
A1 : Steel Siding  
B12 : 3 in. Insulation  
E0 : Inside Surface  
Resistance  
E2 : 1/2 in. Slag or  
Stone  
Mass Location: Mass Integral  
Principle Material: A1,A3,A6, or E1 1 in.  
Stucco,Steel  
Secondary Material: E1 3/4 in. Plaster or  
Gypsum

-----People Information-----

People's Name: people  
People Peak Gain: 710.00  
Peak Occupancy: 2  
Sensible Heat Gain: 250.00  
Latent Heat Gain: 105.00  
Radiant Fraction: 0.700  
Convective Fraction: 0.300  
Annual Schd. Name: room people  
Design Day Schd. Name: room people

>>-----Window for This Surface-----<<

Glass's Name: WINDOW  
Window Width: 6.40  
Window Height: 4.20  
Glass Shading Coefficient: 0.7  
Glass U Factor: 0.6700

-----Light Information-----

Light's Name: Light  
Light's Peak Gain: 783.477  
Radiant Fraction: 0.590  
Convective Fraction: 0.410  
Annual Schd. Name: room light  
Design Day Schd. Name: room light

-----Wall Information-----

Wall's Name: North  
Facing Direction: 0.00  
Tilt Angle: 90.00  
Wall Type: 2  
Actual U Factor: 0.11  
Surface Absorptance: 0.78  
Surface Area: 120.00  
Material Descriptions:  
Resistance  
A0 : Outside Surface  
A1 : Steel Siding  
B12 : 3 in. Insulation  
E0 : Inside Surface  
Resistance  
E2 : 1/2 in. Slag or  
Stone

-----Roof Information-----

Roof's Name: Roof #1  
Facing Direction: 90.00  
Tilt Angle: 15.00  
Roof Type: 1  
Actual U Factor: 0.05  
Surface Absorptance: 0.78  
Surface Area: 360.18  
Material Descriptions:  
Mass Location: ## Undefined ##  
Principle Material: ## Undefined ##  
Suspended Ceiling: ## Undefined ##  
\*\*\* No Window Defined For This Surface \*\*\*

-----Equipment Information-----

Equipment's Name: Equipment (TV)  
 Equipment Peak Gain: 682.00  
 Sensible Heat Gain: 682.00  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: room TV  
 Design Day Schd. Name: room TV

-----Infiltration Information-----

Infiltration's Name: Infiltration  
 Air Change/Hour: 0.50  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Infiltration Information-----

Infiltration's Name: VENT  
 Air Change/Hour: 0.65  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

-----Wall Information-----

Wall's Name: East  
 Facing Direction: 90.00  
 Tilt Angle: 90.00  
 Wall Type: 2  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.78  
 Surface Area: 99.36  
 Material Descriptions:  
 Resistance  
 A0 : Outside Surface  
 Resistance  
 A3 : Steel Siding  
 B12 : 3 in. Insulation  
 E0 : Inside Surface  
 Resistance  
 E2 : 1/2 in. Slab or  
 Stone  
 Mass Location: Mass Integral  
 Principle Material: A1,A3,A6,or E1 1/2 in.  
 Stucco,Steel  
 Secondary Material: E1 3/4 in. Plaster or  
 Gypsum

>>-----Window for This Surface-----<<<

Glass's Name: window  
 Window Width: 6.40  
 Window Height: 4.20  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.6700

-----Zone Information-----

Zone Name: 1W. Typ.  
 Zone Multiplier: 9  
 Summer Indoor Design DBT: 68.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Extreme Light  
 Max. System C. Capacity: 100000.00  
 Max. System H. Capacity: -100000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.10  
 System Annual Schd. Name: motel room control  
 System Design Schd. Name: motel room  
 Ventilating Ann. Schd. Name: room people  
 Ventilating Des. Schd. Name: room people

-----Room Information-----

Room Name: Room  
 Room Multiplier: 1  
 Floor Sur. Area: 347.70  
 Room Ceiling Height: 6.00  
 Room Parameters:  
 Room Geometry : 15 ft x 15 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 1  
 Interior Shade : 50 %  
 Furniture : With  
 Exterior Construction : L.W. with Lt. insin.  
 Partition Type : 5/8 in. Gyp-Air-1/2 in. Gyp  
 Room Location : Bottom Floor  
 Mid Floor Type : 1 in. Wood  
 Slab Type : 4 in. slab on 12 in. soil  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : vinyl tile  
 Glass Percent : 10 %

-----Light Information-----

Light's Name: Light  
 Light's Peak Gain: 783.497  
 Radiant Fraction: 0.500  
 Convective Fraction: 0.400  
 Annual Schd. Name: room light  
 Design Day Schd. Name: room light

-----Infiltration Information-----

Infiltration's Name: Infiltration  
 Air Change/Hour: 0.50  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Equipment Information-----

Equipment's Name: Equipment (TV)  
 Equipment Peak Gain: 682.00  
 Sensible Heat Gain: 682.00  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: room TV  
 Design Day Schd. Name: room TV

-----People Information-----

People's Name: people  
 People Peak Gain: 710.00  
 Peak Occupancy: 1  
 Sensible Heat Gain: 250.00  
 Latent Heat Gain: 105.00  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

-----Infiltration Information-----

Infiltration's Name: VENT  
 Air Change/Hour: 0.65  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

-----Wall Information-----

Wall's Name: West  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 2  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.78  
 Surface Area: 99.36  
 Material Descriptions:  
 Resistance  
 A0 : Outside Surface  
 Resistance  
 A3 : Steel Siding  
 B12 : 3 in. Insulation

Resistance E0 : Inside Surface  
 Stone E2 : 1/2 in. Slag cr  
 Mass Location: Mass Integral  
 Principle Material: A1,A3,A6, or E1 1 in.  
 Stucco,Steel  
 Secondary Material: E1 3/4 in. Plaster or  
 Gypsum

Equipment's Name: Equipment (TV)  
 Equipment Peak Gain: 682.00  
 Sensible Heat Gain: 682.00  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: room TV  
 Design Day Schd. Name: room TV

>>-----Window for This Surface-----<<

Glass's Name: Window  
 Window Width: 6.40  
 Window Height: 4.20  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.6700

-----Infiltration Information-----

Infiltration's Name: Infiltration  
 Air Change/Hour: 0.50  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

----- Zone Information -----

Zone Name: IN.W. Corn.  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 68.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Extreme Light  
 Max. System C. Capacity: 100000.00  
 Max. System H. Capacity: -100000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.10  
 System Annual Schd. Name: motel room control  
 System Design Schd. Name: motel room  
 Ventilating Anr. Schd. Name: room people  
 Ventilating Des. Schd. Name: room people

-----Infiltration Information-----

Infiltration's Name: VENT  
 Air Change/Hour: 0.61  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

-----Wall Information-----

Wall's Name: West  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 2  
 Actual U Factor: 1.11  
 Surface Absorptance: 0.78  
 Surface Area: 99.16  
 Material Descriptions:

-----Room Information-----

Room Name: Room  
 Room Multiplier: 1  
 Floor Sur. Area: 347.70  
 Room Ceiling Height: 8.00  
 Room Parameters:  
 Room Geometry : 15 ft x 15 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 2  
 Interior Shade : 50 %  
 Furniture : With  
 Exterior Construction : L.W. with Lt. Insul.  
 Partition Type : 5/8 in. Gyp-Air-5/8 in. Gyp  
 Room Location : Bottom Floor  
 Mid Floor Type : 1 in. Wood  
 Slab Type : 4 in. slab on 12 in. soil  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : vinyl tile  
 Glass Percent : 10 %

