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# HVACSIM$^+$ Building Systems and Equipment Simulation Program: Building Loads Calculation

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U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
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NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

## ABSTRACT

A non-proprietary building system simulation program called HVACSIM$^+$, which stands for HVAC SIMulation PLUS other systems, has been developed at the National Bureau of Standards (NBS) in an effort to understand the dynamic interactions between a building shell, an HVAC system, and building controls. HVACSIM$^+$ consists of a main simulation program, a library of HVAC system component models, a building shell model, and interactive front end input data generation programs.

The main simulation program employs a hierarchical, modular approach and advanced equation solving techniques to perform dynamic simulations of building/HVAC/control systems. In the building shell model, a fixed time step selected by the user is employed, while a variable time step approach is used in the HVAC and control systems portion of a simulation and the zone model.

This report presents the overall architecture of the HVACSIM$^+$ program, algorithms used in the main simulation program, a brief discussion of the numerical methods used in solving a system of non-linear simultaneous equations, integrating stiff ordinary differential equations and interpolating data and descriptions of the building shell and zone models. Conduction transfer functions, weather data, and simulation procedure are also described. This report is the third document, which describes the building model, supplied with HVACSIM$^+$.

Key words: building dynamics; building simulation; building system modeling; computer simulation programs; control dynamics; dynamic modeling of building systems; dynamic performance of building systems; dynamic simulations; HVAC system simulations; HVACSIM$^+$

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## DISCLAIMER

The program described in this report is furnished by the government and is accepted and used by any recipient with the express understanding that the United States Government makes no warranty, expressed or implied, concerning the accuracy, completeness, reliability, usability, or suitability for any particular purpose of the information and data contained in this program or furnished in connection therewith, and the United States shall be under no liability whatsoever to any person by reason of any use made thereof. This program belongs to the government. Therefore, the recipient further agrees not to assert any proprietary rights therein or to represent this program to anyone as other than a government program.

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# 1. INTRODUCTION

Computer simulations have been a popular means of analyzing building energy use. Compared with experimental investigations, computer simulations do not require installation of various expensive instruments. Simple changes in input data to a simulation model can evaluate their impacts on the model.

In an effort to carry out simulation studies involving the dynamic interactions between a building shell, an HVAC system, and building controls, a non-proprietary building system simulation program called HVACSIM$^+$ has been developed at the National Bureau of Standards (NBS). The program HVACSIM$^+$, which stands for HVAC SIMulation PLUS other systems, is capable of modeling the HVAC (heating, ventilation, and air-conditioning) system plus HVAC controls, the building shell, the heating/cooling plant, and energy management and control systems (EMCS) algorithms. Although the current version of the HVACSIM$^+$ has not implemented the EMCS algorithms yet, these may be added by a user interested in such applications, and familiar with Fortran programming.

The HVACSIM$^+$ consists of a main simulation program, a library of HVAC system components models, a building shell model, and interactive front end data generation programs. The main program is called MODSIM and employs a hierarchical, modular approach and advanced equation solving techniques to perform dynamic simulations of building/HVAC/control systems. The modular approach is based upon the methodology used in the TRNSYS program [1]. In the building shell model, a fixed (but user selectable) time step method is used, while a variable time step approach is employed in the HVAC and control systems portion and the zone model. This hybrid time step method is believed to be unique in the building systems programs.

The HVACSIM$^+$ program has been developed primarily as a research tool for whole building system studies. Flexibility of the HVACSIM$^+$ allows the simulation of HVAC components, control systems, the building shell, or any combination. The program is written in ANSI Standard Fortran 77. Fully structured programming makes the code relatively easy for programmers to understand and maintain.

Some important features of HVACSIM$^+$ were previously introduced [2,3] and the results of some case studies were published [4,5]. A general overview of HVACSIM$^+$ was also presented [6]. Documentation for HVACSIM$^+$ consists primarily of three publications: a Reference Manual [7], a Users Guide [8], and this report. The building loads calculation routines are relatively recent additions to HVACSIM$^+$, and as such are not described in the Reference Manual or the Users Guide. This report serves as reference manual and users guide for the building load portions of HVACSIM$^+$. In addition, mathematical details of the numerical methods used in HVACSIM$^+$ are presented. Sample simulations for building load calculations are appended.

## 2. ARCHITECTURE OF HVACSIM$^+$

The various portions of HVACSIM$^+$ can be divided into three categories: preprocessing, simulation, and postprocessing. Prior to performing a simulation, the data files for a particular building system simulation must be provided. This can be accomplished using programs in the preprocessing group. After a simulation, evaluation of outputs from the simulation is made using the postprocessing program.

Figure 1 shows a flow diagram of programs and data files comprising HVACSIM$^+$. During the preprocessing, a work file for simulation is created by the interactive front end program, HVACGEN [8]. This work file is then converted into the model definition file by the program SLIMCON. The model definition file has the format which the main program MODSIM requires. The work file can be edited interactively by the HVACGEN program. In generating the simulation work file, HVACGEN employs a data file containing component model information.

When a building shell is involved in a simulation, data files of weather conditions and conduction transfer functions for multilayered constructs must also be created. The program RDTAPE reads a weather tape (SOLMET, TMY, TRY, or WYEC tape) or equivalent and selects a portion of the weather data that is of interest. The selected weather data is transformed into the proper input form for MODSIM by the program CRWDTA. If a weather tape is not available or information from a weather tape is missing, the CRWDTA program produces a design day weather data file.

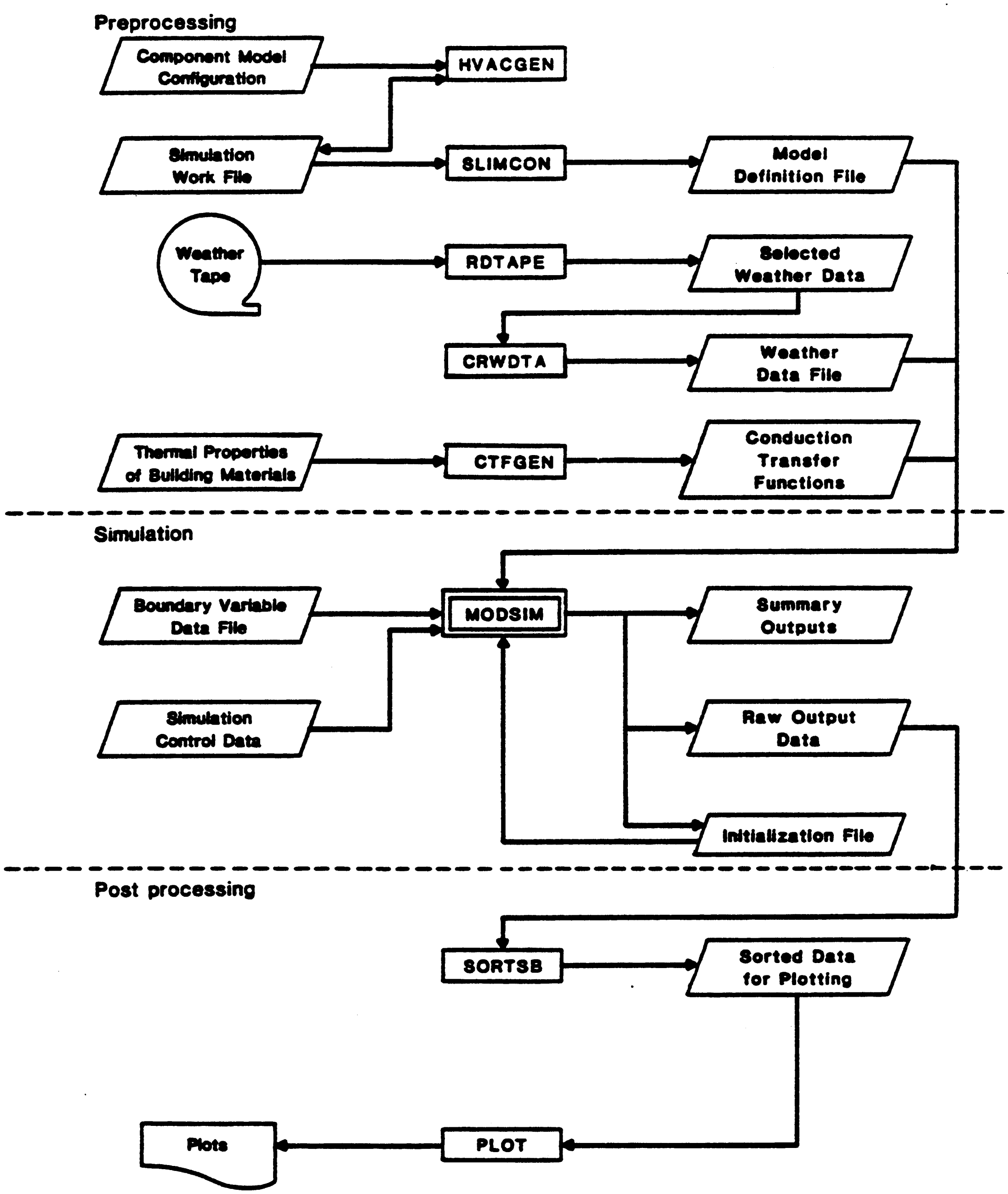


Figure 1. Flow diagram of programs and data files of HVACSIM+

The conduction transfer functions of multilayered building constructs are generated by the CTFGEN program. Except for the front end routines of CTFGEN the main routines in CTFGEN are taken from the TARP program by Walton [9]. The thermal properties of building materials (thickness, thermal conductivity, density, specific heat, and thermal resistance) can be entered into the data bank by using CTFGEN and multilayered constructs can be formed interactively.

The MODSIM program is the heart of HVACSIM$^+$. As shown in Figure 2, the MODSIM program consists of a main drive program and many subprograms for input/output operation, block and state variable status control, integration of stiff ordinary differential equations, solving of a system of simultaneous non-linear algebraic equations, component models of HVAC, controls, building model, and supporting utility.

The simulation program, MODSIM, calls the model definition, conduction transfer functions, weather, and boundary data files. The boundary data file can be created with a conventional editor. The state variables associated with this boundary data file are assigned when HVACGEN generates the work file for a particular simulation.

During the execution of MODSIM, simulation control input data can be entered interactively on a terminal. After a successful simulation, three data files are generated. These are the summary, raw output, and initialization data files. After renaming the initialization file as the input file to MODSIM, a

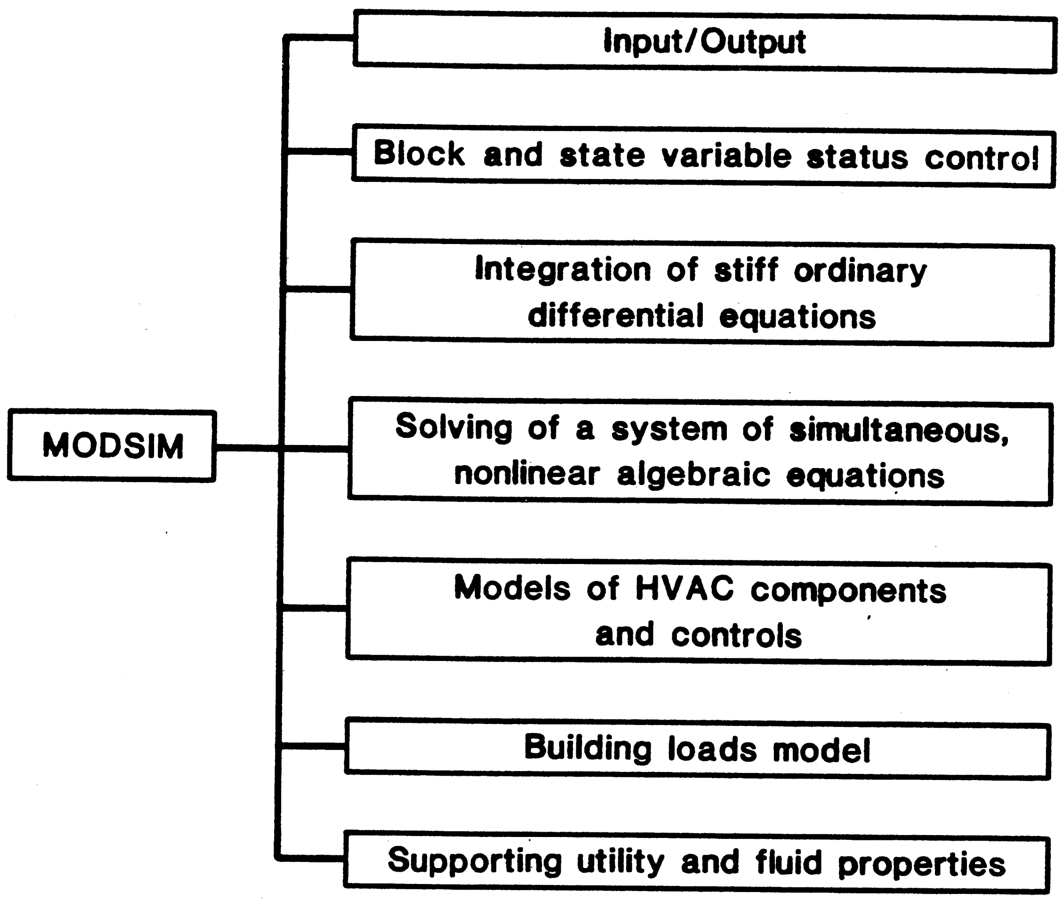


Figure 2. The structure of MODSIM

new simulation can be performed starting from the point where the previous simulation ended.

Postprocessing is necessary if graphical presentation of the raw outputs is desired. The program, SORTSB, sorts the raw output data. The outputs of these programs may then be used for plotting with a user-supplied graphic routine.

It should be noted that the architecture of $HVACSIM^{+}$ had been changed after the overview paper [6] was presented.

## 3. MODULAR SIMULATION PROGRAM, MODSIM

MODSIM stands for MODular SIMulation. Many ideas for the design of MODSIM came from the TRNSYS program, which was developed at the University of Wisconsin Solar Energy Laboratory [1]. The original MODSIM was first written in Fortran IV by Hill [3]. Since then, MODSIM has been rewritten in structured Fortran 77 and modified significantly. Important features of the current MODSIM program are described below.

### 3.1 Hierarchical, Modular Approach

A hierarchical simulation setup data file (model definition file) is employed by MODSIM during a simulation. The hierarchical structure comprises superblocks, blocks, and units. As illustrated in Figure 3, a number of units (or a single unit) form a block, and a number of blocks (or a single block) make up a superblock. Superblocks (or a single superblock) comprise a simulation. Figure 3 shows a setup involving 8 units, 4 blocks, and 2 superblocks. Depending upon the status of the state variables in a block or superblock, a system of equations in a block or in a superblock are solved simultaneously. The coupling of superblocks is done weakly through the state variables. In the interest of economy the whole simulation made up of superblocks is not solved simultaneously.

Using a modular approach, a UNIT in MODSIM represents a component model of a HVAC system, controls, or a building shell component. Each physical component is modeled in the subroutine TYPEn, where n is the index number of the type

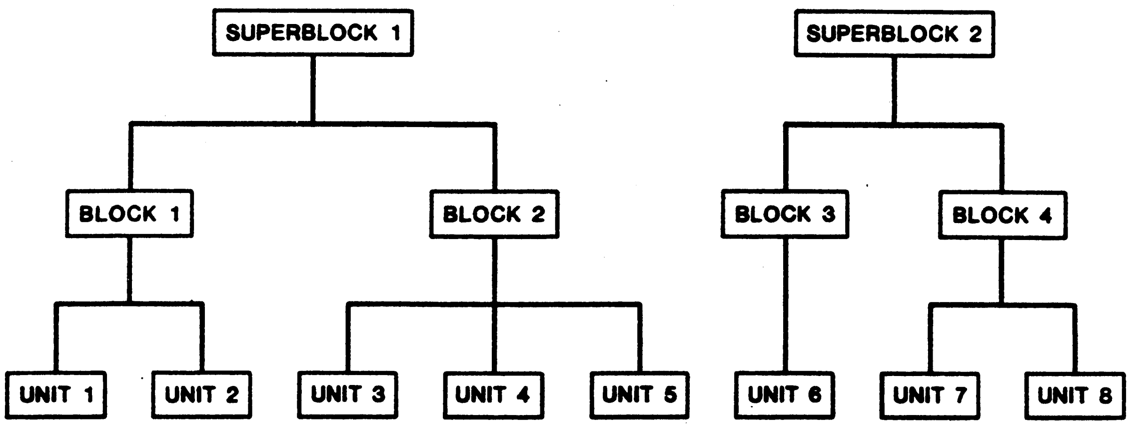


Figure 3. Hierarchical simulation setup

assigned to the specific component. More than one unit can call the same TYPEn subroutine if the same component model is used more than once. For example, if UNIT 2 and UNIT 4 in Figure 3 represent two different fans in the HVAC system, the same TYPE1 subroutine for a fan (n=1) can be used in the simulation. Each subroutine of component model has inputs, outputs, parameters, and a workspace vector for saving intermediate results. The component model configuration data file, which is an input file to the HVACGEN program, contains information on the numbers of inputs, outputs, parameters, elements in the saved workspace vector, and a description of the inputs, outputs, and parameters.

Each UNIT has its distinct index number for input and output variables, and values of parameters. This information is transmitted to the corresponding TYPEn subroutine through arguments.

This hierarchical, modular approach provides great flexibility in setting up a simulation model. The actual breakdown of a building system into blocks and superblocks is left to the user and depends upon the nature of the system and the type of interactions among its various components. Proper 'blocking' produces good simulation results and reduces computational time. Improper 'blocking' of a simulation model can result in a poor simulation.