Resistance A0 : Outside Surface  
 A3 : Steel Siding  
 B12 : 3 in. Insulation  
 E0 : Inside Surface  
 Resistance E2 : 1/2 in. Slag cr  
 Stone  
 Mass Location: Mass Integral  
 Principle Material: A1,A3,A6, or E1 1 in.  
 Stucco,Steel  
 Secondary Material: E1 3/4 in. Plaster or  
 Gypsum

>>-----Window for This Surface-----<<

Glass's Name: Window  
 Window Width: 6.40  
 Window Height: 4.20  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.6700

-----Wall Information-----

Wall's Name: North  
 Facing Direction: 0.00  
 Tilt Angle: 90.00  
 Wall Type: 2  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.78  
 Surface Area: 224.00  
 Material Descriptions:

-----Light Information-----

Light's Name: Light  
 Light's Peak Gain: 243.497  
 Radiant Fraction: 0.590  
 Convective Fraction: 0.410  
 Annual Schd. Name: room light  
 Design Day Schd. Name: room light

Resistance A0 : Outside Surface  
 A3 : Steel Siding  
 B12 : 3 in. Insulation  
 E0 : Inside Surface

-----People Information-----

People's Name: people  
 People Peak Gain: 710.00  
 Peak Occupancy: 2  
 Sensible Heat Gain: 250.00  
 Latent Heat Gain: 105.00  
 Radiant Fraction: 0.70  
 Convective Fraction: 0.300  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

Resistance E2 : 1/2 in. Slag cr  
 Stone  
 Mass Location: Mass Integral  
 Principle Material: A1,A3,A6, or E1 1 in.  
 Stucco,Steel  
 Secondary Material: E1 3/4 in. Plaster or  
 Gypsum

\*\*\* No Window Defined For This Surface \*\*\*

-----Equipment Information-----

----- Zone Information -----

Zone Name: Laundry  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 70.00  
 Summer Indoor Design WBT: 71.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Extreme Light  
 Max. System C. Capacity: 100000.00  
 Max. System H. Capacity: -100000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 1.00  
 System Annual Schd. Name: laundry control  
 System Design Schd. Name: laundry control  
 Ventilating Ann. Schd. Name: laundry's vent  
 Ventilating Des. Schd. Name: laundry's vent

Mass Location: 00 Undefined 00  
 Principle Material: 00 Undefined 00  
 Secondary Material: 00 Undefined 00  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Infiltration Information-----

Infiltration's Name: Infiltration  
 Air Change/Hour: 1.50  
 Annual Schd. Name: laundry machine  
 Design Day Schd. Name: laundry machine

-----Infiltration Information-----

Infiltration's Name: vent  
 Air Change/Hour: 1.75  
 Annual Schd. Name: laundry's vent  
 Design Day Schd. Name: laundry's vent

-----Room Information-----

Room Name: Room  
 Room Multiplier: 1  
 Floor Sur. Area: 695.50  
 Room Ceiling Height: 8.00  
 Room Parameters:  
 Room Geometry : 15 ft x 15 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 1  
 Interior Shade : 0 1  
 Furniture : With  
 Exterior Construction : L.W. with moderate insln.  
 Partition Type : 5/8 in. Gyp-Air-5/8 in. Gyp  
 Room Location : Bottom Floor  
 Mid Floor Type : 1 in. Wood  
 Slab Type : 4 in. slab on 12 in. soil  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : vinyl tile  
 Glass Percent : 1 1

-----Zone Information-----

Zone Name: Swimming room  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 75.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 75.00  
 Winter Indoor R. Humidity: 50.00  
 Room Construction Type: Extreme Light  
 Max. System C. Capacity: 100000.00  
 Max. System H. Capacity: -100000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 1.00  
 System Annual Schd. Name: swim control  
 System Design Schd. Name: swim control  
 Ventilating Ann. Schd. Name: continuous  
 Ventilating Des. Schd. Name: continuous

-----People Information-----

People's Name: People  
 People Peak Gain: 3250.00  
 Peak Occupancy: 5  
 Sensible Heat Gain: 350.00  
 Latent Heat Gain: 300.00  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: laundry machine  
 Design Day Schd. Name: laundry machine

-----Room Information-----

Room Name: Room  
 Room Multiplier: 1  
 Floor Sur. Area: 1702.00  
 Room Ceiling Height: 10.00  
 Room Parameters:  
 Room Geometry : 100 ft x 20 ft  
 Room Height : 10 ft  
 # of Exterior Wall : 3  
 Interior Shade : 0 1  
 Furniture : Without  
 Exterior Construction : L.W. with moderate insln.  
 Partition Type : 5/8 in. Gyp-Air-5/8 in. Gyp  
 Room Location : Single-Story  
 Mid Floor Type : 1 in. Wood  
 Slab Type : 4 in. slab on 12 in. soil  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : vinyl tile  
 Glass Percent : 50 1

-----Light Information-----

Light's Name: Light  
 Light's Peak Gain: 1899.661  
 Radiant Fraction: 0.590  
 Convective Fraction: 0.410  
 Annual Schd. Name: laundry machine  
 Design Day Schd. Name: laundry machine

-----Equipment Information-----

Equipment's Name: wash machine  
 Equipment Peak Gain: 2168.00  
 Sensible Heat Gain: 5118.00  
 Latent Heat Gain: 2050.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: laundry machine  
 Design Day Schd. Name: laundry machine

-----People Information-----

People's Name: people  
 People Peak Gain: 20700.00  
 Peak Occupancy: 10  
 Sensible Heat Gain: 350.00  
 Latent Heat Gain: 340.00  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: swim people  
 Design Day Schd. Name: swim people

-----Wall Information-----

Wall's Name: East  
 Facing Direction: 90.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.78  
 Surface Area: 198.72  
 Material Descriptions:

-----Light Information-----

Light's Name: Light  
 Light's Peak Gain: 2905.484  
 Radiant Fraction: 0.590  
 Convective Fraction: 0.410  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Wall Information-----  
 Wall's Name: east  
 Facing Direction: 90.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.78  
 Surface Area: 303.30  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##

>>-----Window for This Surface-----<<

Glass's Name: swin win  
 Window Width: 14.00  
 Window Height: 7.00  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.6700

-----Wall Information-----

Wall's Name: west  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.78  
 Surface Area: 303.30  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##

>>-----Window for This Surface-----<<

Glass's Name: swin win  
 Window Width: 14.00  
 Window Height: 7.00  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.6700

>>-----Window for This Surface-----<<

Glass's Name: west door  
 Window Width: 3.50  
 Window Height: 7.00  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.4000

-----Infiltration Information-----

Infiltration's Name: vent  
 Air Change/Hour: 6.00  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Equipment Information-----

Equipment's Name: swin pool  
 Equipment Peak Gain: 6.00  
 Sensible Heat Gain: 0.00  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.30  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Zone Information-----

Zone Name: ZW, Spec. 2  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 68.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00

Room Construction Type: Extreme Light  
 Max. System C. Capacity: 100000.00  
 Max. System B. Capacity: -100000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.10  
 System Annual Schd. Name: motel room control  
 System Design Schd. Name: motel room  
 Ventilating Ann. Schd. Name: room people  
 Ventilating Des. Schd. Name: room people

-----Room Information-----

Room Name: Room  
 Room Multiplier: 1  
 Floor Sur. Area: 538.00  
 Room Ceiling Height: 8.00  
 Room Parameters:  
 Room Geometry: 15 ft x 15 ft  
 Room Height: 8 ft  
 # of Exterior Wall: 1  
 Interior Shada: 50 %  
 Furniture: With  
 Exterior Construction: L.W. with Lt. insul.  
 Partition Type: 5/8 in. Gyp-Air-5/8 in. Gyp  
 Room Location: Top Floor  
 Mid Floor Type: 1 in. Wood  
 Slab Type: 4 in. slab on 12 in. soil  
 Ceiling Type: Without Ceiling  
 Roof Type: L.W. w/o susp. ceiling  
 Floor Covering: vinyl tile  
 Glass Percent: 10 %

-----People Information-----

People's Name: people  
 People Peak Gain: 710.00  
 Peak Occupancy: 2  
 Sensible Heat Gain: 250.00  
 Latent Heat Gain: 105.00  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

-----Light Information-----

Light's Name: light  
 Light's Peak Gain: 1212.314  
 Radiant Fraction: 0.590  
 Convective Fraction: 0.410  
 Annual Schd. Name: room light  
 Design Day Schd. Name: room light

-----Roof Information-----

Roof's Name: roof  
 Facing Direction: 270.00  
 Tilt Angle: 15.00  
 Roof Type: 1  
 Actual U Factor: 0.05  
 Surface Absorptance: 0.78  
 Surface Area: 477.93  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Suspended Ceiling: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----

Wall's Name: West  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 2  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.78  
 Surface Area: 137.36  
 Material Descriptions:  
 Resistance A0 : Outside Surface  
 Resistance A3 : Steel Siding  
 Resistance B12 : 3 in. Insulation

Resistance E0 : Inside Surface  
 E2 : 1/2 in. Slag or  
 Stone  
 Mass Location:  
 Principle Material: Mass Integral  
 Stucco,Steel A1,A3,A6,or E1 1 in.  
 Secondary Material: E1 3/4 in. Plaster or  
 Gypsum

Floor Covering : Vinyl tile  
 Glass Percent : 1.0

-----Light Information-----

Light's Name: Light  
 Light's Peak Gain: 1001.196  
 Radiant Fraction: 0.590  
 Convective Fraction: 0.410  
 Annual Schd. Name: room light  
 Design Day Schd. Name: room light

>>-----Window for This Surface-----<<

Glass's Name: window  
 Window Width: 12.00  
 Window Height: 4.20  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.6700

-----Equipment Information-----

Equipment's Name: Equipment (TV)  
 Equipment Peak Gain: 682.00  
 Sensible Heat Gain: 682.00  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: room TV  
 Design Day Schd. Name: room TV

-----Infiltration Information-----

Infiltration's Name: Infiltration  
 Air Change/Hour: 0.50  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Infiltration Information-----

Infiltration's Name: VENT  
 Air Change/Hour: 0.42  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

-----People Information-----

People's Name: people  
 People Peak Gain: 710.00  
 Peak Occupancy: 2  
 Sensible Heat Gain: 250.00  
 Latent Heat Gain: 105.00  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

-----Equipment Information-----

Equipment's Name: Equipment (TV)  
 Equipment Peak Gain: 682.00  
 Sensible Heat Gain: 682.00  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: room TV  
 Design Day Schd. Name: room TV

-----Wall Information-----

Wall's Name: West  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 7  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.78  
 Surface Area: 17.36  
 Material Descriptions:

-----Zone Information-----

Zone Name: 2W, Spec. 1  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 66.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Extreme Light  
 Max. System C. Capacity: 10000.00  
 Max. System H. Capacity: -10000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.10  
 System Annual Schd. Name: motel room control  
 System Design Schd. Name: motel room  
 Ventilating Ann. Schd. Name: room people  
 Ventilating Des. Schd. Name: room people

Resistance A0 : Outside Surface  
 A1 : Steel Siding  
 R12 : 3 in. Insulation  
 E0 : Inside Surface

Resistance E2 : 1/2 in. Slag or  
 Stone  
 Mass Location: Mass Integral  
 Principle Material: A1,A3,A6,or E1 1 in.  
 Stucco,Steel  
 Secondary Material: E1 3/4 in. Plaster or  
 Gypsum

>>-----Window for This Surface-----<<

Glass's Name: window  
 Window Width: 12.00  
 Window Height: 4.20  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.6700

-----Room Information-----

Room Name: Room  
 Room Multiplier: 1  
 Floor Sur. Area: 480.70  
 Room Ceiling Height: 8.00  
 Room Parameters:  
 Room Geometry : 15 ft x 15 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 1  
 Interior Shade : 50 %  
 Furniture : With  
 Exterior Construction : L.W. with Lt. insln.  
 Partition Type : 5/8 in. Gyp-Air-5/8 in. Gyp  
 Room Location : Top floor  
 Mid Floor Type : 1 in. Wood  
 Slab Type : 4 in. slab on 12 in. coll  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling

-----Roof Information-----

Roof's Name: R. of  
 Facing Direction: 27.00  
 Tilt Angle: 15.00  
 Roof Type: 1  
 Actual U Factor: 0.05  
 Surface Absorptance: 0.70  
 Surface Area: 137.36  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Suspended Ceiling: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Infiltration Information-----  
 Infiltration's Name: Infiltration  
 Air Change/Hour: 0.50  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

>>>>>Window for This Surface<<<<<  
 Glass's Name: lobby win  
 Window Width: 7.40  
 Window Height: 8.60  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.6700

-----Infiltration Information-----  
 Infiltration's Name: VENT  
 Air Change/Hour: 0.47  
 Annual Schd. Name: room people  
 Design Day Schd. Name: room people

-----Wall Information-----  
 Wall's Name: East  
 Facing Direction: 90.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.75  
 Surface Area: 519.28  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##

-----Zone Information-----  
 Zone Name: Main Lobby  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 68.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Extreme Light  
 Max. System C. Capacity: 100000.00  
 Max. System H. Capacity: -100000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.00  
 System Annual Schd. Name: Lobby's Control  
 System Design Schd. Name: Lobby's Control  
 Ventilating Ann. Schd. Name: continuous  
 Ventilating Des. Schd. Name: continuous

>>>>>Window for This Surface<<<<<  
 Glass's Name: lobby east  
 Window Width: 26.80  
 Window Height: 8.60  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.6700

-----Room Information-----  
 Room Name: Room  
 Room Multiplier: 1  
 Floor Sur. Area: 1926.00  
 Room Ceiling Height: 8.00  
 Room Parameters:  
 Room Geometry : 100 ft x 20 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 2  
 Interior Shade : 50 ft  
 Furniture : With  
 Exterior Construction : L.W. with Lt. Insin.  
 Partition Type : 5/8 in. Gyp-Aur-1/2 in. Gyp  
 Room Location : Bottom Floor  
 Mid Floor Type : 1 in. Wood  
 Slab Type : 4 in. slab on 12 in. soil  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : Carpet with rubber pad  
 Glass Percent : 10 %

-----Infiltration Information-----  
 Infiltration's Name: Infiltration  
 Air Change/Hour: 1.00  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Infiltration Information-----  
 Infiltration's Name: vent  
 Air Change/Hour: 1.17  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----People Information-----  
 People's Name: People  
 People Peak Gain: 6750.00  
 Peak Occupancy: 15  
 Sensible Heat Gain: 250.00  
 Latent Heat Gain: 200.00  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: lobby people  
 Design Day Schd. Name: lobby people