### 3.2 Controls of State Variables and Blocks

During a simulation, a large portion of time is spent in solving the system of simultaneous equations. Reduction of the number of equations solved simultaneously in a block or a superblock can result in considerable computational savings. In MODSIM, when some of the state variables reach steady state, these variables are removed from the system of state variables that are solved simultaneously, and put aside (or 'frozen') until deviations from the steady-state values are encountered. The criterion for freezing a variable is chosen as

$$\left| x_{n+1} - x_n \right| \leq \frac{1}{2}\left[ e_r \left| x_{n+1} \right| + e_a \right], \tag{3.1}$$

where $x_{n+1}$ and $x_n$ are the state variables at the current and the previous time, and $e_r$ and $e_a$ are the relative and the absolute error tolerance, respectively. These error tolerances must be specified when the simulation work file is created using HVACGEN.

Similarly, a block can be inactivated (or frozen) if all the input variables to the block are frozen. A block is marked active as soon as one of its block inputs becomes unfrozen. When a block is frozen, it is no longer necessary to monitor the frozen state variables in the block.

### 3.3 Hybrid Simulation Time Steps

The MODSIM program incorporates two different types of time steps. One of them is a fixed time step, and the other is a variable time step. The building shell model uses a user-selected fixed time interval because the building shell model needs the conduction transfer functions of building constructs which are calculated on the basis of uniformly distributed time sampling. In addition, weather data is usually provided on the hourly basis. Variable time steps are used for all other component models.

This multi-time step approach has its advantage in saving computation time. Many component models for HVAC and controls systems involve ordinary differential equations. When the system is unsteady, a large time step invites numerical instability. To prevent this instability, small time intervals are necessary at an initial startup of a simulation or during a period when sudden change occurs. After the system becomes stabilized, the use of short time step is no longer needed and is wasteful.

Each superblock in a simulation is an independent subsystem in the sense that it proceeds forward in time independently. The variable time step is determined for each superblock, excluding the superblock for the building shell, by the integration routine used to solve the systems of differential equations. The largest time step allowed in a superblock is, however, limited to the fixed time step used in the building shell model.

### 3.4 Time Dependent Boundary Conditions

A state variable which is external to the system being simulated can be designated as a boundary variable when the simulation work file is generated. The boundary variables may be constant or time dependent. Data at the boundary variables are stored in the boundary data file and read as the simulation progresses. Time intervals in this data file are not required to be equal, since a third order Lagrangian interpolation method is used. Sometimes a change in a boundary variable may be discontinuous (e.g., set point change). In such cases, the integration routine of differential equations is reset at the time of discontinuity to bring the simulation time step to a minimum value. This kind of reset condition is signaled by including in the boundary data file two different data values of a boundary variable at a given time.

## 4. NUMERICAL METHODS IN MODSIM

The numerical methods employed in the MODSIM program involve techniques for solving systems of simultaneous nonlinear algebraic equations, integrating stiff ordinary differential equations, and interpolating data sampled in either a fixed period or variable time intervals. A large number of subprograms in the MODSIM are related to these numerical algorithms.

### 4.1 Nonlinear Equation Solver

The subroutine SNSQ with its associate subprograms is used in MODSIM. This routine is a part of the mathematical software package SNLSE in the CMLIB package, NBS [10], and was coded by Hiebert at Sandia National Laboratories by combining the HYBRD and HYBRDJ in the MINPACK code developed by Argonne National Laboratories [11]. The method used in the SNSQ program is based on Powell's hybrid method [12]. Minor modifications were made to the SNSQ routine to achieve better simulations with HVACSIM$^+$.

A brief mathematical description of the SNSQ routine is presented following closely the approach used in the paper by Hiebert [11].

The system of nonlinear equations can be written in vector form as

$$\underline{f}\ (\underline{x}) = \underline{0} \tag{4.1}$$

where

$$\underline{f} = [f_1,\ f_2,\ldots,f_n]^T,\ \underline{x} = [x_1,\ x_2,\ldots,x_n]^T \tag{4.2}$$

Expanding $\underline{f}$ in a Taylor series, and neglecting the high order terms, the linearized, approximate system becomes

$$\underline{f}(\underline{x}^*) \quad \underline{f}(x^k) + J(\underline{x}^k)\ (\underline{x}^* - \underline{x}^k) \tag{4.3}$$

where $J(\underline{x}^k)$ is a Jacobian evaluated at $\underline{x}^k$.

If $\underline{x}^*$ is the solution vector of the system, then

$$\underline{f}(\underline{x}^*) = 0.$$

The general iteration equation for given $\underline{x}^k$ near $\underline{x}^*$ becomes

$$\underline{x}^{k+1} = \underline{x}^k - J^{-1}(\underline{x}^k)\underline{f}(\underline{x}^k). \tag{4.4}$$

The Newton step of the nonlinear system, $\Delta x$, can be expressed as

$$\Delta\underline{x} = \underline{x}^{k+1} - \underline{x}^k = -J^{-1}(\underline{x}^k)\underline{f}(\underline{x}^k) \tag{4.5}$$

In efforts to reduce the number of calculations involved with this approach, a quasi-Newton method is used in SNSQ. This method approximates the Jacobian using the Broyden's rank-one update [13] instead of calculating the full Jacobian at each iteration. The Jacobian is calculated at the starting point by either the user-supplied subroutine or a forward-difference approximation, but it is not recalculated until the rank-one method fails to give satisfactory progress. If $B_k$ is the approximation of the Jacobian at the kth iteration, then the updated Jacobian [14] is

$$B_{k+1} = B_k - (B_k\underline{q}_k - \underline{v}_k)\underline{q}^T{}_k/\underline{q}^T{}_k\underline{q}_k, \tag{4.6}$$

where $\underline{q}_k = \underline{x}^{k+1} - \underline{x}^k$, $\underline{v}_k = \underline{f}(\underline{x}^{k+1}) - \underline{f}(\underline{x}^k)$, and $\underline{q}^Tk$ is the transpose of $\underline{q}_k$. In the SNSQ routine, the inverse Broyden update is employed. With the inverse Broyden update method, the inverse of the approximate Jacobian, $B_k{}^{-1}$ is stored and updated at each iteration.

The local convergence of the quasi-Newton method is superlinear, and required arithmetic operation per iteration is only $O(n^2)$, while the number of function evaluations per iteration is also only n. The shortcoming of the quasi-Newton method is that a good initial guess must be made for successful convergence. To improve this property, Powell [12] suggested a hybrid method.

The hybrid step is a combination of the quasi-Newton and gradient step. The gradient step is chosen to minimize the Euclidean norm of the residuals. The Gauss-Newton [15] and the steepest scaled gradient steps are actually incorporated in the SNSQ routine. The convergence test is successful so that $\underline{x}^k$ is a solution vector if the following condition is satisfied:

$$||d_k\ (\underline{x}^{k+1} - \underline{x}^k)|| \le e_t||d_1\underline{x}^k|| \tag{4.7}$$

or if $\underline{f}(\underline{x}) = 0$. In the above equation, $d_k$ is the diagonal component of the transformed Jacobian matrix using QR-factorization, $e_t$ is the error tolerance usually specified by the user, and the double bars denote the norms. In HVACSIM$^+$, the value of $e_t$ is specified when the model definition file is created by the HVACGEN front-end program. Although the square-root of the machine precision [16] is recommended for the value of $e_t$ in the SNSQ routine, the choice of the value depends upon the particular simulation setup and its initial values. As a rule of thumb, $e_t$ may be greater than or equal to the sum of $e_r$ and $e_a$.

The block/superblock structures, defined when a simulation setup is made, also strongly influence the convergence characteristics. Even though the use of hybrid step improves the convergence properties, making a good guess for initial conditions is very important to ensure a successful simulation.

As an example, Figure 4 shows the simplified flow diagram for the iterative procedure when $x_1$ and $x_2$ are solved simultaneously and $x_3$ and $x_4$ remain constant at a time step. In the TYPE subroutines for two units in a block, $x_1'$ and $x_2'$ are determined using the function $F_1$ and $F_2$, respectively. Residual functions can be written as

$$\begin{aligned} f_1(x_1,x_2,x_3,x_4) &= x_1' - x_1 = F_1\ (x_2,x_3) - x_1 \\ f_2(x_1,x_2,x_3,x_4) &= x_2' - x_2 = F_2\ (x_1,x_4) - x_2 \end{aligned} \tag{4.8}$$

These function vectors, $f_1$ and $f_2$, and state variables, $x_i$, are entered into the equation solver. When the convergence criterion as given by equation (4.7) is met, the iteraction ceases, and the solutions $x_1*$ and $x_2*$ satisfy $f_1 = f_2 = 0$. After the solutions are obtained, the simulation time is increased by h, which is either variable time step or fixed.

## 4.2 Integration of Stiff Ordinary Differential Equations

The use of variable time step and variable order integration techniques to solve sets of differential equations can reduce the amount of computer time required for dynamic simulations significantly. The algorithm employed is the one developed by Brayton, Gustavson and Hachtel [17]. This is an extension of the famous Gear algorithm called DIFSUB [18], which uses the backward differential formulas associated with Nordsieck's method [19].

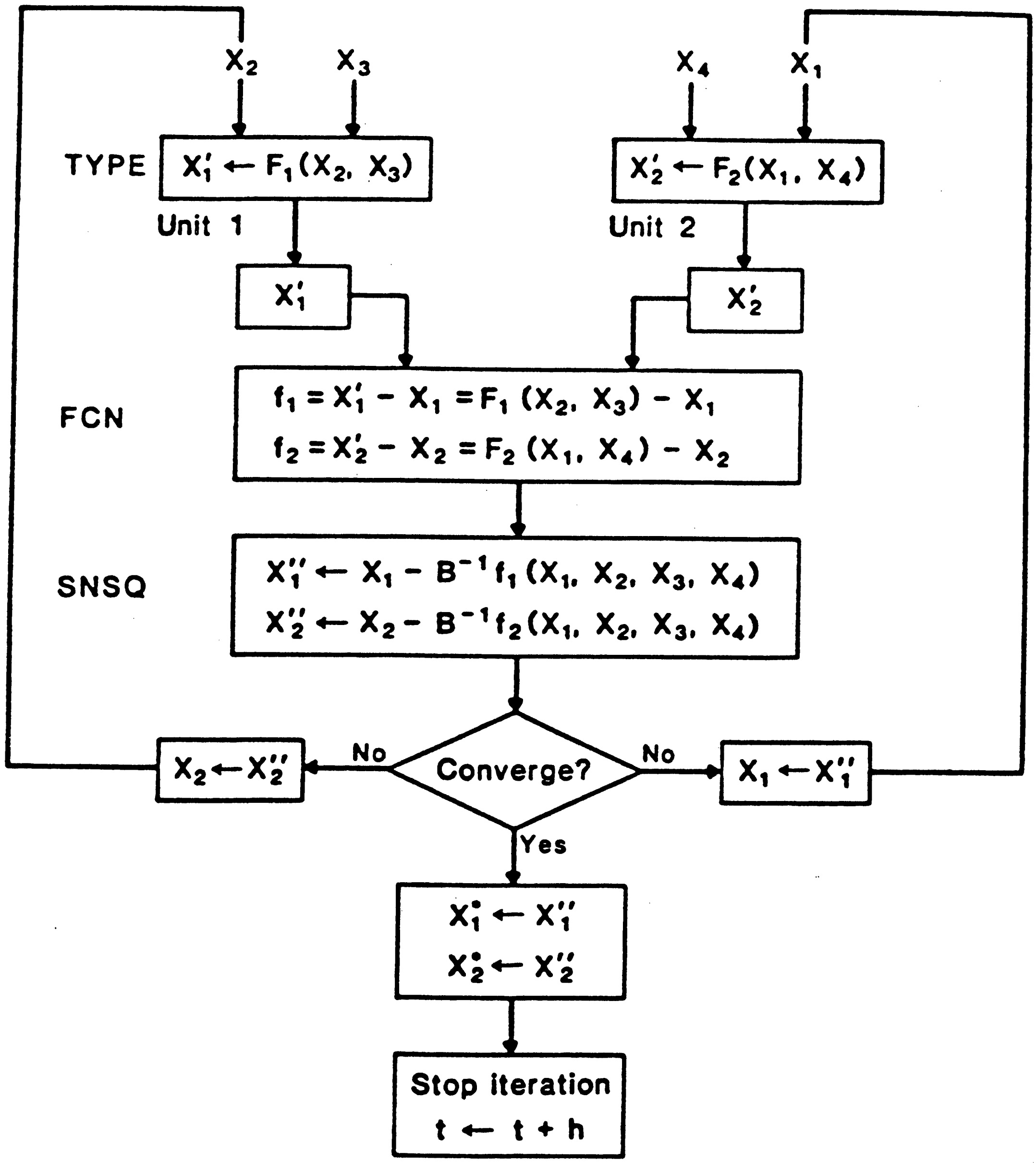


Figure 4. Simplified flow diagram for the iterative procedure in solving simultaneous, nonlinear equations

The discussion which follows will be highlighted information of the method by Brayton, et al [17]. Because a higher order ordinary differential equation can be transformed into a system of first-order differential equations, only integration of first order differential equations will be addressed.

A system of implicit differential algebraic equations can be expressed as

$$\underline{f}(\underline{x},\dot{\underline{x}},t) = 0 \tag{4.9}$$

where $\underline{x}$ is a state variable vector which is a function of time, t, $\dot{\underline{x}}$ is a derivative of $\underline{x}$. If the solution vector $\underline{x}(t)$ of equation (4.9) had been obtained at previous discrete times, $t=t_n$, $t=t_{n-1}, \ldots,$ and $t=t_{n+1-k}$, then the solution $\underline{x}_{n+1}$ at the current time, $t=t_{n+1}$, satisfies

$$\underline{f}(\underline{x}_{n+1}, \dot{\underline{x}}_{n+1}, t_{n+1}) = 0 \tag{4.10}$$

For stiff equations, the backward differentiation formula (BDF) approximates the present value $\dot{\underline{x}}_{n+1}$ at $t=t_{n+1}$ in terms of $\underline{x}_{n+1}$, and the k past values $\underline{x}_n$, $\underline{x}_{n-1}, \ldots, \underline{x}_{n-k+1}$. The k-th order backward differentiation formula is

$$\dot{\underline{x}}_{n+1} = -\frac{1}{h} \sum_{i=0}^{k} \alpha_i \, \underline{x}_{n+1-i}, \tag{4.11}$$

where $\alpha_i$ are constants and h is the present step size $(t_{n+1}-t_n)$. Setting $\underline{g}(\underline{x}_{n+1}) = \dot{\underline{x}}_{n+1}$, and substituting equation (4.11) into equation (4.10) yields a set of nonlinear algebraic equations of $\underline{x}_{n+1}$ at time $t_{n+1}$. This system of nonlinear equations can be solved by a nonlinear equation solver. In the MODSIM program, the previously described SNSQ routine is employed to solve the equations.

At the beginning of simulation, the initial values of $\underline{x}_0$ at t=0 is used with order k=1 for $\underline{x}_1$. Knowing $x_0$ and $x_1$, the new value $x_2$ is computed using $k \leq 2$, and so on. The maximum order of k has been limited to 6 since the order k seldom exceeds 6 in most applications.

As discussed already, the Newton method requires a reasonably good guess for the initial iteration. The predicted value of $\underline{x}_{n+1}$ for the initial guess is formulated using the same regressor expression in equation (4.11).

$$\underline{x}^P_{n+1} = \sum_{i=1}^{k+1} \gamma_i \, \underline{x}_{n+1-i} \tag{4.12}$$

where $\gamma_i$ are constants.

For the k-th order backward differential formula, the local truncation error is given by

$$e_{tr} = E_k + 0(h^{k+2}) \tag{4.13}$$

where

$$E_k = \frac{h}{t_{n+1} - t_{n-k}} (\underline{x}_{n+1} - \underline{x}^P_{n+1}) \tag{4.14}$$

and the term $0(h^{k+2})$ represents higher-order terms in the step size of degrees greater than or equal to k+2.

Although the algorithm for computation of $\alpha_i$ and $\gamma_1$ presented by Brayton, et al. is very complex, it was coded in MODSIM to improve computational efficiency. Chua and Lin [20] explained the variable step-size, variable-order algorithm in a much easier way to follow.

Figure 5 shows a simplified flow chart of the algorithm for integration of stiff ordinary differential equations which is implemented in MODSIM. In the TYPE subroutine, the derivative of state variable x at time $t = t_{n+1}$ is calculated. The difference between the derivative $\dot{x}_{n+1}$ and the value of backward differential formula as formulated in equation (4.11) is denoted as g. The residual function is, in fact, a nonlinear algebraic equation given by

$$g = G(x_{n+1}) + \frac{1}{h} \sum_{i=0}^{k} \alpha_i \underline{x}_{n+1-i} \tag{4.15}$$

When $x_{n+1}$ is the solution of equation (4.15), g is zero. To find the solution at the present time, numerical iteration using the SNSQ routine is performed and convergence is checked. If the solution is converged close to the real solution, the iteraction is terminated and the truncation error of backward differential formula is computed and the order k and the step are determined. The selected step and order are rejected if the truncation error is too large. The strategy of selecting the order and step with the MODSIM is based on the

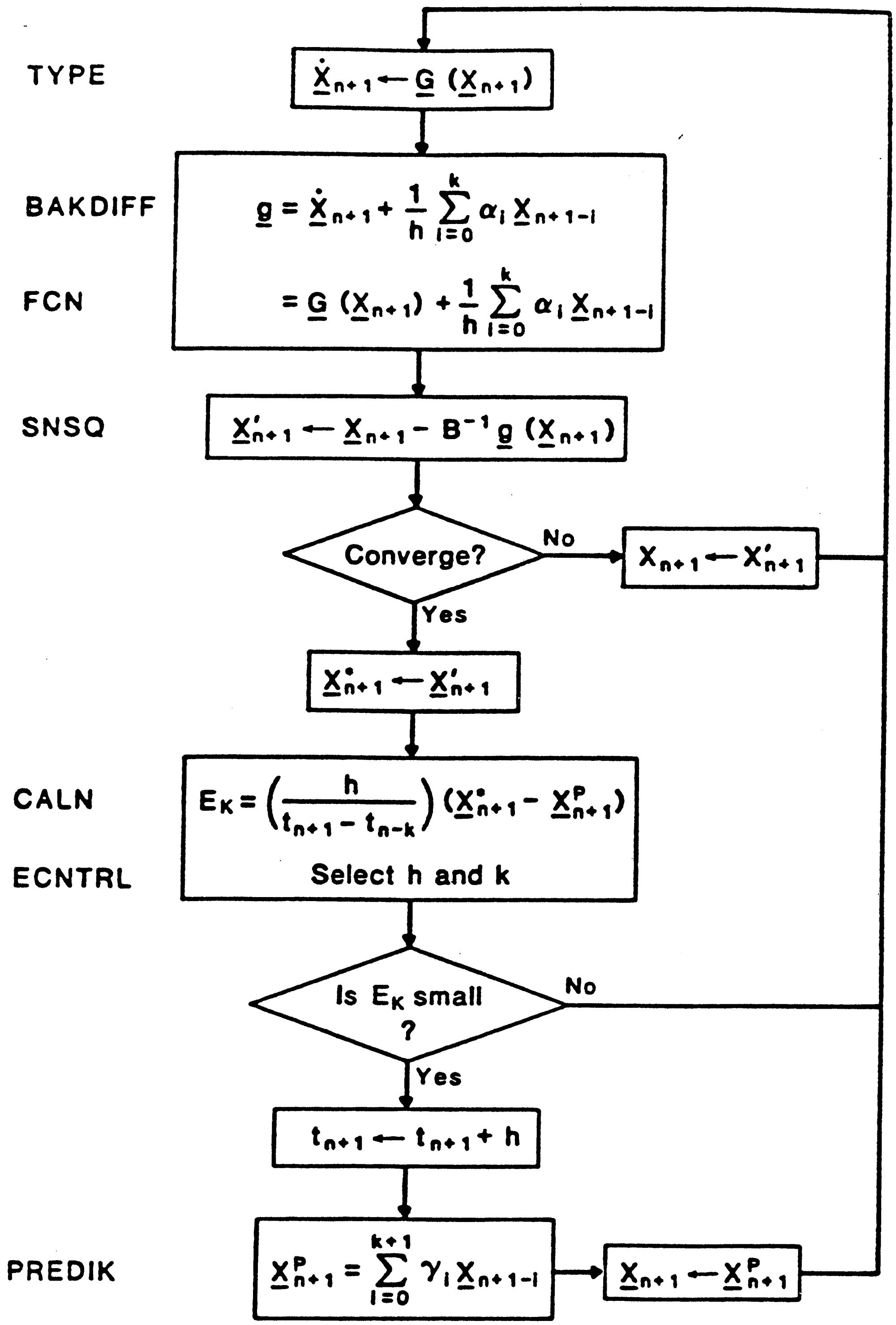


Figure 5. Simplified flow chart of the algorithm for integration of stiff ordinary differential equations

condition

$$E_k \le \frac{3h(e_r|x_{n+1}| + e_a)}{t_f - t_i} \tag{4.16}$$

where $t_i$ and $t_f$ are the initial and final time considered in the integration using the backward differential formula. The time interval, $t_f - t_i$, must be provided as one of input values prior to simulation. This quantity is specified during the time when the simulation work file is generated.

### 4.3 Interpolation of Data

Lagrangian and spline interpolation techniques are used in the MODSIM program. Interpolation of data points for the time dependent boundary variables is made by using the 3rd order Lagrangian interpolation:

$$x(t) = \sum_{i=0}^{4} \left[ \prod_{\substack{j=1 \\ i \neq j}}^{4} \left( \frac{t - t_j}{t_i - t_j} \right) \right] x_i \tag{4.17}$$

where x(t) is the interpolated state variable at time t, and $x_i = x(t_i)$.

For interpolating the hourly weather data, the computer program of the cubic spline interpolation by Ferziger [21] was implemented in MODSIM. The interpolation formula is

$$x(t) = \frac{x(t_i)\,(t_{i+1} - t)}{6} \left[ \frac{(t_{i+1} - t)^2}{h_i} - h_i \right] + \frac{x(t_{i+1})\,(t - t_i)}{6} \left[ \frac{(t - t_i)^2}{h_i} - h_i \right]$$

$$+ \frac{y_i(t_{i+1} - t)}{h_i} + \frac{y_{i+1}(t - t_i)}{h_i}, \quad t_i \_ t \_ t_{i+1} \tag{4.18}$$

where $y_i = x(t_i)$ for $i=1, 2,\ldots,n$, and $h_i = t_{i+1} - t_i$. The second derivatives $x''(t_i)$ and $x''(t_{i+1})$ for $i=2, 3,\ldots, n-1$ are found using the following set of equations for the second derivatives of $x(t)$ at nodes

$$h_{i-1}x''(t_{i-1}) + 2(h_{i-1} + h_i)\, x''(t_i) + h_i x''(t_{i+1}) \tag{4.19}$$

$$= 6\left[\frac{y_{i+1} - y_i}{h_i} - \frac{y_i - y_{i-1}}{h_{i-1}}\right] \quad , \ i=2, 3,\ldots,n-1$$

The coefficients of these sets of equations from a tridiagonal matrix, and the system can be solved for $x''(t_i)$, $i=2,3,\ldots,n-1$ by using the Gaussian elimination method.

Two additional equations are determined from the end conditions. Ferziger's code uses the cantilever condition where

$$x''(t_1) = \lambda x''(t_2) \text{ and } x''(t_n) = \lambda x''(t_{n-1}), \tag{4.20}$$

and $\lambda \varepsilon [0,1]$.

In the MODSIM, 24 points of each component weather data (temperature, pressure, etc.) are read once each day, and the second derivatives of the variable are calculated using the set of equations as shown in equation (4.19). At a given time during the day, the interpolated value is evaluated using equation (4.20) with $\lambda = 1$.

## 5. BUILDING LOADS CALCULATION

In HVACSIM$^+$, a building shell model and a building zone model are used for building thermal loads determination. These models were developed based on Kusuda [22] and Walton [9]. Previously the building shell model contained the zone model [6]. In this report, these models are distinguished. The building shell model utilizes a user-selected fixed time interval, while the zone model uses variable time intervals.

Models for building loads calculation include the effects of different kinds of building shell materials, air temperatures, the moisture content of the air, lighting, equipment, occupancy schedule, solar radiation, wind velocity, orientations of the exterior building surfaces, and the effect of shadowing. Since there are so many factors involved, some simplifying assumptions had to be made. The major assumptions in the current HVACSIM$^+$ program include:

(1) Uniform temperature distributions on a building surface (one dimensional heat transfer across a wall)

(2) Uniform ground temperature distribution

(3) No effects of wind direction, rain, and snow

The approach taken uses the standard response factor method to calculate the conductive heat transfer rates through the building shell. The conduction transfer functions are computed once and stored prior to a simulation. The same time interval used in the calculation of conduction transfer functions of building constructs is applied as the period during which the conductive heat fluxes through the building surfaces are assumed to be invariant.

Primary routines for the building load determination are those dealing with the calculation of building surface temperatures and zone loads. Walls and zones are treated as component models, and are coded as TYPEn subroutines. Because of the use of the fixed time step, the units representing building surfaces must be in a superblock which is separate from those containing units which use a variable time step.

The zone model calculates indoor air dry-bulb temperature and humidity ratio on a variable time step basis and takes into account the dynamic operation of the HVAC system and its controls, and thermal loads.

The building shell model contains three TYPE subroutines (TYPE50, TYPE51, and TYPE53), and the building zone model is designated as TYPE52. In the following sections, details of these TYPE subroutines are described.

## 5.1 TYPE50: ZONE ENVELOPE

### General Description

This subroutine combines information generated by the TYPE51 building surface model. Convective heat gain from building surfaces and mean radiant temperature are computed. Since this routine is a part of the building shell model, it must be in a superblock which takes a user-selected, fixed time step.

### Nomenclature

| | |
|---|---|
| $A_{s,j}$ | area of the j-th building wall surface ($m^2$) |
| $h_{is,c,j}$ | convective heat transfer coefficient of the j-th building inner surface ($W/m^2K$) |
| $h_{is,r,j}$ | radiative heat transfer coefficient of the j-th building inner surface ($W/m^2K$) |
| $I_{sol,j}$ | total solar radiation influx ($W/m^2$) |
| $N_s$ | number of wall surfaces in a zone (-) |
| $\dot{q}_{sl,r}$ | short wave radiant heat flux from the sun and the lights ($W/m^2$) |
| $\dot{Q}_{sw,r}$ | short wave (visible) radiant heat gain from lights (W) |
| $\dot{Q}_{lw,r}$ | long wave (infrared) radiant heat gain from people and equipment (W) |
| $\dot{Q}_{wall}$ | convective heat flow rate from building surfaces in a zone (W) |
| $T_i$ | zone air dry-bulb temperature (C) |
| $T_{is,j}$ | surface temperature of the j-th inner wall (C) |

| | |
|---|---|
| $T_{mr}$ | zone mean radiant temperature (C) |
| $S_{c,j}$ | shading coefficient of the j-th building wall (-) |
| $\alpha_{is,j}$ | short wave absorptance of the j-th inner wall (-) |
| $\tau_{s,j}$ | transmittance of the j-th wall (-) |

Mathematical Description

Short wave radiant heat fluxes from the sun and the lights in a zone are evaluated by using the following expressions:

$$\dot{q}_{sl,r} = \frac{\sum_{j=1}^{N_s} A_{s,j}\,\tau_{s,j}\,S_{c,j}\,I_{sol,j} + \dot{Q}_{sw,r}}{\sum_{j=1}^{N_s} A_{s,j}\,(\alpha_{is,j} + \tau_{s,j})} \qquad (5.1)$$

Convective heat flow rate across the air film between the zone air and interior surface of the building shell is given by

$$\dot{Q}_{wall} = \sum_{j=1}^{N_s} h_{is,c,j} A_{s,j} (T_{is,j} - T_i) \qquad (5.2)$$

The expression of mean radiation temperature is obtained from

$$T_{mr} = \frac{\sum_{j=1}^{N_s} h_{is,r,j} A_{s,j} T_{is,j} + \dot{Q}_{lw,r}}{\sum_{j=1}^{N_s} h_{is,r,j} A_{s,j}} \qquad (5.3)$$

Configuration

| Inputs | | Description |
|---|---|---|
| 1 | $T_i$ | zone air dry-bulb temperature (C) |
| 2 | $\dot{Q}_{sw,r}$ | short wave radiant heat gain from lights (kW) |
| 3 | $\dot{Q}_{lw,r}$ | long wave radiant heat gain from people and equipment (kW) |
| 4 | $T_{is,1}$ | surface temperature of the 1st inner wall (C) |
| 5 | $T_{is,2}$ | surface temperature of the 2nd inner wall (C) |
| 6 | $T_{is,3}$ | surface temperature of the 3rd inner wall (C) |
| 7 | $T_{is,4}$ | surface temperature of the 4th inner wall (C) |
| 8 | $T_{is,5}$ | surface temperature of the 5th inner wall (C) |
| 9 | $T_{is,6}$ | surface temperature of the 6th inner wall (C) |
| 10 | $T_{is,7}$ | surface temperature of the 7th inner wall (C) |
| 11 | $T_{is,8}$ | surface temperature of the 8th inner wall (C) |
| 12 | $T_{is,9}$ | surface temperature of the 9th inner wall (C) |
| 13 | $T_{is,10}$ | surface temperature of the 10th inner wall (C) |

| Outputs | | Description |
|---|---|---|
| 1 | $T_{mr}$ | mean radiant temperature (C) |
| 2 | $\dot{Q}_{wall}$ | convective heat gain from building surfaces (kW) |

| Parameters | | Description |
|---|---|---|
| 1 | IZN | identification number of zone (-), $1 \leq IZN \leq MAXZN$ |
| 2 | $N_s$ | number of building surfaces in a zone (-), $1 \leq N_s \leq MAXNS$ |

Note that variables which are not identified as inputs, outputs, or parameters, but used in the TYPE50 subroutine, appear in COMMON blocks. It should be noted that the unit for heat flow rates is kW for inputs and outputs, although the unit of W is used in the mathematical description.

In the current version of HVACSIM$^{+}$, MAXZN = 6, and MAXNS = 10.

## 5.2 TYPE51: BUILDING SURFACE

### General Description

This subroutine computes outer and inner surface temperatures of a building surface construct, and determines average solar flux on the outer surface. Because this TYPE51 subroutine is a part of the building shell model, it must be in a superblock which takes a user-selected, fixed time interval.

### Nomenclature

| | |
|---|---|
| $f_{sg}$ | angle factor between ground and surface (-) |
| $f_{ss}$ | angle factor between sky and surface (-) |
| $g_r$ | ground reflectivity (-) |
| $h_{is,c,j}$ | convective heat transfer coefficient of the j-th building inner surface ($W/m^2K$) |
| $h_{is,r,j}$ | radiative heat transfer coefficient of the j-th building inner surface ($W/m^2K$) |
| $h_{os,j}$ | convective plus radiative heat transfer coefficient of the j-th building outer surface ($W/m^2K$) |
| $I_b$ | direct normal solar beam radiation ($W/m^2$) |
| $I_g$ | ground reflective radiation ($W/m^2$) |
| $I_h$ | total horizontal solar radiation ($W/m^2$) |
| $I_{sol,j}$ | average solar radiation influx on the j-th surface ($W/m^2$) |
| $I_s$ | diffuse (sky) solar radiation ($W/m^2$) |
| $N_f$ | order of conduction transfer function calculation (-) |
| $N_t$ | number of conduction transfer function terms (-) |
| $\dot{q}_{i,j,n}$ | current conductive heat flux at the inner surface ($W/m^2$) |

$\dot{q}_{o,j,n}$ current conductive heat flux at the outer surface ($W/m^2$)

$q'_{i,j}$ conductive heat flux at the inside of the j-th surface at the present time due to past temperature history

$q'_{o,j}$ conductive heat flux at the outside of the j-th surface at the present time ($W/m^2$)

$\dot{q}_{sl,r}$ short wave radiation heat flux from the sun and lights ($W/m^2$)

$\dot{q}_{sol,o,j}$ solar heat flux on the outside surface of the j-th construct ($W/m^2$)

$R_{k,j}$ flux term related to overall conductance (-)

$S_d$ fraction of shadowed area to total exposed surface area (-)

$T_i$ zone air dry-bulb temperature (C)

$T_{is,j}$ inside surface temperature of the j-th construct (C)

$T_{mr}$ mean radiant temperature (C)

$T_o$ outside air dry-bulb temperature (C)

$T_{os,j}$ outside surface temperature of the j-th construct (C)

$U_j$ overall conductance ($W/m^2K$)

$V_w$ wind speed (m/s)

$X_{m,j}$ X-component of conduction transfer function at the m time steps ago ($W/m^2K$)

$Y_{m,j}$ Y-component of conduction transfer function at the m time steps ago ($W/m^2K$)

$Z_{m,j}$ Z-component of conduction transfer function at the m time steps ago ($W/m^2K$)

$X_{o,j}$ X-component of conduction transfer function at the present time ($W/m^2K$)

$Y_{o,j}$ Y-component of conduction transfer function at the present time ($W/m^2K$)

$Z_{o,j}$ Z-component of conduction transfer function at the present time ($W/m^2K$)

$\alpha_{is,j}$ radiation absorptance of the j-th inner surface (-)

$\alpha_{os,j}$ radiation absorptance of the j-th outer surface (-)

$\beta$ solar altitude angle (degrees)

$\gamma$ tilt angle (degrees)

$\theta$ solar beam incident angle (degrees)

$\xi$ surface azimuth angle (degrees)

$\phi$ solar azimuth angle from south (degrees)

## Mathematical Description

Conductive heat flow through a multilayered construct has been solved successfully by the response factor method, in which the surface temperature of each homogeneous layer is represented by a series of pulse functions. Based on the response factor method, conduction transfer functions are calculated for a multilayered wall. A heat balance at the j-th interior surface is used to determine the interior surface temperature by [9]:

$$T_{is,j} = \frac{h_{is,c,j}T_i + h_{is,r,j}T_{mr} + \alpha_{is,j}\,\dot{q}_{sl,r} + \dot{q}'_{i,j} + Y_{o,j}T_{os,j}}{h_{is,c,j} + h_{is,r,j} + Z_{o,j}} \tag{5.4}$$

The current conductive heat flux at the inner surface is

$$\dot{q}_{i,j,n} = Y_{o,j}\,T_{os,j} - Z_{o,j}\,T_{is,j} + \dot{q}'_{i,j} \tag{5.5}$$

where

$$\dot{q}'_{i,j} = \sum_{m=1}^{N_t} Y_{m,j}\, T_{os,j,n-m} - \sum_{m=1}^{N_t} Z_{m,j}\, T_{is,j,n-m}, + \sum_{k=1}^{N_f} R_{k,j}\, \dot{q}_{i,j,n-k} \tag{5.6}$$

In the equations above, the subscript n is the current time, while m denotes the past time. Note that the time interval is fixed. The flux, $R_{k,j}$, is related to the overall conductance, $U_j$, as

$$U_j(1- \sum_{k=1}^{N_f} R_{k,j}) = \sum_{m=0}^{N_t} X_{m,j} = \sum_{m=0}^{N_t} Y_{m,j} = \sum_{m=o}^{N_t} Z_{m,j} \tag{5.7}$$

The values of $R_{k,j}$ and $U_j$ as well as $X_{m,j}$, $Y_{m,j}$ and $Z_{m,j}$ are computed by the CTFGEN program.