-----Equipment Information-----  
 Equipment's Name: Equipment  
 Equipment Peak Gain: 2000.00  
 Sensible Heat Gain: 1800.00  
 Latent Heat Gain: 200.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.700  
 Convective Fraction: 0.300  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Wall Information-----  
 Wall's Name: West  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.11  
 Surface Absorptance: 0.78  
 Surface Area: 274.64  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##

-----Light Information-----  
 Light's Name: Light  
 Light's Peak Gain: 3287.170  
 Radiant Fraction: 0.550  
 Convective Fraction: 0.410  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Roof Information-----  
 Roof's Name: Roof  
 Facing Direction: 90.00  
 Tilt Angle: 15.00  
 Roof Type: 1  
 Actual U Factor: 0.05  
 Surface Absorptance: 0.79  
 Surface Area: 995.57  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Suspended Ceiling: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*



## **Appendix C**

### **HVAC Input File for the BESTEST**

>>> The Input Data of Building Bestest

Design Day Sched. Name: continuous

----- Building Information -----

Building's Name: Bestest
Building's Location: Asheville, N. Carolina
Latitude: 39.80
Longitude: 104.90
Building's Time Zone: 7
Time: Clock Time
Atm. Pressure: 14.70

Summer Design Conditions:

Month: 6
Day: 21
Design Dry Bulb Temp.: 98.00
Mean Coincident WBT: 74.00
Mean Daily Range: 24.00

Winter Design Conditions:

Design Dry Bulb Temp.: 33.00
Relative Humidity: 60.00
Average Air Temp.: 48.30
Ground Amplitude: 18.00

----- Zone Information -----

Zone Name: Zone 620
Zone Multiplier: 1
Summer Indoor Design DBT: 78.00
Summer Indoor Design WBT: 70.00
Winter Indoor Design DBT: 0.00
Winter Indoor Design WBT: 0.00
Summer Indoor R. Humidity: 50.00
Winter Indoor R. Humidity: 30.00
Room Construction Type: Extreme Light
Max. System C. Capacity: 50000.00
Max. System H. Capacity: -50000.00
System Air Flow Rate: 0.00
Outdoor Air Flow Rate: 0.00
System Throttling Range: 0.01
System Annual Sched. Name: 600 annual
System Design Sched. Name: 600 daily
Ventilating Ann. Sched. Name: continuous
Ventilating Des. Sched. Name: continuous

----- Room Information -----

Room Name: Room 620
Room Multiplier: 1
Floor Sur. Area: 516.60
Room Ceiling Height: 8.86
Room Parameters:
Room Geometry : 15 ft x 15 ft
Room Height : 8 ft
# of Exterior Wall : 4
Interior Shade : 0 1
Furniture : Without
Exterior Construction : L.W. with moderate insln.
Partition Type : 5/8 in. Gyp-Air-1/8 in. Gyp
Room Location : Top Floor
Mid Floor Type : 1 in. Wood
Slab Type : Mid Floor Type
Ceiling Type : Without Ceiling
Roof Type : L.W. w/o susp. ceiling
Floor Covering : vinyl tile
Glass Percent : 10 1

----- Infiltration Information -----

Infiltration's Name: Infiltration
Air Change/Hour: 0.50
Annual Sched. Name: continuous
Design Day Sched. Name: continuous

----- Equipment Information -----

Equipment's Name: Equipment
Equipment Peak Gain: 682.40
Sensible Heat Gain: 682.40
Latent Heat Gain: 0.00
Equipment Multiplier: 1
Radiant Fraction: 0.600
Convective Fraction: 0.400
Annual Sched. Name: continuous

----- Wall Information -----

Wall's Name: North
Facing Direction: 0.00
Tilt Angle: 90.00
Wall Type: 1
Actual U Factor: 0.00
Surface Absorptance: 0.60
Surface Area: 232.50
Material Descriptions:
Mass Location: ## Undefined ##
Principle Material: ## Undefined ##
Secondary Material: ## Undefined ##
\*\*\* No Window Defined For This Surface \*\*\*

----- Roof Information -----

Roof's Name: Roof
Facing Direction: 0.00
Tilt Angle: 0.00
Roof Type: 2
Actual U Factor: 0.06
Surface Absorptance: 0.60
Surface Area: 516.60
Material Descriptions:
Resistance A0 : Outside Surface
Resistance B7 : 1 in. Wood
Resistance R12 : 3 in. Insulation
Resistance E0 : Inside Surface
Resistance E2 : 1/2 in. Slag or Stone
Mass Location: Mass Integral
Principle Material: B7 1 in. Wood
Suspended Ceiling: Without
\*\*\* No Window Defined For This Surface \*\*\*

----- Wall Information -----

Wall's Name: West
Facing Direction: 270.00
Tilt Angle: 90.00
Wall Type: 1
Actual U Factor: 0.09
Surface Absorptance: 0.60
Surface Area: 174.38
Material Descriptions:
Mass Location: ## Undefined ##
Principle Material: ## Undefined ##
Secondary Material: ## Undefined ##

>>-----Window for This Surface-----<<<

Glass's Name: West Window
Window Width: 9.84
Window Height: 6.56
Glass Shading Coefficient: 0.88
Glass U Factor: 0.5100

----- Wall Information -----

Wall's Name: East
Facing Direction: 90.00
Tilt Angle: 90.00
Wall Type: 1
Actual U Factor: 0.09
Surface Absorptance: 0.60
Surface Area: 174.38
Material Descriptions:
Mass Location: ## Undefined ##
Principle Material: ## Undefined ##
Secondary Material: ## Undefined ##

>>-----Window for This Surface-----<<<

Glass's Name: West Window
Window Width: 9.84
Window Height: 6.56
Glass Shading Coefficient: 0.88
Glass U Factor: 0.5100

```

-----Wall Information-----
Wall's Name:          South
Facing Direction:    180.00
Tilt Angle:          90.00
Wall Type:           1
Actual U Factor:     0.09
Surface Absorptance: 0.60
Surface Area:        232.50
Material Descriptions:
Mass Location:       ## Undefined ##
Principle Material:  ## Undefined ##
Secondary Material:  ## Undefined ##
*** No Window Defined For This Surface ***

```

```

Wall Type:           1
Actual U Factor:     0.09
Surface Absorptance: 0.60
Surface Area:        232.50
Material Descriptions:
Mass Location:       ## Undefined ##
Principle Material:  ## Undefined ##
Secondary Material:  ## Undefined ##
*** No Window Defined For This Surface ***

```

```

-----Zone Information-----
Zone Name:           Zone 630
Zone Multiplier:     1
Summer Indoor Design DBT: 78.00
Summer Indoor Design WBT: 70.00
Winter Indoor Design DBT: 0.00
Winter Indoor Design WBT: 0.00
Summer Indoor R. Humidity: 50.00
Winter Indoor R. Humidity: 36.00
Room Construction Type: Extreme Light
Max. System C. Capacity: 50000.00
Max. System H. Capacity: -50000.00
System Air Flow Rate: 0.00
Outdoor Air Flow Rate: 0.00
System Throttling Range: 0.01
System Annual Schd. Name: 600 annual
System Design Schd. Name: 600 daily
Ventilating Ann. Schd. Name: continuous
Ventilating Des. Schd. Name: continuous