On the outside surface, which is exposed to sunlight (IEXPOS=2), the outer surface temperature can be computed by:

$$T_{os,j} = \frac{h_{os,j}\, T_o + \dot{q}_{sol,o,j} + \dot{q}'_{o,j} + f_{1,j}\, f_{2,j}}{h_{os,j} + X_{o,j} - f_{1,j}\, Y_{o,j}} \tag{5.8}$$

where

$$f_{1,j} = \frac{Y_{o,j}}{h_{is,c,j} + h_{is,r,j} + Z_{o,j}}$$

$$f_{2,j} = h_{is,c,j}T_i + h_{is,r,j}T_{mr} + \alpha_{is,j}\, \dot{q}_{sl,r} + \dot{q}'_{i,j}$$

$$\dot{q}_{sol,o,j} = \alpha_{os,j}\, I_{sol,j} \tag{5.9}$$

The current conductive heat flux at the outer surface is

$$\dot{q}_{o,j,n} = Y_{o,j} \; T_{is,j} - X_{o,j} \; T_{os,j} + \dot{q}'_{o,j} \tag{5.10}$$

where

$$\dot{q}'_{o,j} = \sum_{m=1}^{N_t} Y_{m,j} \; T_{is,j,n-m} - \sum_{m=1}^{N_t} X_{m,j} \; T_{os,j,n-m}, + \sum_{k=1}^{N_f} R_{k,j} \; \dot{q}_{o,j,n-k} \tag{5.11}$$

When the outside surface is exposed to another zone or to ground (IEXPOS=1), the outside surface temperature is equal to the inside surface temperature in another zone for the same construct or to the ground temperature ($T_{os,j}$ = $T_{osinf,j}$).

If a massive wall, which represents thermal mass, is within a zone (IEXPOS=0), both the inside and the outside surface temperatures are considered to be equal. The following expression can be used.

$$T_{is,j} = T_{os,j} = \frac{h_{is,c,j}T_i + h_{is,r,j}T_{mr} + \dot{q}_{sl,r} + \dot{q}'_{i,j}}{h_{is,c,j} + h_{is,r,j} + Z_{o,j} - Y_{o,j}} \tag{5.12}$$

Solar fluxes on the interior and exterior surfaces are evaluated based on either solar data from a weather tape or computation. When a surface has a surface azimuth angle, $\xi$, which is the angle from the south to the projection of normal to the surface onto the horizontal plane in clockwise direction, and a tilt angle, $\tau$, which is the angle between the normal to the surface and the normal to the horizontal plane, the cosine of incident angle of the sun's rays is expressed by

$$\cos\theta = \cos\beta \cos(\phi - \xi) \sin\gamma + \sin\beta \cos\gamma \tag{5.13}$$

where $\theta$, $\phi$, and $\beta$ are the incident angle, the solar azimuth angle from the south, and the solar altitude angle, respectively.

Defining the angle factor between ground and surface, $f_{sg}$, and that between sky and surface, $f_{ss}$, as

$$f_{sg} = 0.5\ (1 - \cos\gamma) \tag{5.14}$$

$$f_{ss} = 0.5\ (1 + \cos\gamma) \tag{5.15}$$

the average solar radiation influx, $I_{sol}$, on the j-th surface is given by

$$I_{sol,j} = I_b\ (1 - S_d) \cos\theta + I_s\ f_{ss} + I_g\ f_{sg} \tag{5.16}$$

where $I_b$, $I_s$, and $I_g$ are direct, diffusive, and ground reflective radiation. $S_d$ is the shaded fraction of exposed outer surface.

The ground reflective radiation is dependent on ground reflection, $g_r$, and total solar radiation on a horizontal surface, $I_h$.

$$I_g = g_r\ I_h \tag{5.17}$$

Configuration

| Inputs | Description |
|---|---|
| 1 $T_i$ | zone air dry-bulb temperature (C) |
| 2 $T_{mr}$ | mean radiant temperature (C) |
| 3 $T_{osinf,j}$ | outer surface temperature of unexposed surface (C) |

| | | |
|---|---|---|
| 4 | $S_d$ | shaded fraction of exposed outer surface (-), $0 \le S_d \le 1$ |

| Outputs | | Description |
|---|---|---|
| 1 | $T_{is,j}$ | inner surface temperature (C) |
| 2 | $I_{sol,j}$ | average solar radiation influx on the outer surface ($W/m^2$) |

| Parameters | | Descriptions |
|---|---|---|
| 1 | IZN | identification number of zone (-), $1 \le IZN \le MAXZN$ |
| 2 | j | identification number of surface (-), $1 \le j \le MAXNS$ |
| 3 | IEXPOS | 0 if the wall construct is inside the zone<br>1 if the wall construct is between zones or exposed to ground<br>2 if the wall construct is exposed to sunlight |
| 4 | ISTR | identification number of construct (-), $1 \le ISTR \le MAXSTR$ |
| 5 | $A_{s,j}$ | surface area ($m^2$) |
| 6 | $\xi$ | surface azimuth angle, measured from south to the projection of normal to the surface onto the horizontal plane in clockwise direction (degrees), $0 \le \xi \le 360$ |
| 7 | $\gamma$ | tilt angle of the surface, measured from the normal to the surface to the normal to the horizontal plane (degrees), $0 \le \gamma \le 180$<br>$\gamma = 0$ for flat roof<br>$\gamma = 180$ for floor |
| 8 | $g_r$ | ground reflectivity (-), $0 \le g_r \le 1$ |
| 9 | IROFS | outside surface roughness index (-), $1 \le IROFS \le 6$<br>1 --- stucco |

2 --- brick, rough plaster

3 --- concrete

4 --- clear pine

5 --- smooth plaster

6 --- glass, paint or pine

| | | |
|---|---|---|
| 10 | $\alpha_{os,j}$ | solar absorptance of the outer surface (-), $0 \le \alpha_{os,j} \le 1$ |
| 11 | $\alpha_{is,j}$ | short wave absorptance of the inner surface (-), $0 \le \alpha_{is,j} \le 1$ |
| 12 | $\varepsilon_j$ | emissivity of the inner surface (-), $0 \le \varepsilon_j \le 1$ |
| 13 | $\tau_{s,j}$ | transmittance of the glass window (-), $0 \le \tau_{s,j} \le 1$<br>$\tau_{s,j} = 0$ for opaque wall |
| 14 | $S_c$ | shading coefficient of glass window (-), $0 \le S_c \le 1$<br>$S_c = 0$ for opaque wall |

Note that variables which are not identified as inputs, outputs, or parameters, but are used in the TYPE51 subroutine, appear in COMMON blocks.

In the current version of HVACSIM$^+$, MAXZN = 6, MAXNS = 10, and MAXSTR = 10.

## 5.3 TYPE52: ZONE MODEL

### General Description

In this TYPE52 subroutine, zone air temperature and humidity ratio are computed based on zone loads. Most of the zone loads except convective heat gain from building surfaces are internally determined in this subroutine. In fact, this zone model belongs to the building shell model. However, the zone model must be treated differently when the model definition file is created by HVACGEN because the zone model uses variable time steps.

### Nomenclature

| | |
|---|---|
| $C_{air}$ | thermal capacitance of air (kJ/K) |
| $C_{fur}$ | effective thermal capacitance of furnishing (kJ/K) |
| $C_{p,i}$ | specific heat of zone air (kJ/kgK) |
| $C_{p,o}$ | specific heat of outdoor air (kJ/kgK) |
| $C_{p,s}$ | specific heat of supply air (kJ/kgK) |
| $e_m$ | air mass multiplier for moisture capacitance of zone (-) |
| $f_c$ | ratio of convective heat to total sensible heat from lights (-) |
| $f_{lw}$ | ratio of long wave radiative heat to total sensible heat from lights (-) |
| $f_{sw}$ | ratio of short wave radiative heat to total sensible heat from lights (-) |
| $h_{fg}$ | latent heat of vaporization of water (kJ/kg) |
| $I_{air}$ | air exchange rate (1/h) |
| $\dot{m}_{infl}$ | mass flow rate due to infiltration (kg/s) |

| | |
|---|---|
| $\dot{m}_s$ | mass flow rate of supply air (kg/s) |
| $N_p$ | number of people in the zone (-) |
| $\dot{Q}_{equip,c}$ | convective heat gain from equipment (kW) |
| $\dot{Q}_{equip,lat}$ | latent heat gain from equipment (kW) |
| $\dot{Q}_{equip,r}$ | radiant heat gain from equipment (kW) |
| $\dot{Q}_{infl}$ | sensible heat gain or loss due to infiltration (kW) |
| $\dot{Q}_{light,c}$ | convective heat gain from lighting (kW) |
| $\dot{Q}_{light,r,w}$ | long wave radiative heat gain from lighting (kW) |
| $\dot{Q}_{lw,r}$ | long wave radiative heat gain in the zone (kW) |
| $\dot{Q}_{people,c}$ | convective heat gain from people (kW) |
| $\dot{Q}_{people,lat}$ | latent heat gain from people (kW) |
| $\dot{Q}_{people,r}$ | radiative heat gain from people (kW) |
| $\dot{Q}_s$ | sensible heat gain by supply air (kW) |
| $\dot{Q}_{sw,r}$ | short wave radiative heat gain (kW) |
| $\dot{Q}_{wall}$ | convective heat gain from building zone surfaces (kW) |
| $r_e$ | ratio of radiative heat to total sensible heat from equipment (-) |
| $r_p$ | ratio of radiative heat to total sensible heat from people (-) |
| $T_i$ | zone air dry-bulb temperature (C) |
| $T_o$ | outdoor air dry-bulb temperature (C) |
| $T_s$ | supply air dry-bulb temperature (C) |
| $U_e$ | equipment utilization coefficient (-) |
| $U_{light}$ | lighting utilization coefficient (-) |
| $V_i$ | volume of zone air (interior space of zone) ($m^3$) |

| | |
|---|---|
| $W_{e,lat}$ | latent heat gain from equipment (kW) |
| $W_{e,s}$ | sensible heat gain from equipment (kW) |
| $W_i$ | humidity ratio of zone air (-) |
| $W_{light}$ | sensible heat gain from lights (kW) |
| $W_o$ | humidity ratio of outside air (-) |
| $W_{p,lat}$ | latent heat gain from a person (kW) |
| $W_{p,s}$ | sensible heat gain from a person (kW) |
| $W_s$ | humidity ratio of supply air (-) |
| $\rho_i$ | density of zone air (kg/m$^3$) |
| $\rho_{infl}$ | density of infiltrated air (kg/m$^3$) |

Mathematical Description

Convective heat gains from people occupying the zone, from equipment such as typewriters, computers, coffee pots, copying machine, etc. and from lights are:

$$\dot{Q}_{people,c} = (1 - r_p) N_p W_{p,s} \tag{5.18}$$

$$\dot{Q}_{equip,c} = (1 - r_e)\, U_e W_{e,s} \tag{5.19}$$

$$\dot{Q}_{light,c} = f_c U_{light} W_{light} \tag{5.20}$$

Latent heat gains from people and equipment are also considered, while moisture absorptance and desorption by the building structure and interior furnishings are not explicitly included in the building zone model.

$$\dot{Q}_{people,lat} = N_p W_{p,lat} \tag{5.21}$$

$$\dot{Q}_{equip,lat} = U_e\, W_{e,lat} \tag{5.22}$$

Long wave radiant heat gains from people, equipment, and lights, along with the radiative heat from building surfaces are used to obtain mean radiant temperature of the zone. The use of mean radiant temperature is much simpler than using detailed radiant heat-exchange between walls. Short wave radiation due to lights and the sun are not directly involved in the computation of the mean radiation temperature.

Long wave radiative heat gains from people, equipment, and lights, are

$$\dot{Q}_{people,r} = r_p N_p W_{p,s} \tag{5.23}$$

$$\dot{Q}_{equip,r} = r_e U_e W_{e,s} \tag{5.24}$$

$$\dot{Q}_{light,r,lw} = f_{lw}\, U_{light}\, W_{light} \tag{5.25}$$

Total long wave radiative heat gains are expressed as the sum of the above equations:

$$\dot{Q}_{lw,r} = \dot{Q}_{people,r} + \dot{Q}_{equip,r} + \dot{Q}_{light,r,lw} \tag{5.26}$$

Short wave radiant heat gain from lighting is

$$\dot{Q}_{sw,r} = f_{sw} U_{light} W_{light} \tag{5.27}$$

Sensible heat gain or loss due to infiltration is given by

$$\dot{Q}_{infl} = \rho_{infl}\, V_i\, I_{air}\, (C_{p,o}\, T_o - C_{p,i}\, T_i) \tag{5.28}$$

The zone air temperature is obtained using

$$(C_{fur} + C_{air}) \frac{dT_i}{dt} = \dot{Q}_s + \dot{Q}_{infl} + \dot{Q}_{wall} + \dot{Q}_{light,c} + \dot{Q}_{people,c} + \dot{Q}_{equip,c} \tag{5.29}$$

Heat flow rate from building surfaces is computed by the shell model (TYPE50 and TYPE51).

The heat gain by supply air is expressed as

$$\dot{Q}_s = C_{p,s}\, \dot{m}_s\, (T_s - T_i) \tag{5.30}$$

Zone air humidity is calculated from the zone air moisture balance equation. In terms of humidity ratio, W, the moisture content of zone air is expressed.

$$\rho_i\, V_i\, e_m \frac{dW_i}{dt} = (\dot{Q}_{people,lat} + \dot{Q}_{equip,lat})/h_{fg} + \dot{m}_{infl}\,(W_o - W_i) + \dot{m}_s\,(W_s - W_i) \tag{5.31}$$

where $h_{fg}$ is latent heat of vaporization of water, which can be obtained from the fluid property library, and $e_m$ is an air mass multiplier for moisture capacitance of zone. Outdoor humidity ratio, $W_o$, comes from weather data.

Configuration

| Inputs | Description |
|---|---|
| 1 $P_{i,g}$ | gauge pressure of zone air (kPa) |
| 2 $T_i$ | zone air dry-bulb temperature (C) |
| 3 $W_i$ | humidity ratio of zone air (-) |
| 4 $P_{s,g}$ | gauge pressure of supply air (kPa) |
| 5 $\dot{m}_s$ | mass flow rate of supply air (kg/s) |

| | |
|---|---|
| 6 $T_s$ | supply air dry-bulb temperature (C) |
| 7 $W_s$ | humidity ratio of supply air (-) |
| 8 $\dot{Q}_{wall}$ | convective heat flow rate from building surfaces (kW) |
| 9 $N_p$ | number of persons in the zone (-) |
| 10 $U_e$ | equipment utilization coefficient (-), $0 \le U_e \le 1$ |
| 11 $U_{light}$ | lighting utilization coefficient (-), $0 \le U_{light} \le 1$ |

| <u>Outputs</u> | <u>Description</u> |
|---|---|
| 1 $T_i$ | zone air dry-bulb temperature (C) |
| 2 $W_i$ | humidity ratio of zone air (C) |
| 3 $\dot{Q}_{sw,r}$ | short wave (visible) radiant internal gain from lights (kW) |
| 4 $\dot{Q}_{lw,r}$ | long wave (thermal) radiant internal gain from people, equipment, and lights (kW) |

| <u>Parameters</u> | <u>Descriptions</u> |
|---|---|
| 1 IZN | identification number of zone (-), $1 \le IZN \le MAXZN$ |
| 2 $C_{fur}$ | effective thermal capacitance of furnishing (kJ/K) |
| 3 $e_m$ | air mass multiplier for moisture capacitance of zone (-) |
| 4 $V_i$ | volume of zone air (interior space of zone) ($m^3$) |
| 5 $I_{s,air}$ | standard air exchange rate (1/h) |
| 6 $W_{p,s}$ | sensible heat gain from a person (kW) |
| 7 $W_{p,lat}$ | latent heat gain from a person (kW) |
| 8 Wlight | heat gain due to lighting in the zone (kW) |
| 9 LIGHT | type of lighting |

1 for fluorescent lights

2 for incandescent lights

10 $W_{e,s}$ sensible heat gain due to equipment (kW)

11 $W_{e,lat}$ latent heat gain due to equipment (kW)

12 $r_e$ ratio of radiative heat to total sensible heat from equipment (-), $0 \le r_e \le 1$

Note that the following constant values are assigned in the DATA statement in the TYPE 52 subroutine:

$r_p = 0.7$

for fluorescent lights, $f_c = 0.6$, $f_{lw} = 0.2$, and $f_{sw} = 0.2$

for incandescent lights, $f_c = 0.1$, $f_{lw} = 0.8$, and $f_{sw} = 0.1$

## 5.4 TYPE53: WEATHER INPUT

### General Description

This TYPE53 subroutine places weather data read by the RDENV subroutine into the state vector. The inputs are really just for mnemonic purposes. The parameters are the indices of the variables. Input indices should always equal parameter values. This routine does nothing when the building shell model is not used, and is optional when the building shell model is used. One unit per simulation is sufficient, and it is recommended that the unit using the TYPE53 subroutine should be placed in the same superblock where the building shell portion is modeled (TYPE50 and TYPE51).