```

```

-----Roof Information-----
Roof's Name:         Roof
Facing Direction:    0.00
Tilt Angle:          0.00
Roof Type:           2
Actual U Factor:     0.06
Surface Absorptance: 0.60
Surface Area:        516.60
Material Descriptions:
Resistance           A0 : Outside Surface
                    B7 : 1 in. Wood
                    B12: 3 in. Insulation
                    E0 : Inside Surface
Resistance           E2 : 1/2 in. Slag or
                    Stone
Mass Location:       Mass Integral
Principle Material:  B7 1 in. Wood
Suspended Ceiling:  Without
*** No Window Defined For This Surface ***

```

```

-----Room Information-----
Room Name:           Room 630
Room Multiplier:     1
Floor Sur. Area:     516.60
Room Ceiling Height: 8.86
Room Parameters:
Room Geometry       : 15 ft x 15 ft
Room Height         : 8 ft
# of Exterior Wall  : 4
Interior Shade     : 0 1
Furniture           : Without
Exterior Construction : L.W. with moderate insln.
Partition Type      : 5/8 in. Gyp-Air-1/4 in. Gyp
Room Location       : Top Floor
Mid Floor Type      : 1 in. Wood
Slab Type           : Mid Floor Type
Ceiling Type        : Without Ceiling
Roof Type           : L.W. w/ susp. ceiling
Floor Covering      : vinyl tile
Glass Percent       : 10 1

```

```

-----Wall Information-----
Wall's Name:          South
Facing Direction:    180.00
Tilt Angle:          90.00
Wall Type:           1
Actual U Factor:     0.09
Surface Absorptance: 0.60
Surface Area:        232.50
Material Descriptions:
Mass Location:       ## Undefined ##
Principle Material:  ## Undefined ##
Secondary Material:  ## Undefined ##
*** No Window Defined For This Surface ***

```

```

-----Infiltration Information-----
Infiltration's Name: Infiltration
Air Change/Hour:     0.50
Annual Schd. Name:   continuous
Design Day Schd. Name: continuous

```

```

-----Wall Information-----
Wall's Name:          South
Facing Direction:    180.00
Tilt Angle:          90.00
Wall Type:           1
Actual U Factor:     0.09
Surface Absorptance: 0.60
Surface Area:        174.38
Material Descriptions:
Mass Location:       ## Undefined ##
Principle Material:  ## Undefined ##
Secondary Material:  ## Undefined ##

```

```

-----Equipment Information-----
Equipment's Name:     Equipment
Equipment Peak Gain: 682.40
Sensible Heat Gain:  682.40
Latent Heat Gain:    0.00
Equipment Multiplier: 1
Radiant Fraction:    0.600
Convective Fraction: 0.400
Annual Schd. Name:   continuous
Design Day Schd. Name: continuous

```

```

>>-----Window for This Surface-----
Glass's Name:         West Window
Window Width:         9.81
Window Height:        6.56
Glass Shading Coefficient: 0.87
Glass U Factor:        0.5000
Overhang Length:      3.28
Glass to Overhang:    1.61
Overhang Protrusion:  0.0
Reveal Depth:         0.0

```

```

-----Wall Information-----
Wall's Name:          North
Facing Direction:    0.00
Tilt Angle:          90.00

```

```

-----Wall Information-----
Wall's Name:          West
Facing Direction:    270.00
Tilt Angle:          90.00
Wall Type:           1
Actual U Factor:     0.09
Surface Absorptance: 0.60
Surface Area:        174.38
Material Descriptions:

```

Mass Location: ## Undefined ##  
Principle Material: ## Undefined ##  
Secondary Material: ## Undefined ##

>>-----Window for This Surface-----<<

Glass's Name: West Window  
Window Width: 9.84  
Window Height: 6.56  
Glass Shading Coefficient: 0.88  
Glass U Factor: 0.5377  
Overhang Length: 3.25  
Glass to Overhang: 1.64  
Overhang Projection: 0.00  
Reveal Depth: 0.00

-----Zone Information-----

Zone Name: Zone 640  
Zone Multiplier: 1  
Summer Indoor Design DBT: 78.00  
Summer Indoor Design WBT: 70.00  
Winter Indoor Design DBT: 0.00  
Winter Indoor Design WBT: 0.00  
Summer Indoor R. Humidity: 50.00  
Winter Indoor R. Humidity: 30.00  
Room Construction Type: Extreme Light  
Max. System C. Capacity: 50000.00  
Max. System H. Capacity: -50000.00  
System Air Flow Rate: 0.00  
Outdoor Air Flow Rate: 0.00  
System Throttling Range: 0.01  
System Annual Schd. Name: 640 annual  
System Design Schd. Name: 640 daily  
Ventilating Ann. Schd. Name: continuous  
Ventilating Des. Schd. Name: continuous

-----Room Information-----

Room Name: Room 600  
Room Multiplier: 1  
Floor Sur. Area: 516.60  
Room Ceiling Height: 8.86  
Room Parameters:  
Room Geometry: 15 ft x 15 ft  
Room Height: 8 ft  
# of Exterior Wall: 4  
Interior Shade: 0 ft  
Furniture: Without  
Exterior Construction: L.W. with moderate insln.  
Partition Type: 5/8 in. Gyp-Air-5/8 in. Gyp  
Room Location: Top Floor  
Mid Floor Type: 1 in. Wood  
Slab Type: Mt. Floor Type  
Ceiling Type: Without Ceiling  
Roof Type: L.W. w/o susp. ceiling  
Floor Covering: vinyl tile  
Glass Percent: 10 %

-----Infiltration Information-----

Infiltration's Name: Infiltration  
Air Change/Hour: 0.50  
Annual Schd. Name: continuous  
Design Day Schd. Name: continuous

-----Wall Information-----

Wall's Name: West  
Facing Direction: 270.00  
Tilt Angle: 90.00  
Wall Type: 1  
Actual U Factor: 0.09  
Surface Absorptance: 0.60  
Surface Area: 174.38  
Material Descriptions:  
Mass Location: ## Undefined ##  
Principle Material: ## Undefined ##  
Secondary Material: ## Undefined ##  
\*\*\* No Window Defined For This Surface \*\*\*

-----Equipment Information-----

Equipment's Name: Equipment

Equipment Peak Gain: 682.40  
Sensible Heat Gain: 682.40  
Latent Heat Gain: 0.00  
Equipment Multiplier: 1  
Radiant Fraction: 0.600  
Convective Fraction: 0.400  
Annual Schd. Name: continuous  
Design Day Schd. Name: continuous

-----Wall Information-----

Wall's Name: East  
Facing Direction: 90.00  
Tilt Angle: 90.00  
Wall Type: 1  
Actual U Factor: 0.09  
Surface Absorptance: 0.60  
Surface Area: 174.38  
Material Descriptions:  
Mass Location: ## Undefined ##  
Principle Material: ## Undefined ##  
Secondary Material: ## Undefined ##  
\*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----

Wall's Name: North  
Facing Direction: 0.00  
Tilt Angle: 90.00  
Wall Type: 1  
Actual U Factor: 0.09  
Surface Absorptance: 0.60  
Surface Area: 232.50  
Material Descriptions:  
Mass Location: ## Undefined ##  
Principle Material: ## Undefined ##  
Secondary Material: ## Undefined ##  
\*\*\* No Window Defined For This Surface \*\*\*