### Configuration

| Inputs | Description |
|---|---|
| 1 $T_o$ | outdoor air temperature (C) |
| 2 $W_o$ | outdoor air humidity ratio (-) |
| 3 $P_o$ | barometric pressure (kPa) |
| 4 $I_b$ | direct normal solar beam radiation ($W/m^2$) |
| 5 $I_s$ | diffuse (sky) solar radiation ($W/m^2$) |
| 6 $I_h$ | total horizontal solar radiation ($W/m^2$) |

| Outputs | Description |
|---|---|
| none | |

| Parameters | Description |
|---|---|
| 1 NTOA | index for $T_o$ |
| 2 NWOA | index for $W_o$ |
| 3 NPOA | index for $P_o$ |
| 4 NDN | index for $I_b$ |
| 5 NSKY | index for $I_s$ |
| 6 NHOR | index for $I_h$ |

## 6. UTILITY ROUTINES FOR BUILDING LOADS CALCULATION

The TYPE subroutines for building loads determination require routines for property of moist air, heat transfer coefficients, view factors, and air exchange rate. In addition, the building shell model needs weather data and conduction transfer functions of building constructs as mentioned previously (see Figure 1).

### 6.1 Properties of Moist Air

When humidity ratio of moist air, $W_i$ is given, the specific heat of air, $C_p$, can be obtained from [23]

$$C_p = 1 + 1.805\ W\ (kJ/kgK) \tag{6.1}$$

The density of moist air, $\rho$, can be computed by

$$\rho = \rho_{dry}\ (1+W) = \left[\frac{P - P_w}{R_a (T+273)}\right] (1+W) \qquad (kg/m^3) \tag{6.2}$$

where W is humidity ratio, $R_a$ is the gas constant for dry air (=0.287055 kJ/kgK), P is atmospheric pressure, and $P_w$ is the vapor pressure which is given by

$$P_w = \frac{WP}{W + 0.62198} \quad (kPa) \tag{6.3}$$

Humidity ratio at saturation state can be determined from

$$W_{sat} = \frac{0.62198}{P - P_{sw}}\ Psw \qquad (-) \tag{6.4}$$

where $P_{sw}$ is saturated vapor pressure (kPa) and can be computed by [24]

$$P_{sw} = 3.376 \ \mathrm{EXP}\left[15.463 - \frac{7284}{1.8T + 424}\right] \ \text{(kPa)} \tag{6.5}$$

The function CP contains the expressions for moist air.

## 6.2 Air Exchange Rate

The air exchange rate is calculated using wind speed, and the dry-bulb temperature difference between indoor and outdoor air [25].

$$I_{air} = I_{s,air} \ [0.15 + (0.013)(2.2369) \ V_w + (0.005)(1.8) \ |T_o - T_i|]/0.695 \tag{6.6}$$

where $I_{s,air}$ and $V_w$ are standard air exchange rate (1/h), and wind speed (m/s) respectively. Standard air exchange can be chosen one of the following values:

Living space - 1.5 for leaky building
1.0 for standard building
0.5 for moderately tight building
Attic space - 20.0 for mechanical ventilation
6.0 for natural ventilation
Crawl space - 3.0

The air exchange rate expression is in the CP function.

## 6.3 MRT View Factors

Radiation exchange between zone surfaces is obtained by using the mean radiant temperature network (MRTN) method introduced by Carroll [26]. Surfaces interact with a mean radiant temperature instead of directly with each other.

Because of it, the number of interactions is reduced from $n^2$ to n. The MRT network method includes a factor called 'MRT view factor' which is expressed by

$$F_j = \frac{1}{1 - \dfrac{A_{s,j}\ F_j}{\sum_{k=1}^{N_s} A_{s,k}F_k}} \quad , \ j=1,2,\ldots,N_s \tag{6.7}$$

where $A_{s,j}$ is the j-th surface area ($m^2$), and $N_s$ is the number of surfaces in the zone. This equation is solved iteratively. Maximum number of iterations is assigned to be 100 in DATA statement of the VIEW subroutine. The subroutine VIEW was written to compute the view factors based on the TARP package. The VIEW subroutine is called at the beginning of simulation, and the calculated view factors are stored for succeeding computations.

## 6.4 Heat Transfer Coefficients

The convective heat transfer coefficient of the j-th inner surface is obtained from one of the following expressions [9]:

$$h_{is,c,j} = \frac{9.482\ |\ T_i - T_{is,j}\ |^{0.333}}{7.238 - |\ \cos\gamma\ |} \qquad \text{if } T_{is,j} \geq T_i \tag{6.8}$$

$$h_{is,c,j} = \frac{1.810\ |\ T_i - T_{is,j}\ |^{0.333}}{1.382 + |\ \cos\gamma\ |} \qquad \text{if } T_{is,j} \leq T_i \tag{6.9}$$

where $\gamma$ denotes the tilt angle of the surface from horizontal plane. The unit of heat transfer coefficients is watts/$m^2$K.

Using view factors of surfaces which enclose the zone (see equation (6.7)), the radiant heat transfer coefficients are computed. For the j-th surface, the coefficient is

$$h_{is,r,j} = \frac{4\sigma(T_{is,j} + 273)}{\frac{1}{F_j} + \frac{1-\varepsilon_j}{\varepsilon_j}} \qquad (6.10)$$

where $\sigma$ is Stephan-Boltzmann's constant (=5.670X10$^{-8}$watts/$m^2K^4$), $F_j$ the view factor, and $\varepsilon_j$ the emissivity.

The convective plus radiative heat transfer coefficient, $h_{os,j}$, is given in a simple expression as a function of wind speed, $V_w$(m/s).

$$h_{os,j} = a_o + a_1 V_w + a_2 V^2_w \qquad (6.11)$$

in which $a_o$, $a_1$, and $a_2$ are coefficients which can be determined by the surface roughness index. Walton provided the values of these coefficients with respect to roughness index in his TARP reference manual [9]. The wind speed is the reported value without modification for surface height or orientation.

| IROFS | $a_o$ | $a_1$ | $a_2$ |
|---|---|---|---|
| 1 | 11.58 | 5.894 | 0.0 |
| 2 | 12.49 | 4.065 | 0.028 |
| 3 | 10.79 | 4.192 | 0.0 |
| 4 | 8.23 | 4.000 | -0.057 |
| 5 | 10.22 | 3.100 | 0.0 |
| 6 | 8.23 | 3.330 | -0.036 |

The function HISCF contains expressions for heat transfer coefficients.

## 7. CONDUCTION TRANSFER FUNCTION CALCULATION

Conduction transfer functions of walls, floors, roofs, and windows are required by the TYPE51 subroutine for a building shell modeling. The subroutine also needs a term related to conductive heat fluxes on both external and internal surfaces of constructs. The CTFGEN program calculates the conduction transfer functions and the flux transfer functions. In this section, the overview of CTFGEN and the methodology employed in CTFGEN for computing conduction transfer functions will be described.

### 7.1 Overview of CTFGEN

The CTFGEN program consists of two portions: the front end and the main routines. In the front end portion, inputs and output operations are handled, and in the main routine, conduction transfer functions and flux transfer functions are determined. Thermal properties of building materials (thickness, thermal conductivity, density, specific heat, and thermal resistance) are stored in a sequential access data file (THERM.DAT). By using CTFGEN, thermal properties of additional building materials can be added in the data file. User selected building materials can be composed to form a multilayered building construct (sometimes called construction), after selecting necessary thermal property data from a temporary, direct access file, which contains the same information in the sequential access file.

The main calculation routine was originated from TARP, (slightly modified from BLAST) and its calculation procedure is as follows:

(1) Determine the upper and lower bounds for searching roots (poles) for residue calculation and determine the roots (SEARCH)

(2) Calculate derivative matrices and total construct matrices, and obtain residue elements for non-zero poles (DER, MATRIX)

(3) Calculate zero residue elements (ZERORE)

(4) Compute response factors and determine high order conduction transfer functions (RFCOMP)

(5) Check convergence. If not converged, reduce the increment for searching and go to step (1)

(6) Calculate flux transfer functions

Since a discussion of the calculation procedure involves a lengthy mathematical description, only important expressions will be reviewed in this report. Further detailed information may be found in references [27, 28].

## 7.2 Heat Conduction of a Multilayered Construct

Equation for heat conduction for a one-dimensional heat flow in a homogeneous layer of building material is given by

$$k \frac{\partial^2 T(x,t)}{\partial x^2} = \rho C_p \frac{\partial T(x,t)}{\partial t} \tag{7.1}$$

where $T(x,t)$ is the temperature $k$, $\rho$, and $C_p$ are thermal conductivity, density, and specific heat, respectively. The heat flux through the slab is

$$q(x,t) = -k \frac{\partial T(x,t)}{\partial x} \tag{7.2}$$

Assuming that k, $\rho$, and $C_p$ are constant and $T(x,0)=0$, and applying Laplace transform on the above equations, ordinary differential equations in terms of x and Laplace parameter s are obtained.

$$\frac{d^2T(x,s)}{dx^2} = \frac{s}{\alpha}\,T(x,s) \tag{7.3}$$

and

$$q(x,s) = -\,k\,\frac{dT(x,s)}{dx} \tag{7.4}$$

where $\alpha$ is thermal diffusivity defined by $k/\rho C_p$. Imposing boundary conditions on equations (7.3) and (7.4) such that

$T_1(s) = T(o,s)$, $T_2(s) = T(\ell,s)$, $q_1(s) = q(0,s)$, and $q_2(s) = q(\ell,s)$, where $\ell$ is the thickness of the construct, a matrix expression is obtained.

$$\begin{bmatrix} T_1(s) \\ q_1(s) \end{bmatrix} = \begin{bmatrix} A(s) & B(s) \\ C(s) & D(s) \end{bmatrix} \begin{bmatrix} T_2(s) \\ q_2(s) \end{bmatrix} \tag{7.5}$$

where $A(s) = \cosh\,(\ell\sqrt{\tfrac{s}{\alpha}})$

$$B(s) = \frac{1}{k}\sqrt{\frac{\alpha}{s}}\,\sinh\,(\ell\sqrt{\tfrac{s}{\alpha}})$$

$$C(s) = k\sqrt{\frac{s}{\alpha}}\,\sinh\,(\ell\sqrt{\tfrac{s}{\alpha}})$$

$$D(s) = \cosh\,(\ell\sqrt{\tfrac{s}{\alpha}})$$

Since a multilayered construct also has the same form of transfer matrix .

(transmission matrix) as the single-layered construct, the total construct matrix for n layers becomes

$$\begin{bmatrix} A(s) & B(s) \\ C(s) & D(s) \end{bmatrix} = \begin{bmatrix} A_1(s) & B_1(s) \\ C_1(s) & D_1(s) \end{bmatrix} \cdots \begin{bmatrix} A_n(s) & B_n(s) \\ C_n(s) & D_n(s) \end{bmatrix} \tag{7.6}$$

Equations (7.5) and (7.6) are coded in the subroutine MATRIX.

When the j-th layer of a multilayered construct has very low thermal capacitance, the transfer matrix of the j-th layer yields

$$\lim_{C_j \to o} \begin{bmatrix} A_j(s) & B_j(s) \\ C_j(s) & D_j(s) \end{bmatrix} = \begin{bmatrix} 1 & \frac{\ell_i}{k_j} \\ 0 & 1 \end{bmatrix} \tag{7.7}$$

Heat flux equations on the outer (j=1) and inner (j=n+1) surfaces of the multilayered construct can be expressed as

$$\begin{bmatrix} q_o(s) \\ q_i(s) \end{bmatrix} = \begin{bmatrix} \frac{D(s)}{B(s)} & -\frac{1}{B(s)} \\ \frac{1}{B(s)} & -\frac{A(s)}{B(s)} \end{bmatrix} \begin{bmatrix} T_o(s) \\ T_i(s) \end{bmatrix} \tag{7.8}$$

where $T_o(s) = T_1(s)$ and $T_i(s) = T_{n+1}(s)$.

With the sign convention for heat fluxes in the TARP program, the heat flux leaving the surface has a positive sense, as shown in Figure 6. Using this convention, equation (7.8) can be rewritten as

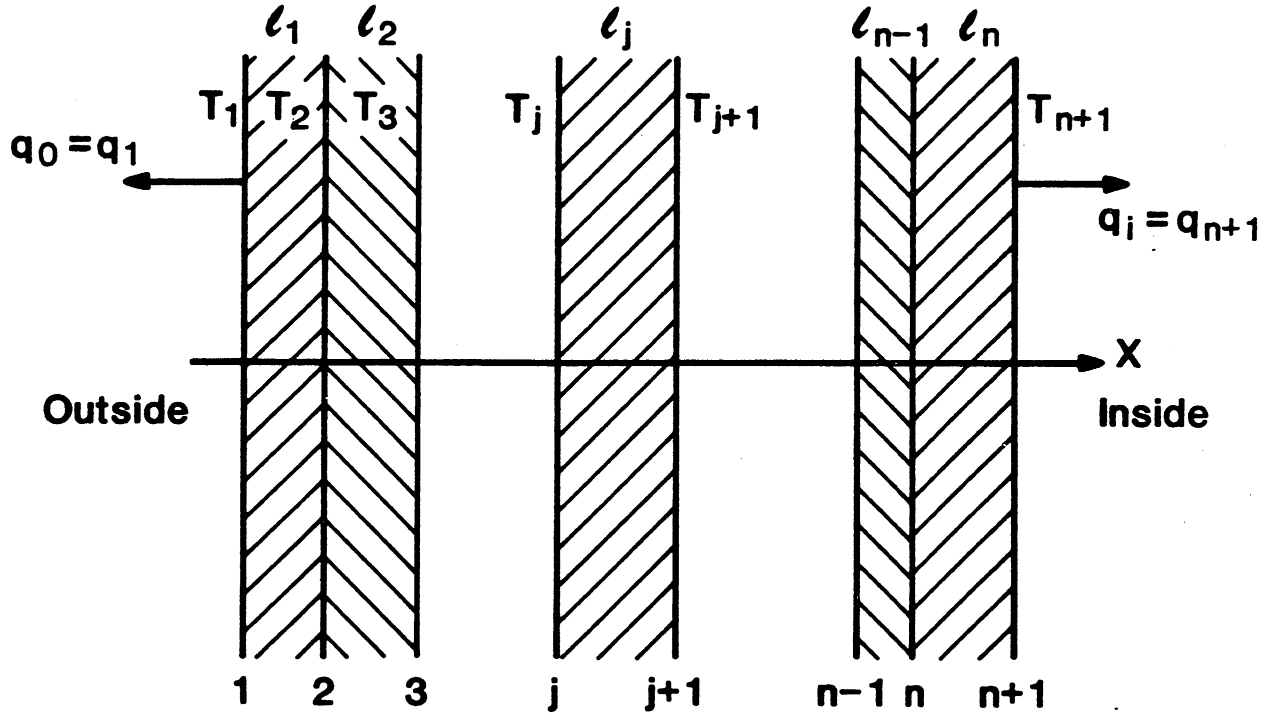


Figure 6. A multilayer construct

$$\begin{bmatrix} q_o(s) \\ \\ q_i(s) \end{bmatrix} = \begin{bmatrix} -\dfrac{D(s)}{B(s)} & \dfrac{1}{B(s)} \\ \\ \dfrac{1}{B(s)} & -\dfrac{A(s)}{B(s)} \end{bmatrix} \begin{bmatrix} T_o(s) \\ \\ T_i(s) \end{bmatrix} \tag{7.9}$$

Heat flux equations in the time domain can be obtained by applying the inversion theorem of the Laplace transform to equation (7.9).

## 7.3 Response Factors

Assuming that the boundary temperature functions, $T_i(t)$ and $T_o(t)$, can be represented by a series of pulse functions with a uniform time interval, equation (7.9) can be written as

$$\begin{bmatrix} q_o(s) \\ \\ q_i(s) \end{bmatrix} = P(s) \begin{bmatrix} -\dfrac{D(s)}{B(s)} & \dfrac{1}{B(s)} \\ \\ \dfrac{1}{B(s)} & -\dfrac{A(s)}{B(s)} \end{bmatrix} \begin{bmatrix} T_{o,t-m}(s) \\ \\ T_{i,t-m}(s) \end{bmatrix} \tag{7.10}$$

where $m=0,1,2,\ldots,\infty$, and $P(s)$ is a pulse function in Laplace transform. The subscript $t-m$ denotes the past time lagging $m\delta$ from the current time. The variable $\delta$ is sample time.

If the pulse function is represented by a triangular pulse with base of $2\delta$ and unit height, and if response factors are defined as follows:

$$\text{external response factor:} \quad \overline{X}_m = L^{-1}\left[P(s)\,\frac{D(s)}{B(s)}\right] \quad m=0,1,2\ldots \tag{7.11}$$

cross response factor: $\bar{Y}_m = L^{-1}\left[P(s)\,\frac{1}{B(s)}\right] m=0,1,2\ldots$ (7.12)

internal response factor: $\bar{Z}_m = L^{-1}\left[P(s)\,\frac{A(s)}{B(s)}\right] m=0,1,2\ldots$ (7.13)

then the heat fluxes can expressed in terms of response factors.

$$\begin{bmatrix} q_o(t) \\ \\ q_i(t) \end{bmatrix} = \sum_{m=0}^{\infty} \begin{bmatrix} -\bar{X}_m & \bar{Y}_m \\ \\ \bar{Y}_m & -\bar{Z}_m \end{bmatrix} \begin{bmatrix} T_{o,t-m}(t) \\ \\ T_{i,t-m}(t) \end{bmatrix} \tag{7.14}$$

Kusuda [27] and Hittle [28] described well the procedure for computing response factors in detail.

The general formula for inverting a Laplace transformed expression q(s) based on Cauchy's residue theorem is given by

$$q(t) = \frac{1}{2\pi i}\oint_C q(s)e^{st}\,ds = \sum_j \mathrm{Res}(a_j) \tag{7.15}$$

where t is time, and $a_j$ is the j-th pole which is a root determined by setting the denominator of $q(s)e^{st}$ to be zero, i.e, B(s)=0.

A modified false position method is implemented for finding roots of an algebraic equation, and coded in the ILLINI subroutine. Improved root search technique associated with the false position method was also used as suggested by Hittle and Bishop [29] in the subroutine SEARCH.

Generalized equation for response factors with roots $\beta_j$ $(j=1,2,\ldots,\infty)$ is

$$\bar{F}_m = (-1)^m a_m \left[\frac{b_m R(s)}{B(s)} + \frac{R'(s)}{\delta B(s)} - \frac{R(s)\ B'(s)}{\delta [B(s)]^2}\right]_{s=0} \tag{7.16}$$

$$+ \sum_{j=1}^{\infty} \left. \frac{R(s)\ e^{-(m+1)\delta\beta_j^2} \left(1 - c_m e^{\delta\beta_j^2}\right)^2}{\delta\beta_j^4 B'(s)} \right|_{s=-\beta_j^2}$$

where R'(s) and B'(s) are derivatives of R(s) and B(s).

| | $a_m$ | $b_m$ | $c_m$ |
|---|---|---|---|
| m=0 | 1 | 1 | 0 |
| m=1 | 1 | 0 | 2 |
| m>1 | 0 | 0 | 1 |

| $\bar{F}_m$ | R(s) | R'(s) |
|---|---|---|
| $\bar{X}_m$ | D(s) | D'(s) |
| $\bar{Y}_m$ | 1 | 0 |
| $\bar{Z}_m$ | A(s) | A'(s) |

Total derivatives of A(s), B(s), and D(s) are evaluated by differentiating the total construct matrix with respect to Laplace parameter s.

$$\begin{bmatrix} A'(s) & B'(s) \\ C'(s) & D'(s) \end{bmatrix} = \frac{d}{ds} \begin{bmatrix} A(s) & B(s) \\ C(s) & D(s) \end{bmatrix} \tag{7.17}$$

The subroutine DER computes the derivatives and the residue for non-zero poles, $\beta_j^2$, which is shown as the second term of equation (7.16). A portion of zero residue (s=0) is calculated in the ZERORE subroutine, and its result is combined with that by the DER subroutine to form equation (7.16) in the subroutine RFCOMP.

An important property of response factors is

$$\left|\sum_{m=0}^{\infty} \bar{X}_m\right| = \left|\sum_{m=0}^{\infty} \bar{Y}_m\right| = \left|\sum_{m=0}^{\infty} \bar{Z}_m\right| = U \tag{7.18}$$

where U is the overall conductance represented by

$$U = \frac{1}{\sum_{i=1}^{n} \frac{\ell_i}{k_i}} = \frac{1}{\sum_{i=1}^{n} r_i} \tag{7.19}$$

$r_i$ is the thermal resistance of the i-th layer.

## 7.4 Conduction Transfer Functions

As seen in equation (7.16), response factors when m>1 have the same form.

$$\bar{F}_m = \sum_{j=1}^{\infty} g_j \lambda_j^{m+1}, \quad m>1 \tag{7.20}$$

where $\lambda_j = e^{-\delta\beta_j^2}$ and $g_j = \left.\dfrac{R(s)\ (1 - e^{\delta\beta_j^2})^2}{\delta\beta_j^4 B'(s)}\right|_{s=-\beta_j^2}$

The subscript j is the index of the roots of B(s)=0, all of which are located on the negative real axis.

Based on equation (7.20), conduction transfer functions (CTF) are defined such that for j-th order

$$F_{j,o} = \bar{F}_o \tag{7.21}$$

$$F_{j,m} = F_{j-1,m} - \lambda_j F_{j-1,m-1} \tag{7.22}$$

For internal, cross, and external conduction transfer functions, $F_{j,m}$ is replaced by $X_{j,m}$, $Y_{j,m}$, and $Z_{j,m}$, respectively. Calculation of high order conduction transfer functions continues starting from the first order (j=1) until the following condition is met:

$$| 1 - H_{k,m} | < \varepsilon \quad (m=1,2,\ldots), \tag{7.23}$$

where

$$H_{k,m} = \frac{\sum_{j=1}^{k} F_{j,m}}{U \prod_{j=1}^{k} (1-\lambda_j)}$$

and $\varepsilon$ is a small number.

When the convergence condition is satisfied, the resulting order is k. In

CTFGEN, the maximum order chosen is 5.

After computing CTF using equation (7.22), these CTF are again adjusted.

$$X_m = X_{k,m}/H_{k,m}$$
$$Y_m = Y_{k,m}/H_{k,m} \tag{7.24}$$
$$Z_m = Z_{k,m}/H_{k,m}$$

The $X_m$, $Y_m$, and $Z_m$ for m=1,2,... are calculated for each construct and stored in an output data file (CTFDATA.DAT).

Conductive heat flux equation incorporating with CTF are then represented by

$$q_{i(t)} = \sum_{m=0}^{N_t} Y_m T_{o,t-m} - \sum_{m=0}^{N_t} Z_m T_{i,t-m} + \sum_{j=1}^{N_f} R_j q_{i,t-j} \tag{7.25}$$

$$q_o(t) = \sum_{m=0}^{N_t} Y_m T_{i,t-m} - \sum_{m=0}^{N_t} X_m T_{o,t-m} + \sum_{j=1}^{N_f} R_j q_{o,t-j} \tag{7.26}$$

where $R_j$ is the flux-related variable (flux transfer function). For $N_f$=5, Peavy [30] presented $R_j$ values in terms of $\lambda_j$. See the subroutine RFCOMP. Calculated values of $R_j$ are also stored in the output data file to be called by the TYPE51 subroutine.

## 8. WEATHER DATA

When a simulation involves building thermal loads, weather data are required by MODSIM. The subroutine RDENV in MODSIM expects to read outside air dry-bulb temperature, humidity ratio, barometric pressure, wind speed, direct normal solar beam radiation, sky diffuse radiation, and total horizontal solar radiation for each hour. The hourly weather data are interpolated for a fraction of an hour by using the spline interpolating routine which was explained in the section 4.3.

The program RDTAPE reads a weather tape (see Figure 1) and writes the selected weather data on an output data file (WTPOUT.DAT). The weather data in the file are transformed into the proper input format required by RDENV by the program CRWDTA. If a weather tape or equivalent is not available or some information from a weather tape is missing, CRWDTA generates artificial data to fill missing portions.

### 8.1 Weather Tape Reading Routine

The program RDTAPE requires inputs for the type of weather tape, the weather station identification number, and the beginning and ending dates of selected weather information. The conventional data is converted into Julian day and positioning a tape is performed based on the Julian day.

Since, for simplicity, the effects of rain, snow, and wind direction are not considered in the current version of HVACSIM$^{+}$, the subroutines for reading tapes were simplified accordingly. RDTAPE is capable to read four kinds of tapes: 'NOAA SOLMET,' 'NOAA Typical Meteorological Year (TMY),' 'NOAA Test Reference Year (TRY),' and 'Weather Year for Energy Calculation (WYEC),' tapes. Most of the subroutines in RDTAPE are based on BLAST [31] and TARP.

## 8.2 Weather Data File Generation

The program CRWDTA allows several options. It can read the output of RDTAPE and rewrite the information in the format required by RDENV, dividing total horizontal solar radiation values into beam and diffuse components if necessary. Alternatively, it can generate smooth 'design day' solar radiation and temperature data for a clear or cloudy sky design day. The latitude, longitude, and time zone data must be entered at the beginning of data file generation by CRWDTA. The output data file of CRWDTA (WEATHER.DAT) contains month, day, hour, dry-bulb temperature (C), humidity ratio (-), barometric pressure (kPa), wind speed (m/s), direct beam solar radiation ($W/m^2$), sky diffusive radiation ($W/m^2$), and total horizontal radiation ($W/m^2$).

If information on direct beam or sky diffuse radiation is missing from a weather tape (e.g., WYEC tape), the direct and diffuse radiation values are computed by the subroutine WTPINP in the CRWDTA program. In order to use the correlation, equation of time, E, declination angle, $\delta$, extraterrestrial normal radiation intensity, $G_{o,n}$, are calculated using equations presented by Duffie and Beckman [32].

$$E = \frac{1}{60} [9.87 \sin(2B) - 7.53 \cos(B) - 1.5 \sin(B)] \text{ (h)} \tag{8.1}$$

$$\delta = 23.45 \sin [2\pi(284+n)/365] \quad \text{(degrees)} \tag{8.2}$$

$$G_{o,n} = 1367 \; [1+0.033 \cos (2\pi n/365)] \quad (W/m^2) \tag{8.3}$$

where $B = 2\pi(n-81)/364$

$n$ is the day of year, $1 \leq n \leq 365$

Sunrise time, $t_{sr}$, and sunset time, $t_{ss}$, are

$$t_{sr} = \left(\frac{LONG}{15} - TZN\right) - E + 12\left(1 - \frac{\omega_s}{\pi}\right) \tag{8.4}$$

$$t_{ss} = \left(\frac{LONG}{15} - TZN\right) - E + 12\left(1 + \frac{\omega_s}{\pi}\right) \tag{8.5}$$

In the above equation, LONG is longitude angle in degrees, and $\omega_s$ sunset hour angle given by

$$\omega_s = \cos^{-1} [- \tan(L)\tan(\delta)] \tag{8.6}$$

where L is latitude angle in degrees. Time zone number, TZN, in the United States for standard time is 4 = Atlantic, 5 = Eastern, 6 = Central, 7 = Mountain, or 8 = Pacific.

When total horizontal radiation, $I_h$, is zero, direct beam and diffuse radiation values are also zero. The following discussion refers only to hours with non-zero $I_h$.

Since solar radiation data are generally integrated energy or average power over a period of an hour, the program uses the solar hour angle half an hour ago to represent the average solar position for the hour. Exceptions occur for the two hours each day which include sunrise or sunset. In these cases, only time interval after sunrise and before sunset is considered. Denoting $\omega_1$ and $\omega_2$ as solar hour angle at the beginning time and the ending time, respectively, for the i-th hour of the day, these hour angle expressions are

$$\omega_1 = \frac{\pi}{12} [\max(t_{i-1}, t_{sr}) - 12 + E + TZN] - \frac{\pi}{180} LONG \tag{8.7}$$

$$\omega_2 = \frac{\pi}{12} [\min(t_i, t_{ss}) - 12 + E + TZN] - \frac{\pi}{180} LONG \tag{8.8}$$

The cosine of the solar zenith angle, Z, is calculated using the average of $\omega_1$ and $\omega_2$.

$$\cos(Z) = \sin(\delta)\sin(L)+\cos(\delta)\cos(L)\cos[(\omega_1 + \omega_2)/2] \tag{8.9}$$

Extraterrestrial horizontal radiation, $I_o$, is a time averaged value for an hour from $\omega_1$ to $\omega_2$.

$$I_o = \frac{12}{\pi} G_{o,n}\left\{\cos(L)\cos(\delta)[\sin(\omega_2) - \sin(\omega_1)]+(\omega_2-\omega_1)\sin(L)\sin(\delta)\right\} \quad (8.10)$$

If direct beam radiation, $I_b$, is known and diffuse radiation, $I_s$, is missing, the value of $I_s$ is obtained from

$$I_s = I_h - I_b\cos(Z) \quad (8.11)$$

If $I_s$ is known while $I_b$ is not given, $I_b$ is computed from

$$I_b = (I_h - I_s)/\cos(Z) \quad (8.12)$$

When both $I_s$ and $I_b$ are unknown, the estimation of $I_s$ is made using the hourly diffuse correlation of Erbs, Klein, and Duffie [33].

$$\frac{I_s}{I_h} = 1.0 - 0.09\ k_T \text{ for } 0\leq k_T\leq 0.22 \quad (8.13)$$

$$= 0.9511 - 0.1604\ k_T + 4.388\ k_T^2 - 16.638\ k_T^3 + 12.336\ k_T^4$$

$$\text{for } 0.22 < k_T\leq 0.80$$

$$= 0.165 \text{ for } 0.80< k_T\leq 1.0$$

where $k_T$ is the hourly clearness index given by

$$k_T = I_h/I_o \quad (8.14)$$

With $I_s$ obtained by equation (8.13), $I_b$ is calculated using equation (8.12).

The weather tapes mentioned previously do not give humidity ratio but dew point temperature. The humidity ratio is determined using the dew point temperature. Refer to section 6.1 and the function WF.

The program CRWDTA generates smooth artificial design day weather data if a weather tape or equivalent data file is not available. Clear or cloudy sky design day data can be created after entering input data: initial day and month, number of days for which weather calculation will be made, barometric pressure, wind speed, relative humidity, minimum and maximum dry-bulb temperatures.

To create cloudy sky design day data (ISFLAG =3), a fixed value of daily clearness index, $\bar{k}_T$, must be given. With this $\bar{k}_T$, hourly clearness index, $k_T$, at the i-th hour of day can be calculated from the following relation:

$$k_T = \bar{k}_T \left\{ a+b\cos[(\omega_1 + \omega_2)/2] \right\} \tag{8.15}$$

where $a = 0.409 + 0.5016 \sin(\omega_s - \pi/3)$

$b = 0.6609 - 0.4767 \sin(\omega_s - \pi/3)$

Total horizontal radiation, $I_h$, is then obtained.

$$I_h = k_T I_o \tag{8.16}$$

Knowing $I_h$, equations (8.11) and (8.12) give the values of $I_s$ and $I_b$. See the subroutine SOLAR.

Clear sky design day data (ISFLAG=2) is generated by the subroutine SOLAR in CRWDTA. CRWDTA implements all three methods presented by Machler and Iqbal [34]. The method used by the program depends upon user's responses to questions asked when clear sky data generation is requested. Horizontal visibility, geographic correction factor, and precipitable water are involved.

Method 1 is the simplest method, which is a modification of the ASHRAE clear sky irradiation algorithm. When horizontal visibility is zero, the method 1 is used.

$$I_b = k_A A_m e^{-\alpha B_m} \tag{8.16}$$

$$I_s = C_m I_h \tag{8.17}$$

where $A_m$, $B_m$, and $C_m$ are apparent solar constant, exponential attenuation coefficient, and diffuse fraction factor, respectively. These are sets of twelve constants, one for each month. Machler and Iqbal presented modified values of $A_m$, $B_m$, and $C_m$. The variable $\alpha$ is defined by

$$\alpha = (P/P_o)/\cos(Z) \tag{8.18}$$

in which P, $P_o$ and Z are barometric pressure, standard atmospheric pressure (=101.3kPa) and zenith angle, respectively.

The correction factor for regional variation, $k_A$, is 'clearness number' listed in ASHRAE Handbook (e.g., 1981 Fundamentals, p. 27.8) [35].

Method 2 uses horizontal visibility at ground level as a parameter of atmospheric turbidity. If horizontal visibility is not zero, but precipitable atmospheric moisture is zero, the method 2 is used.

$$I_b = G_{o,n}\,\tau_a\,(0.775)^{f(0.5)} \tag{8.19}$$

$$I_s = I_b\,(0.1 + 0.3/VIS) \tag{8.20}$$

where f(x) is defined by $\alpha^x$ (i.e., $f(0.5)=\alpha^{0.5}$), VIS is horizontal visibility at ground level in km, and $\tau_a$ is atmospheric transmittance.

$$\tau_a = (1 - 1.13\ VIS^{-0.57})^{f(0.85)} \tag{8.21}$$

Method 3 is applied to modify the equation for $I_b$, if a non-zero value for precipitable water is given.

$$I_b = G_{o,n}\,\tau_a\,(0.775)^{f(0.5)}\,(1.0223 - 0.00149M)^{f(0.27)} \tag{8.22}$$

where M is the precipitable water in mm.

Approximated dry-bulb temperature calculation is made using empirical values shown in the table of ASHRAE Handbook [35] for summertime. For the i-th hour,

$$T_i = T_{max} - (T_{max} - T_{min}) \cdot \phi_i / 100 \tag{8.23}$$

where $T_{max}$, $T_{min}$, and $\phi_i$ are design day maximum, minimum temperatures, and percentage of the daily range as empirical values. This temperature calculation is coded in the subroutine DB. Note that equation (8.23) is not valid for wintertime. Calculation procedure for wintertime temperature has not been implemented in CRWDTA.

Assuming constant relative humidity for a day, hourly humidity ratio is computed using the expressions in ASHRAE Handbook p. 6.4. The subroutine HUMIDY determines the hourly humidity ratio.

## 9. SIMULATION PROCEDURE

Generally, a computer simulation using HVACSIM+ involves three steps: preprocessing, simulation, and postprocessing.

### 9.1 Preprocessing - Input Data Generation

(1) Creation of Simulation Work File

The building load and the system component portions are considered as separate parts. The type description file (TYPAR.DAT) must be accessible by both HVACGEN and SLIMCON. See the Reference Manual [7] and the Users Guide [8] for details.

-------Building Load Component Portion-----

(i) Draw a sketch of the building to be simulated and divide the building shell into a number of zones as necessary.

(ii) Make block diagrams for the building load components and assign a UNIT number to each component along with the proper TYPE number.

(iii) Fill out all the required information on the worksheets, which are appended in APPENDIX B, for the building load components: TYPE50, TYPE51, TYPE52, and TYPE53.