-----Roof Information-----

Roof's Name: Roof  
Facing Direction: 0.00  
Tilt Angle: 0.00  
Roof Type: 2  
Actual U Factor: 0.06  
Surface Absorptance: 0.60  
Surface Area: 516.60  
Material Descriptions:  
Resistance AD : Outside Surface  
Resistance B7 : 1 in. Wood  
Resistance E0 : 1 in. Insulation  
Resistance E2 : 1/2 in. Slab :  
Stone  
Mass Location: Mass Integral  
Principle Material: B7 : 1 in. Wood  
Suspended Ceiling: Without  
\*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----

Wall's Name: South  
Facing Direction: 180.00  
Tilt Angle: 90.00  
Wall Type: 1  
Actual U Factor: 0.09  
Surface Absorptance: 0.60  
Surface Area: 232.50  
Material Descriptions:  
Mass Location: ## Undefined ##  
Principle Material: ## Undefined ##  
Secondary Material: ## Undefined ##

>>-----Window for This Surface-----<<

Glass's Name: South Window  
Window Width: 15.60  
Window Height: 6.56  
Glass Shading Coefficient: 0.88  
Glass U Factor: 0.5377

----- Zone Information -----  
 Zone Name: Zone 940  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 75.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Medium  
 Max. System C. Capacity: 50000.00  
 Max. System H. Capacity: -50000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.01  
 System Annual Schd. Name: 640 annual  
 System Design Schd. Name: 640 daily  
 Ventilating Ann. Schd. Name: continuous  
 Ventilating Des. Schd. Name: continuous

-----Room Information-----  
 Room Name: Room 94  
 Room Multiplier: 1  
 Floor Sur. Area: 516.60  
 Room Ceiling Height: 8.66  
 Room Parameters:  
 Room Geometry : 15 ft x 15 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 4  
 Interior Shade : 0.1  
 Furniture : Without  
 Exterior Construction : B.W. with moderate insn.  
 Partition Type : 9 in. Conc. block  
 Room Location : Top Floor  
 Mid Floor Type : 2.5 in. Conc.  
 Slab Type : Mid Floor Type  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : vinyl tile  
 Glass Percent : 10.1

-----Infiltration Information-----  
 Infiltration's Name: Infiltration  
 Air Change/Hour: 0.50  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Equipment Information-----  
 Equipment's Name: Equipment  
 Equipment Peak Gain: 682.40  
 Sensible Heat Gain: 682.40  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.600  
 Convective Fraction: 0.400  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Roof Information-----  
 Roof's Name: Roof  
 Facing Direction: 0.00  
 Tilt Angle: 0.00  
 Roof Type: 2  
 Actual U Factor: 0.06  
 Surface Absorptance: 0.60  
 Surface Area: 516.60  
 Material Descriptions:  
 Resistance  
 A0 : Outside Surface  
 B7 : 1 in. Wood  
 B12 : 3 in. Insulation  
 E. : Inside Surface  
 Resistance  
 E2 : 1/2 in. Slag or  
 Stone  
 Mass Location: Mass Integral  
 Principle Material: B7 1 in. Wood  
 Suspended Ceiling: Without  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----  
 Wall's Name: West  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.05  
 Surface Absorptance: 0.60  
 Surface Area: 174.38  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----  
 Wall's Name: East  
 Facing Direction: 90.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.05  
 Surface Absorptance: 0.60  
 Surface Area: 174.38  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----  
 Wall's Name: South  
 Facing Direction: 180.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.05  
 Surface Absorptance: 0.60  
 Surface Area: 232.50  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##

>>>>>Window for This Surface<<<<<  
 Glass's Name: South Window  
 Window Width: 19.60  
 Window Height: 6.56  
 Glass Shading Coefficient: 0.80  
 Glass U Factor: 0.5300

-----Wall Information-----  
 Wall's Name: North  
 Facing Direction: 0.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.05  
 Surface Absorptance: 0.60  
 Surface Area: 232.50  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

----- Zone Information -----  
 Zone Name: Zone 920  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 75.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Medium  
 Max. System C. Capacity: 50000.00  
 Max. System H. Capacity: -50000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.01

System Annual Schd. Name: 600 annual  
 System Design Schd. Name: 600 daily  
 Ventilating Ann. Schd. Name: continuous  
 Ventilating Des. Schd. Name: continuous

-----Room Information-----

Room Name: Room 926  
 Room Multiplier: 1  
 Floor Sur. Area: 516.60  
 Room Ceiling Height: 8.86  
 Room Parameters:  
 Room Geometry : 15 ft x 15 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 4  
 Interior Shade : 0.1  
 Furniture : Without  
 Exterior Construction : H.W. with moderate insln.  
 Partition Type : 8 in. Conc. block  
 Room Location : Top Floor  
 Mid Floor Type : 2.5 in. Conc.  
 Slab Type : Mid Floor Type  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : vinyl tile  
 Glass Percent : 10.1

-----Infiltration Information-----

Infiltration's Name: Infiltration  
 Air Change Hour: 0.50  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Equipment Information-----

Equipment's Name: Equipment  
 Equipment Peak Gain: 682.40  
 Sensible Heat Gain: 682.40  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.600  
 Convective Fraction: 0.400  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Wall Information-----

Wall's Name: North  
 Facing Direction: 0.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 232.50  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Roof Information-----

Roof's Name: Roof  
 Facing Direction: 0.00  
 Tilt Angle: 0.00  
 R-Value Type: 2  
 Actual U Factor: 0.06  
 Surface Absorptance: 0.60  
 Surface Area: 516.60  
 Material Descriptions:  
 Resistance  
 A0 : Outside Surface  
 B7 : 1 in. Wood  
 B12 : 1 in. Insulation  
 E0 : Inside Surface  
 Resistance  
 E2 : 1/2 in. Slag or Stone  
 Mass Location: Mass Integral  
 Principle Material: B7 1 in. Wood  
 Suspended Ceiling: Without  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----

Wall's Name: East  
 Facing Direction: 90.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 174.38  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##

>>>>Window for This Surface<<<<

Glass's Name: West Window  
 Window Width: 7.84  
 Window Height: 6.56  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.5300

-----Wall Information-----

Wall's Name: South  
 Facing Direction: 180.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 232.50  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----

Wall's Name: West  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 174.38  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##

>>>>Window for This Surface<<<<

Glass's Name: West Window  
 Window Width: 7.84  
 Window Height: 6.56  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.5300

-----Zone Information-----

Zone Name: Zone 900  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 78.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 65.00  
 Winter Indoor Design WBT: 60.00  
 Summer Indoor P. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Medium  
 Max. System C. Capacity: 50000.00  
 Max. System H. Capacity: 50000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.01  
 System Annual Schd. Name: 600 annual  
 System Design Schd. Name: 600 daily  
 Ventilating Ann. Schd. Name: continuous  
 Ventilating Des. Schd. Name: continuous

-----Room Information-----

Room Name: Room 910

Room Multiplier: 1  
 Floor Sur. Area: 516.60  
 Room Ceiling Height: 8.00  
 Room Parameters:  
 Room Geometry : 15 ft x 15 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 4  
 Interior Shade : 0.1  
 Furniture : Without  
 Exterior Construction : H.W. with moderate inslc.  
 Partition Type : 5 in. Conc. block  
 Room Location : Top Floor  
 Mid Floor Type : 2.5 in. Conc.  
 Slab Type : Mid Floor Type  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : Vinyl tile  
 Glass Percent : 10.4

Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 174.38  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Equipment Information-----

Equipment's Name: Equipment  
 Equipment Peak Gain: 682.40  
 Sensible Heat Gain: 682.40  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.600  
 Convective Fraction: 0.400  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Infiltration Information-----

Infiltration's Name: Infiltration  
 Air Change/Hour: 0.50  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Wall Information-----