(iv) Execute the HVACGEN program. During the execution, enter necessary data which was prepared on the worksheets. Note that one of SUPERBLOCKS is reserved only for the zone envelope (TYPE50), the building surface (TYPE51), and the weather input (TYPE53). Zone models (TYPE52) should reside in the other SUPERBLOCK or SUPERBLOCKS which may also contain the system component models.

----- System Component Portion -------

(i) Draw a sketch of the building system to be simulated.

(ii) Make block diagrams for system components which serve the zones, and assign a UNIT number to each component with a proper TYPE number.

(iii) Fill out all the required information on the worksheets, which are appended in APPENDIX in reference [8], for the system components.

(iv) Execute the HVACGEN program. Enter necessary information and edit the simulation work file if needed.

(2) Creation of Model Definition File

After creating the simulation work file, the SLIMCON program can generate the model definition file (MODELDEF.DAT) for the MODSIM program from the simulation work file. Since it is very difficult to make any changes in the model definition file, any changes should be made in the simulation work file instead.

(3) Creation of Boundary Variable File

Any explicitly defined, indexed input or output variables in TYPEn subroutines can be boundary variables.

(i) Edit the simulation work file to declare the boundary variables using the HVACGEN program.

(ii) Make a boundary data file (BOUNDARY.DAT) using a user's editing program. The first column of the boundary variabe data file must contain values of time (Time intervals need not be equal). For step changes, two sequential records should be entered having the same value of time but different values of a boundary variable.

(4) Creation of Conduction Transfer Function File

(i) Find out what kind materials are used to form the building envelope element ( wall, roof, ceiling, floor, partition, or window).

(ii) Search the thermal property data bank of building materials (THERM.DAT) whether required data are available. If not, obtain thermal property data from other sources.

(iii) Execute the CTFGEN program interactively to add thermal property data and/or obtain conduction transfer functions of the specific constructs. When a construct has very low thermal capacitance ($C_p \approx 0$), the value of thermal resistance must be specified. The output file of CTFGEN (CTFDATA.DAT) will be used by the RDENV subroutine of the MODSIM program.

(5) Creation of Weather Data File

(i) Execute the RDTAPE program interactively to read weather information from a weather tape or equivalent.

(ii) Using the output file of the RDTAPE program (WTPOUT.DAT), execute the CRWDTA program to create the weather data file (WEATHER.DAT) for the subroutine RDENV of the MODSIM program. If no weather tape data is accessible or for simplicity it is not desired to use a weather tape for simplicity, an artificial weather data file can be generated by the CRWDTA program.

## 9.2 Simulation

(1) Allocation of Output Files

The output files of the MODSIM program, MODSUM.DAT, MODOUT.DAT, and INITOUT.DAT, are automatically allocated on the computer disk storage spaces by the Fortran77 OPEN statements in the MODSIM.

(2) Execution of MODSIM

A simulation is performed by MODSIM using previously created data files. During the execution, some of the data can be monitored on the screen of a computer terminal. With the building model, a simulation involves two steps of execution. The first step is the initialization run for temperature and flux histories for computation of conductive heat transfer rates for a given period of time, usually 24 hours. The second step is the actual simulation.

(3) Continuation of Simulation

At the end of each run of MODSIM for a given period, the output file, INITOUT.DAT, is created. This file has all of the data which are needed to continue the simulation at the next time period. However, INITOUT.DAT must be renamed as INITIN.DAT before the next, continuing simulation is begun. Otherwise no continuation of the simulation is made.

## 9.3 Postprocessing - Output Data Analysis

Execution of the SORTSB program produces a sorted data file for a specific SUPERBLOCK from the MODOUT.DAT file. This step is necessary to generate an input file for a user-supplied plotting routine, if more than one SUPERBLOCK is associated.

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## APPENDIX A: Short Descriptions of Functions and Subroutines in HVACSIM+

### (1) Primary Program of HVACSIM+

* Main Program

( File : MODSIM5 )

MODSIM – Modular simulation program

* Input/Output

( File : MODINO5 )

BLOCK DATA – Assignment of logical unit numbers to files, setting numerical values of typical properties of air and water, and giving label names

BOUNDS – Reading of time-dependent boundary variables, and interpolating them using the 3rd order Lagrangian interpolation

INDATA – Entering input data for a simulation on the console

OPNFIL – Opening of input and output files

RCONF – Reading of the model definition and the initialization files

REPORT – Generation of the report file at equal intervals

SUMARY – Writing of a summary of configurtion of simulation

VLAB – Returning labels and numbers

* Block and State Variable Status Control

( File : MODBLK5 )

ASEMBL – Assembling of BLOCK inputs and outputs

BACTIV – Control of BLOCK activity

FRZVAR – Variable freezing

INPUTS – Assignment of state variables to inputs of UNIT

INSCAN – Scanning the inputs of SUPERBLOCKs to detect changes larger than the error tolerance

INTLIZ - Initialization of the simulation

OUTPUT - Storing of outputs from UNIT

RESTAT - Resetting of outputs of a BLOCK for unfrozen variables

UNFREZ - Checking for frozen variables

* Integration of Stiff Ordinary Differential Equations

( File : MODBDF5 )

BAKDIF - Calculation of derivatives using backward difference formulars

CALN - Computation of the minimum time step

ECNTRL - Calculation of truncation errors and determination of time step and integration order

IPERM - Permutation of vectors

NORDER - Increasing or decreasing the order of integration

PREDIK - Calculation of predicted values for the next time step

RESET - Resetting the differential equation integrator

SAVECO - Saving and replacing coefficients

UPDATE - Updating coefficients for BAKDIF and PREDIK

* Routines needed for Solving a System of Equations

( File : MODEQT5 )

BLOCK - Calculation of a new state vector by calling a BLOCK

FNC - Calculation of the residual functions for a BLOCK

SUPERB - Calculation of a new state vector by calling a SUPERBLOCK

SUPFNC - Calculation of the residual functions for a SUPERBLOCK

( File : SELECT5 )

SELECT - Calling TYPEn subtoutines

* Nonlinear Algebraic Equation Solver

( File : SNSQA )

SNSQ - Finding a zero of a system of nonlinear functions

SNSQ1 - The same as SNSQ but called by the BLOCK subroutine

SNSQ2 - The abbreviated version of SNSQ

( File : SNSQB )

DOGLEG - Determination of the convex combination x of the Gauss-Newton and scaled gradient directions

ENORM - Calculation of the Euclidean norm of x

QFORM - Accumulation of orthogonal matrix Q from the computed QR factorization

QRFAC - QR factorization of a matrix using Householder transformations

R1MPYQ - Computation of A*Q for a given matrix A

R1UPDT - Determination of an orthogonal matrix Q

( File : SNSQC )

FDJAC1 - A forward difference approximation to the Jacobian matrix. Called by SNSQ.

FDJAC2 - The same as FDJAC1 except argument. Called by SNSQ1 and SNSQ2.

R1MACH - Machine-dependent constants for the local computer environment

* Models of HVAC Components and Controls

( File : TYPES )

TYPE1 - Fan and pump model

TYPE2 - Conduit (duct or pipe)

TYPE3 - Inlet conduit (duct or pipe)

TYPE4 - Flow merge

TYPE5 - Damper or valve

TYPE6 - Flow split

TYPE7 - Temperature sensor

TYPE8 - Proportional-Integral controller

TYPE9 - Linear valve with pneumatic actuator

TYPE10 - Hot water coil model

TYPE11 - Hot water to air heating coil

TYPE12 - Cooling or dehumidifying coil

TYPE13 - Three-way valve model

TYPE14 - Evaporative humidifier

TYPE15 - Room model with constant zone loads

TYPE16 - Sticky proportional controller

TYPE17 - Mixing dampers and merge

TYPE18 - Plenum

TYPE19 - Flow balance control

TYPE20 - High/low limit controller

TYPE21 - Clamped split

TYPE22 - Steam spray humidifier

TYPE23 - Steam nozzle

TYPE24 - Ideal gas nozzle

TYPE25 - Steam to air heating coil

TYPE26 - Control signal inverter

TYPE27 - Moist air flow merge

TYPE28 - Constant flow resistance

TYPE29 - Inlet constant flow resistance

* Building Loads Model components

( File : TYPESB )

TYPE50 - Zone envelope (Building Shell)

TYPE51 - Building surface (Building Shell)

TYPE52 - Zone model

TYPE53 - Weather input (Building Shell)

* Supporting Utility for System Components

( File : UTILITY )

HYSTER - Hysterisis of actuators

DELAY - Transport delays in ducting components

SUFED - Coefficients for the polynomial of the efficiency of heat exchanger fin

BESI - Modified Bessel function

BESK - K Bessel function

POLFIT - Polynomial fitting

* Supporting Utility for Building Load Components

( File : UTILITYB )

CP - Specific heat of moist air, vapor pressure, air exchange rate, and humidity ratio at saturated state

HISCF - Computation of convective heat transfer coefficient of the inner surface to the zone air, convective plus radiative heat transfer coefficient of the outer surface, and radiative heat transfer coefficient of the inner surface

VIEW - View factors using MRT network method

( File : RDENV )

RDENV - Reading of weather data and conduction transfer functions. Interpolation of hourly data using the spline interpolation.

SPLINE - The second derivatives for the spline interpolation

SPEVAL - Interpolation by using the cubic spline method

* Steam and Liquid Water Properties

( File : WATPR )

TSATS - Saturation temperature of steam vs. pressure

PSATS - Saturation pressure of steam vs. temperature

VSATS - Saturation specific volume of steam vs. temperature and pressure

VSATW - Saturation specific volume of water vs. saturation temperature

HSATW - Saturation enthalpy of liquid water vs. saturation temperature

HFG - Latent heat of vaporization of water vs. saturation temperature

HSATS - Enthalpy of saturated steam vs. saturation temperature

SSATW - Saturation entropy of liquid water vs. saturation temperature

SSATS - Entropy of saturated steam vs. saturation temperature

VS - Specific volume of superheated steam vs. pressure and temperature

HS - Enthalpy of superheated steam vs. pressure and temperature

SS - Entropy of superheated steam vs. pressure and temperature

TPSS - Temperature of steam vs. pressure and entropy

CPS - Specific heat of steam at constant pressure vs. temperature

CVS - Specific heat of steam at constant volume vs. specific volume and temperature

VISSV - Dynamic viscosity of saturated vapor vs. pressure

VISSPH - Dynamic viscosity of superheated steam vs. temperature

STEAMK - Thermal conductivity of superheated steam vs. temperature

WRHO - Density of water vs. temperature

WMU - Viscosity of water vs. temperature

WK - Thermal conductivity vs. temperature

WCP - Specific heat of water vs. temperature

* Air Properties

( File : AIRPR )

CPCVA - Specific heats of air at constant pressure and volume, and speed of sound in air

HA - Enthalpy of air vs. temperature

PHIA - Entropy of air vs. temperature

TPHIA - Temperature of air vs. entropy

VISCA - Dynamic viscosity of air vs. temperature

AKA - Thermal conductivity of air vs. temperature

* Refrigerant Properties

( File : REFRIGPR )

REFRIG - BLOCK DATA for coefficients of refrigerant equations

PSAT - Saturation pressure of refrigerant vs. temperature

TSAT - Saturation temperature of refrigerant vs. saturation pressure

TVSAT - Saturation temperature of refrigerant vs. saturation specific volume

PGAS - Pressure of refrigerant vs. specific volume and temperature

VGAS - Specific volume of refrigerant vs. pressure and temperature

HGAS - Enthalpy of refrigerant vs. pressure, specific volume, and temperature

SGAS - Entropy of refrigerant vs. specific volume and temperature

HPS - Enthalpy of refrigerant vs. pressure and entropy

TPH - Temperature of refrigerant vs. pressure and enthalpy

TVH - Temperature of refrigerant vs. specific volume and enthalpy

DHLAT - Latent heat of vaporization of refrigerant vs. pressure, specific volume, and temperature

RHOLIQ - Density of refrigerant vs. temperature

CV - Specific heat of refrigerant at constant volume vs. specific volume and temperature

CPCV - Specific heats of refrigerant at constant volume and pressure, and speed of sound in refrigerant vs. specific volume and temperature

(2) Conduction Transfer Function Calculation

( File : CTFGEN )

| | | |
|---|---|---|
| CTF | - | Main program to create the CTF data file (CTFDATA.DAT) |
| THERMP | - | Adding new data of thermal properties of building materials in the thermal property data file (THERM.DAT) |
| BANKTP | - | Making a temporary direct access file of the thermal property data |
| DER | - | Calculation of the total construct and total derivative matrices, and determination of residue elements for a non-zero root |
| DUMPRF | - | Printing description of conductive layers, values of roots, conduction transfer functions, and flux transfer functions |
| ERROR | - | Printing error messages |
| ILLINI | - | Computation of roots in the interval using modified false position method |
| INITRF | - | Calling subroutines related to calculation of conduction transfer functions |
| MATRIX | - | Evaluation of the conduction matrix for a multilayered slab |
| RCOMP | - | Computation of conduction transfer and flux transfer functions for multilayered constructs |
| SEARCH | - | Determination of the upper and lower bounds within which a root must exist. |
| ZERORE | - | Calculation of zero residue elements |

(3) Weather Data

* Weather Tape Reading

( File : RDTAPE )

| | | |
|---|---|---|
| RDTAPE | - | Main program to read weather tapes |
| RDWTP | - | Positioning and checking weather tapes |
| RDSOLM | - | Reading of a NOAA SOLMET tape |
| RDTMY | - | Reading of a NOAA Typical Meteorological Year (TMY) tape |

RDTRY - Reading of a NOAA Test Reference Year (TRY) tape

RDWYEC - Reading of Weather Year for Energy Calculations (WYEC) tape

WRTFIL - Writing output data (WTPOUT.DAT)

JDS - Evaluation of Julian date

* Weather Data File Generation

( File : CRWDTA )

CRWDTA - Main program to create the weather data file

WTPINP - Reading the output file of the RDTAPE program and computation of solar radiation data which are missed in the weather tape

WF - Humidity ratio vs. dew point temperature and pressure

SOLAR - Generation of artificial weather data of solar radiation

DB - Design day outdoor air dry-bulb temperature for summer

HUMIDY - Humidity ratio assuming constant relative humidity

COPYFL - Writing outputs on the weather data file (WEATHER.DAT)

(4) Front-End Program for Handling a Simulation Work File

* Main Module

( File : HVACGEN1 )

HVACGE - Main program of the HVACGEN program

INFORM - BLOCK DATA containing the types of data and COMMON BLOCK information

DATAIN - Verification of input information

COPMOD - Input data processor

CHECK - Checking whether the parsed word is a number

REWORD - Checking whether the input is reserved word

REMAIN - Control of transfer to the requested module

HOLDIT - Producing a pause for acknowledgment of error display

SCROLL - Making a screen display paused when the screen is full

OKAY - Checking whether an existing value is acceptable

RITE - Displaying of console messages and menu

PROMPT - Providing the index labels corresponding to category numbers

* Create Module

( File : HVACGEN2 )

CREATE - Control of transfer to the proper routine for create mode

CRUNIT - Creating a UNIT to be used in a work file

CRBLK - Creating a BLOCK to be used in a work file

CRSUP - Creating a SUPERBLOCK to be used in a work file

CRSIM - Calling CRSIM1, CRSIM2, CRSIM3, and CRSIM4 for SIMULATION setup

CRSIM1 - Entering the simulation title, and error tolerances

CRSIM2 - Entering initial values of state variables

CRSIM3 - Entering boundary information

CRSIM4 - Entering the information of reported variables

RECRT - Calling a proper module according to the entry of reserved words (ABORT, HELP, VIEW, EDIT, and TYPES )

TYPES - Listing the TYPEs avaiable in the TYPAR.DAT file

* File Control Module

( File : HVACGEN3 )

FSAVE - Calling the routine for saving the created file for UNIT, BLOCK, SUPERBLOCK, or SIMULATION setup

READIN - Selecting the module for reading a file based on the file extension

OPNFIL - Entering the file name and opening the file

RDUNT - Reading the file of UNIT with the extention UNT

RDBLK - Reading the file of BLOCK with the extension BLK

RDSIM - Reading the file of SIMULATION setup with the extension SIM

SAVUNT - Writing information to the UNIT file

SAVBLK - Writing information to the BLOCK file

SAVSUP - Writing information to the SUPERBLOCK file

SAVSIM - Writing information to the SIMULATION file

TYPEIN - Creating a direct access file for TYPAR.DAT at the first call, and reading the information from the direct access file.