-----Wall Information-----

Wall's Name: North  
 Facing Direction: 0.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 232.50  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

Wall's Name: South  
 Facing Direction: 180.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 232.50  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##

>>>>Window for This Surface<<<<

-----Roof Information-----

Roof's Name: Roof  
 Facing Direction: 0.00  
 Tilt Angle: 0.00  
 Roof Type: 2  
 Actual U Factor: 0.06  
 Surface Absorptance: 0.60  
 Surface Area: 516.60  
 Material Descriptions:  
 Resistance AP : Outside Surface  
 R7 : 1 in. Wood  
 BT2 : 3 in. Insulation  
 E0 : Inside Surface  
 Resistance EP : 1/2 in. Stagger  
 Stone  
 Mass Location: Mass Integral  
 Principle Material: R7 1 in. Wood  
 Suspended Ceiling: Without  
 \*\*\* No Window Defined For This Surface \*\*\*

Glass's Name: South Window  
 Window Width: 19.60  
 Window Height: 6.56  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.3100  
 Overhang Length: 3.28  
 Glass to Overhang: 1.64  
 Overhang Projection: 0.00  
 Recess Depth: 0.00

-----Zone Information-----

Zone Name: Zone 900  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 78.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Medium  
 Max. System Capacity: 50000.00  
 Max. System R. Capacity: -50000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.01  
 System Annual Schd. Name: 600 annual  
 System Design Schd. Name: 600 daily  
 Ventilating ANN. Schd. Name: continuous  
 Ventilating Des. Schd. Name: continuous

-----Room Information-----

-----Wall Information-----

Wall's Name: West  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 174.38  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

Room Name: Room 900  
 Room Multiplier: 1  
 Floor Sur. Area: 516.60  
 Room Ceiling Height: 8.00  
 Room Parameters:  
 Room Geometry : 15 ft x 15 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 4  
 Interior Shade : 0.1  
 Furniture : Without  
 Exterior Construction : H.W. with moderate inslc.  
 Partition Type : 5 in. Conc. block  
 Room Location : Top Floor  
 Mid Floor Type : 2.5 in. Conc.

-----Wall Information-----

Wall's Name: East  
 Facing Direction: 90.00

Slab Type : Mid Floor Type  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : vinyl tile  
 Glass Percent : 10 %

Facing Direction: 0.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 232.50

-----Infiltration Information-----

Infiltration's Name: Infiltration  
 Air Change/Hour: 0.55  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----

-----Equipment Information-----

Equipment's Name: Equipment  
 Equipment Peak Gain: 682.40  
 Sensible Heat Gain: 682.40  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.600  
 Convective Fraction: 0.400  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

Wall's Name: South  
 Facing Direction: 180.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 232.50  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##

>>----Window for This Surface-----

-----Roof Information-----

Roof's Name: Roof  
 Facing Direction: 0.00  
 Tilt Angle: 0.00  
 Roof Type: 2  
 Actual U Factor: 0.06  
 Surface Absorptance: 0.60  
 Surface Area: 516.60  
 Material Descriptions:  
 Resistance A0 : Outside Surface  
 Resistance B7 : 1 in. Wood  
 Resistance B12 : 3 in. Insulation  
 Resistance E0 : Inside Surface  
 Resistance E2 : 1/2 in. Slab on Stone  
 Mass Location: Mass Integral  
 Principle Material: B7 1 in. Wood  
 Suspended Ceiling: Without  
 \*\*\* No Window Defined For This Surface \*\*\*

Glass's Name: South Window  
 Window Width: 16.60  
 Window Height: 6.56  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.5300

-----Zone Information-----

Zone Name: Zone 600  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 78.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Roof Construction Type: Extreme Mount  
 Max. System C. Capacity: 50000.00  
 Max. System H. Capacity: -50000.00  
 System Air Flow Rate: 0.00  
 Gains or Air Flow Rate: 0.00  
 System Throttling Valve: 0.01  
 System Annual Schd. Name: 600 annual  
 System Design Schd. Name: 600 daily  
 Ventilating Ann. Schd. Name: continuous  
 Ventilating Des. Schd. Name: continuous

-----Wall Information-----

Wall's Name: West  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 174.30  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Room Information-----

Room Name: Room 600  
 Room Multiplier: 1  
 Floor Sct. Area: 516.60  
 Room Ceiling Height: 8.86  
 Room Parameters:  
 Room Geometry : 15 ft. x 15 ft.  
 Room Height : 8 ft.  
 # of Exterior Wall : 4  
 Interior Shade : 0 %  
 Furniture : Without  
 Exterior Construction : L.W. with moderate insul.  
 Partition Type : 5/8 in. Gyp-Air-5/8 in. Gyp  
 Room Location : Top Floor  
 Mid Floor Type : 1 in. Wood  
 Slab Type : Mid Floor Type  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/o susp. ceiling  
 Floor Covering : vinyl tile  
 Glass Percent : 10 %

-----Wall Information-----

Wall's Name: East  
 Facing Direction: 90.00  
 Tilt Angle: 90.00  
 Wall Type: 11  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 174.30  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Infiltration Information-----

Infiltration's Name: Infiltration  
 Air Change/Hour: 0.55  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Wall Information-----

Wall's Name: North

-----Wall Information-----



Wall's Name: West  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 174.36  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Equipment Information-----

Equipment's Name: Equipment  
 Equipment Peak Gain: 682.40  
 Sensible Heat Gain: 682.40  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.600  
 Convective Fraction: 0.400  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Wall Information-----

Wall's Name: East  
 Facing Direction: 90.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 174.36  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----

Wall's Name: North  
 Facing Direction: 0.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 232.56  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----

Wall's Name: South  
 Facing Direction: 180.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 232.56  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##

>>>>Window for This Surface<<<<

Glass's Name: South Window  
 Window Width: 19.60  
 Window Height: 6.00  
 Glass Shading Coefficient: 0.77  
 Glass U Factor: 0.5300

-----Roof Information-----

Roof's Name: Roof

Facing Direction: 0.00  
 Tilt Angle: 0.00  
 Roof Type: 2  
 Actual U Factor: 0.06  
 Surface Absorptance: 0.60  
 Surface Area: 516.60  
 Material Descriptions:  
 Resistance  
 A0 : Outside Surface  
 B7 : 1 in. Wood  
 R12 : 3 in. Insulation  
 E0 : Inside Surface  
 Resistance  
 E2 : 1 2 in. Slab of  
 Stone  
 Mass Location: Mass Integral  
 Principle Material: B7 1 in. Wood  
 Suspended Ceiling: Without  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Zone Information-----

Zone Name: Zone 610  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 78.00  
 Summer Indoor Design MBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design MBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Extreme Light  
 Max. System C. Capacity: 50000.00  
 Max. System H. Capacity: -50000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.01  
 System Annual Schd. Name: 600 Annual  
 System Design Schd. Name: 600 daily  
 Ventilating Ann. Schd. Name: continuous  
 Ventilating Des. Schd. Name: continuous

-----Room Information-----

Room Name: Room 61  
 Room Multiplier: 1  
 Floor Sur. Area: 516.60  
 Room Ceiling Height: 8.86  
 Room Parameters:  
 Room Geometry : 15 ft x 15 ft  
 Room Height : 8 ft  
 # of Exterior Wall : 1  
 Interior Shading : 0.1  
 Furniture : Without  
 Exterior Construction : L.W. with separate drain.  
 Partition Type : 1 1/2 in. Gyp-Air-50' in. W/1  
 Room Location : Top Floor  
 Mid Floor Type : 1 in. Wood  
 Slab Type : Mid Floor Type  
 Ceiling Type : Without Ceiling  
 Roof Type : L.W. w/r susp. ceiling  
 Floor Covering : vinyl tile  
 Glass Percent : 10.1

-----Infiltration Information-----

Infiltration's Name: Infiltration  
 Air Change/Hour: 0.50  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Equipment Information-----

Equipment's Name: Equipment  
 Equipment Peak Gain: 682.40  
 Sensible Heat Gain: 682.40  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.600  
 Convective Fraction: 0.400  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Wall Information-----

Wall's Name: East

Facing Direction: 90.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 174.38  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

Surface Area: 174.38  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

----- Zone Information -----

Zone Name: Zone 930  
 Zone Multiplier: 1  
 Summer Indoor Design DBT: 78.00  
 Summer Indoor Design WBT: 70.00  
 Winter Indoor Design DBT: 0.00  
 Winter Indoor Design WBT: 0.00  
 Summer Indoor R. Humidity: 50.00  
 Winter Indoor R. Humidity: 30.00  
 Room Construction Type: Medium  
 Max. System C. Capacity: 50000.00  
 Max. System H. Capacity: -50000.00  
 System Air Flow Rate: 0.00  
 Outdoor Air Flow Rate: 0.00  
 System Throttling Range: 0.01  
 System Annual Schd. Name: 600 annual  
 System Design Schd. Name: 600 daily  
 Ventilating Ann. Schd. Name: continuous  
 Ventilating Des. Schd. Name: continuous

-----Wall Information-----

Wall's Name: North  
 Facing Direction: 0.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 232.50  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Room Information-----

Room Name: Room 930  
 Room Multiplier: 1  
 floor Sur. Area: 516.60  
 Room Ceiling Height: 8.86  
 Room Parameters:  
 Room Geometry: 15 ft x 15 ft  
 Room Height: 8 ft  
 # of Exterior Wall: 4  
 Interior Shade: 0.1  
 Furniture: Without  
 Exterior Construction: H.W. with moderate insln  
 Partition Type: P in. Conc. block  
 Room Location: Top Floor  
 Mid Floor Type: 2.5 in. Conc.  
 Slab Type: Mid Floor Type  
 Ceiling Type: Without Ceiling  
 Roof Type: L.W. w/ sup. ceiling  
 Floor Covering: vinyl tile  
 Glass Percent: 10.1

-----Roof Information-----

Roof's Name: Roof  
 Facing Direction: 0.00  
 Tilt Angle: 0.00  
 Roof Type: 2  
 Actual U Factor: 0.06  
 Surface Absorptance: 0.60  
 Surface Area: 516.60  
 Material Descriptions:  
 A0 : Outside Surface  
 Resistance  
 B1 : 1 in. Wood  
 B12 : 3 in. Insulation  
 E0 : Inside Surface  
 Resistance  
 E2 : 1/2 in. Slab or  
 Stone  
 Mass Location: Mass Integral  
 Principle Material: B1 1 in. Wood  
 Suspended Ceiling: Without  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Infiltration Information-----

Infiltration's Name: Infiltration  
 Air Change/Hour: 1.50  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Wall Information-----

Wall's Name: South  
 Facing Direction: 180.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 232.50  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##

-----Equipment Information-----

Equipment's Name: Equipment  
 Equipment Peak Gain: 682.40  
 Sensible Heat Gain: 682.40  
 Latent Heat Gain: 0.00  
 Equipment Multiplier: 1  
 Radiant Fraction: 0.600  
 Convective Fraction: 0.400  
 Annual Schd. Name: continuous  
 Design Day Schd. Name: continuous

-----Window for This Surface-----

Glass's Name: South Window  
 Window Width: 14.60  
 Window Height: 1.50  
 Glass Shading Coefficient: 0.88  
 Glass U Factor: 0.4700  
 Overhang Length: 3.20  
 Glass to Overhang: 1.61  
 Overhang Protrusion: 0.00  
 Reveal Depth: 0.00

-----Wall Information-----

Wall's Name: North  
 Facing Direction: 0.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60  
 Surface Area: 232.50  
 Material Descriptions:  
 Mass Location: ## Undefined ##  
 Principle Material: ## Undefined ##  
 Secondary Material: ## Undefined ##  
 \*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----

Wall's Name: West  
 Facing Direction: 270.00  
 Tilt Angle: 90.00  
 Wall Type: 1  
 Actual U Factor: 0.09  
 Surface Absorptance: 0.60

-----Roof Information-----

Roof's Name: Roof  
Facing Direction: 0.00  
Tilt Angle: 0.00  
Roof Type: 2  
Actual U Factor: 0.06  
Surface Absorptance: 0.60  
Surface Area: 516.60  
Material Descriptions:  
Resistance A0 : Outside Surface  
Resistance B7 : 1 in. Wood  
Resistance E1 : 3 in. Insulation  
Resistance E0 : Inside Surface  
Resistance E2 : 1/2 in. Slag or Stone  
Mass Location: Mass Integral  
Principle Material: B7 1 in. Wood  
Suspended Ceiling: Without  
\*\*\* No Window Defined For This Surface \*\*\*

-----Wall Information-----

Wall's Name: East  
Facing Direction: 90.00  
Tilt Angle: 90.00  
Wall Type: 11  
Actual U Factor: 0.09  
Surface Absorptance: 0.60  
Surface Area: 174.19  
Material Descriptions:  
Mass Location: ## Undefined ##  
Principle Material: ## Undefined ##  
Secondary Material: ## Undefined ##

>>>>>Window for This Surface<<<<<

Glass's Name: West Window  
Window Width: 9.84  
Window Height: 6.56  
Glass Shading Coefficient: 0.88  
Glass U Factor: 0.5100  
Overhang Length: 3.28  
Glass to Overhang: 1.64  
Overhang Protrusion: 0.00

Reveal Depth: 0.00

-----Wall Information-----

Wall's Name: West  
Facing Direction: 270.00  
Tilt Angle: 90.00  
Wall Type: 11  
Actual U Factor: 0.09  
Surface Absorptance: 0.60  
Surface Area: 174.19  
Material Descriptions:  
Mass Location: ## Undefined ##  
Principle Material: ## Undefined ##  
Secondary Material: ## Undefined ##

>>>>>Window for This Surface<<<<<

Glass's Name: West Window  
Window Width: 9.84  
Window Height: 6.56  
Glass Shading Coefficient: 0.88  
Glass U Factor: 0.5100  
Overhang Length: 3.28  
Glass to Overhang: 1.64  
Overhang Protrusion: 0.00  
Reveal Depth: 0.00

-----Wall Information-----

Wall's Name: South  
Facing Direction: 180.00  
Tilt Angle: 90.00  
Wall Type: 11  
Actual U Factor: 0.09  
Surface Absorptance: 0.60  
Surface Area: 232.50  
Material Descriptions:  
Mass Location: ## Undefined ##  
Principle Material: ## Undefined ##  
Secondary Material: ## Undefined ##  
\*\*\* No Window Defined For This Surface \*\*\*

VITA

Xin Chen

Candidate for the Degree of

Master of Science

Thesis: ADDITION OF ANNUAL BUILDING ENERGY ANALYSIS CAPABILITY  
TO A DESIGN LOAD CALCULATION PROGRAM

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Professional Experience:

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Professional Memberships:

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