* View Module

( File : HVACGEN4 )

VIEW - Control of transfer to the proper routine for view mode

VEWUNT - Viewing the inputs, outputs, and parameters for the UNIT

VEWBLK - Viewing the information for the BLOCK

VEWSIM - Providing the menu for different view options

STRUCT - Viewing of the structure of the SIMULATION setup

VARVAL - Viewing of the initial values of state variables for inputs in the SIUMULATION

BOUND - Viewing of the boundary information for the SIMULATION

RPTVAR - Viewing of the reported variables in the SIMULATION

ERROR - Viewing of the error tolerances, and the freezing and scan options in the SIMULATION

REVEW - Directing to either HELP or ABORT mode

VEWALL - Viewing of all information in the SIMULATION

* Edit and Help Module

( File : HVACGEN5 )

EDIT - Control of transfer to the proper routine for edit mode

EDUNT - Editing the information in the UNIT

EDSIM - Editing the information in the SIMULATION

EDTITL - Editing the title

EDSTR - Calling the routines for editing the structure

EDVAL - Editing the initial values of state variables

EDBND - Calling the routines for editing the boundary information

INSERT - Entering the index of a boundary variable to the SIMULATION

DELETE - Deleting the index of a boundary variable from the SIMULATION

EDREP - Calling the routines for editing the information of reported variables

PRCHNG - Editing the reporting interval

RPINRT - Entering the index of a reported variable to the SIMULATION

RPDELT - Deleting the index of a reported variable from the SIMULATION

EDERR - Editing the error tolerances and the freezing and scan options

REEDT - Calling the help module

REEDIT - Calling the help module (similar to REEDT)

( File : HVACGEN6 )

INSSIM - Calling the routine for inserting or replacing UNIT or BLOCK

INSUNT - Inserting a UNIT in the SIMULATION

INSCHK - Giving the number of UNITs in the BLOCK

INSBLK - Inserting a BLOCK in the SIMULATION

INCK2 - Giving the information of SUPERBLOCK and UNIT to the subroutine INSBLK

RECALC - Recalculation of the new position of the variables in the state vector after an insertion

TYPINF - Getting information of the input and output category indeces from the TYPAR.DAT file

REBND - Calculation of the new position in the state vector of the boundary variables

REREPT - Calculation of the new position in the state vector of the reported variables

| | |
|---|---|
| DELSIM | - Calling the routine for deleting a UNIT or BLOCK from a SIMULATION |
| DELUNT | - Deleting a UNIT from the SIMULATION setup |
| DELBLK | - Deleting a BLOCK from the SIMULATION setup |
| DELCHK | - Checking the UNIT number to be deleted |
| DELCK2 | - Checking the BLOCK number to be deleted |
| REPSIM | - Calling the routine for replacing a UNIT in the SIUMULATION |
| REPUNT | - Replacing a UNIT in the SIMULATION |
| HELP | - Description of available commands in the HVACGEN program |
| EXTBLK | - Saving the information in the BLOCK of the SIMULATION file in a BLOCK file |

(5) Model Definition File Generation

(File : SLIMCON )

| | |
|---|---|
| SIMCON | - Main program of the SLIMCON program to generate a model definition file (MODELDEF.DAT) using a simulation work file with the extension SIM |
| FILEOP | - Opening the input and output files |
| TYPAR | - Getting information from the TYPAR.DAT file |
| REPORT | - Displaying the configuration parameters along with the maximum values assigned |
| VARCHK | - Checking whether any of the time-dependent boundary variables are solved simultaneously |
| OUTCHK | - Checking if two or more outputs are assigned to a single state variable |
| TDBVIS | - Finding the largest number of time-dependent boundary variables in any one SUPERBLOCK |

(6) Sorting the Raw Data File

( File : SORTSB )

| | |
|---|---|
| SORTSB | - Program to sort the raw output data file (MODOUT.DAT) for each SUPERBLOCK to create a data file which can be used as an input data file to a user-supplied plotting routine |

=========================================================================
APPENDIX B: Worksheets for Data Entry for TYPE 50, 51, 52, and 53
=========================================================================

*********************************************************************

TYPE 50 ZONE ENVELOPE UNIT=

INPUTS:

| | |
|---|---|
| TIA: | Zone air dry-bulb temperature (C) ------------------T |
| QISW: | Internal (short wave) radiant gain from lights(kW)--Q |
| QILW: | Internal (long wave) radiant gain (kW) -------------Q |
| TIS(1): | Inner surface temperature (C) ---------------------T |
| TIS(2): | Inner surface temperature (C) ---------------------T |
| TIS(3): | Inner surface temperature (C) ---------------------T |
| TIS(4): | Inner surface temperature (C) ---------------------T |
| TIS(5): | Inner surface temperature (C) ---------------------T |
| TIS(6): | Inner surface temperature (C) ---------------------T |
| TIS(7): | Inner surface temperature (C) ---------------------T |
| TIS(8): | Inner surface temperature (C) ---------------------T |
| TIS(9): | Inner surface temperature (C) ---------------------T |
| TIS(10): | Inner surface temperature (C) ---------------------T |

OUTPUTS:

| | |
|---|---|
| TMR: | Mean radiant temperature (C) -----------------------T |
| QWALL: | Convective heat gain from building surfaces (kW) ---Q |

PARAMETERS:

| | |
|---|---|
| 1 IZN: | Identification number of zone ----------------------- |
| 2 NS: | Number of surfaces of zone ------------------------- |

NOTE: When the number of surfaces is less than 10, an index of the last surface may be used for the remaining temperature inputs.

****************************************************************************

TYPE 51 BUILDING SURFACE UNIT=

INPUTS:

```
TIA:        Indoor air dry-bulb temperature (C) ---------------T
TMR:        Mean radiant temperature (C) -----------------------T
TOSINF:     Outer surface temperature of unexposed wall(C)------T
FSHADW:     Shaded fraction of exposed outer surface (-) -------C
```

OUTPUTS:

```
TIS:        Inner surface temperature (C) ----------------------T
SOLINT:     Integrated solar flux incident on surface (W/m2) ---Q
```

PARAMETERS:

```
 1 IZN:     Identification number of zone ---------------------
 2 ID:      Identification number of surface ------------------
 3 IEXPSO:  0=W/in zone, 1=betw. zones, 2=exposed to sun (-) ---
 4 ISTR:    Identification number of the construct -------------
 5 AS:      Surface area  (m2) ---------------------------------
 6 ORIENT:  Azimuth angle between normal to surface & south ----
 7 TILT:    Tilt angle : flat roof=0, floor=180 (degree) -------
 8 GRF:     Ground reflectivity (-) ----------------------------
 9 IROFS:   Outer surface roughness index [1,6] (-) ------------
10 ABSOS:   Solar absorptance of the outer surface (-) ---------
11 ABSIS:   Short wave absorptance of the inner surface --------
12 EMITIS:  Emissivity of the inner surface (-) ----------------
13 TRANSM:  Transmittance of the glass window (-) --------------
14 SC:      Shading coefficient of the glass window (-) --------
```

NOTE: If outer surface is exposed to outside air (IEXPOS=2), the index of TOSINF may be the same index of TIS.

The orintation angle of an west facing surface is 90 degrees, while an east facing surface is 270 degrees.

The surface roughness index, IROFS, is defined as follows:

```
IROFS = 1   Stucco
        2   Brick, rough plaster
        3   Concrete
        4   Clear pine
        5   Smooth plaster
        6   Glass, paint on pine
```

```
*****************************************************************************

TYPE 52    ZONE MODEL                                UNIT=

INPUTS:
PIAG:       Gage pressure of zone air (kPa) --------------------P
TIA:        Zone air dry-bulb temperature (C) -----------------T
WIA:        Humidiy ratio of zone air (-) ---------------------H
PSAG:       Gage pressure of supply air (kPa) -----------------P
MSA:        Mass flow rate of supply air (kg/s) ---------------M
TSA:        Supply air dry-bulb temperature (C) ---------------T
WSA:        Humidity ratio of supply air (-) ------------------H
QWALL:      Convective heat gain from building surfaces (kW) ---Q
NUMPEP:     Number of people (occupant in the zone) -----------C
UTCEQP:     Equipment utilization coeff. (-) ------------------C
UTCLIT:     Lighting utilization coeff. (-) -------------------C

OUTPUTS:
TIA:        Zone air dry-bulb temperature [diff. eq.] (C) ------T
WIA:        Humidiy ratio of zone air [diff. eq.] --------------H
QISW:       Internal (short wave) radiant gain from lights(kW)--Q
QILW:       Internal (long wave) radiant gain (kW) -------------Q

PARAMETER:
 1 IZN:     Identification number of zone ----------------------
 2 CFUR:    Effective thermal capacitance of furnishing (kJ/K) -
 3 EFFMIA:  Air mass multiplier for zone moisture capacitance --
 4 VOLUME:  Volume of zone air (interior space of zone) (m3) ---
 5 SAIREX:  Std air exchange rate (0.5=tight,1.0=std,1.5=leaky)-
 6 WPEPS:   Sensible heat gain from a person (kW)  -------------
 7 WPEPL:   Latent heat gain from a person (kW)  ---------------
 8 WLIT:    Heat gain due to lighting in the zone (kW) ---------
 9 LIGHT:   1 = Fluorescent, 2 = Incandescent ------------------
10 WEQPS:   Sensible heat gain due to equipment (kW) -----------
11 WEQPL:   Latent heat gain due to equipment (kW) -------------
12 REQP:    Radiative to sensible heat from equipment (-)-------
```

```
*****************************************************************************

TYPE 53   WEATHER INPUT                                    UNIT=

INPUTS:
TAMB:        Ambient (outdoor) air temperature (C)----------------T
HUMRAT:      Outdoor air humidity ratio (-) ----------------------H
PBAR:        Barometric pressure (kPa) ---------------------------P
IDN:         Direct normal solar radiation (W/m2) ----------------Q
ISKY:        Diffuse (sky) solar radiation (W/m2) ----------------Q
IHOR:        Total horizontal solar radiation (W/m2) -------------Q

OUTPUTS:     none

PARAMETERS:
 1 Index for ambient temperature  (e.g. 5 if TAMB= T5) ---------
 2 Index for outdoor air humidity ratio ------------------------
 3 Index for barometric pressure -------------------------------
 4 Index for direct normal solar radiation ---------------------
 5 Index for diffuse (sky) solar radiation ---------------------
 6 Index for total horizontal solar radiation ------------------
```

================================================================================
## APPENDIX C: Example 1 One-zone Building Model
================================================================================

A single-zone building model is simulated in this example, following the Simulation Procedure outlined in Chapter 9 of this report. The purpose of the example is to demonstrate how to use HVACSIM+ with the building loads model described in this report(see Figure 1). No system component is connected to the zone and no boundary variable is considered. Artificially generated weather data is used. Screen images of I/O operation during the executions of programs and all related data files are presented.
Different results from the outputs of this example are anticipated when a computer with different values of machine precisions from those used in this example. See the function R1MACH in the file SNSQC.

The machine precisions used are:

```
        R1MACH(1) = 5.3976E-79
        R1MACH(2) = 7.2370E+75
        R1MACH(3) = 5.9605E-8
        R1MACH(4) = 9.5367E-7
```

### A. Preprocessing - Input Data Generation
### (1) Creation of Simulation Work File

As shown in Figure C-1, the example model is an office module located on a floor (other than the top or ground floor) of a multi-story building. The building surfaces faced to the south are exposed to the sun, while other surfaces are unexposed, interior surfaces.

Figure C-2 is a simplified block diagram which shows the input-output connections of UNITS. Since UNIT 9 (Weather Input) has no direct connection to any UNIT, it is not shown here.

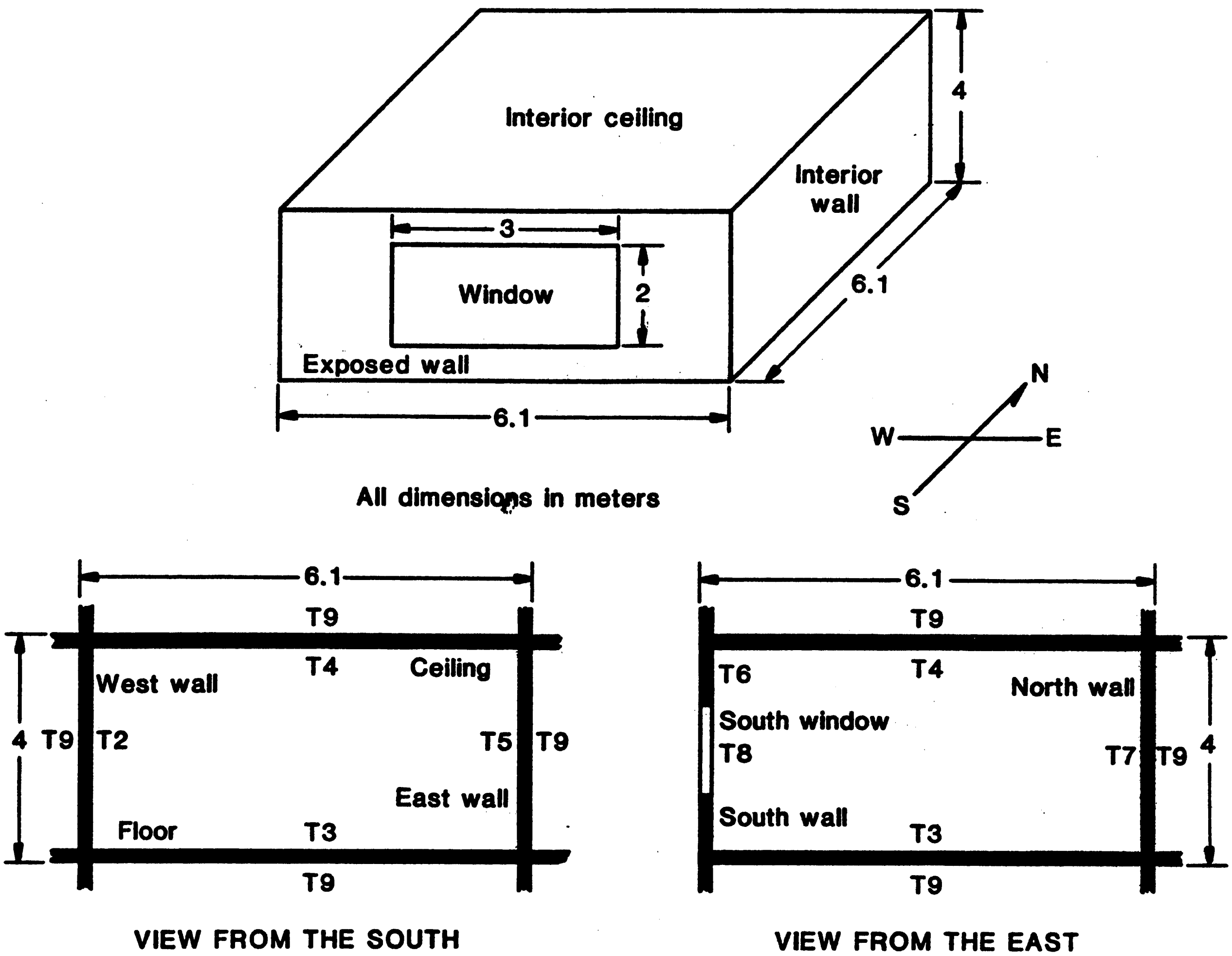


Figure C-1. A single-zone model

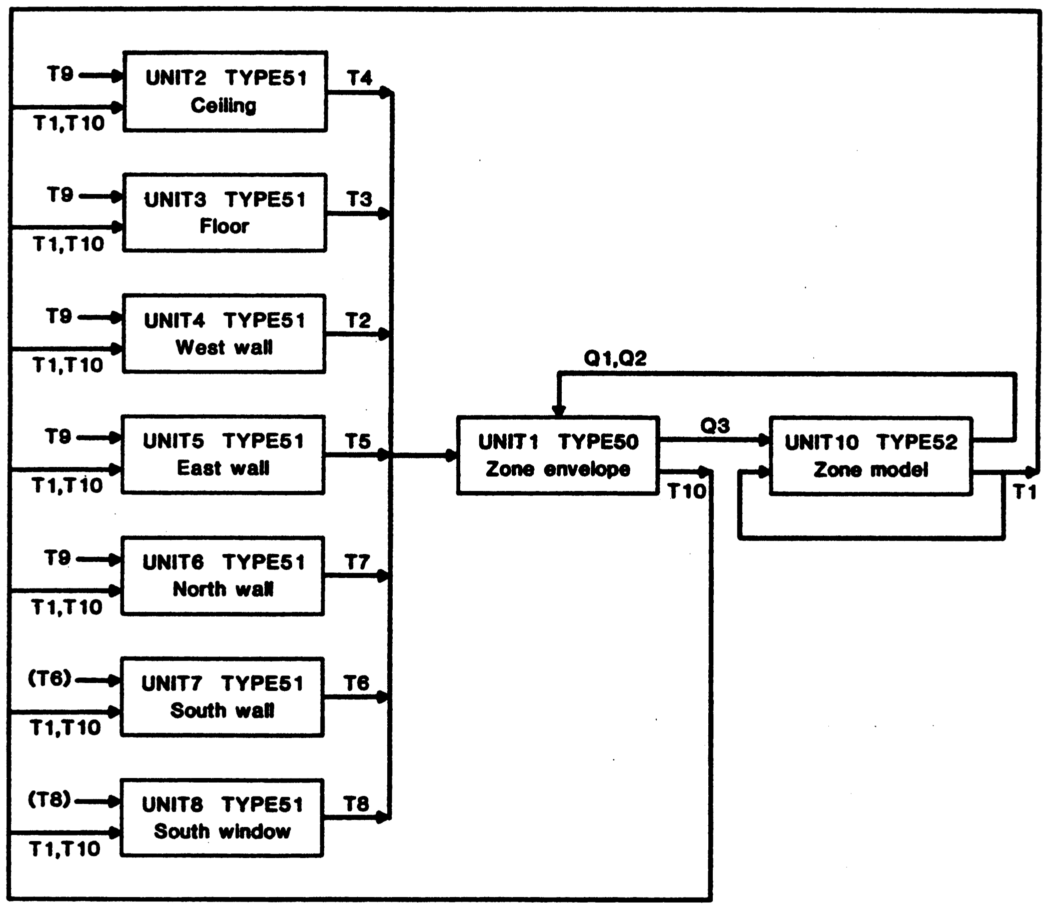


Figure C-2. Block diagram of the single-zone model

```
--------------
* Worksheets
--------------

***********************************************************************************

TYPE 50   ZONE ENVELOPE                               UNIT= 1

INPUTS:
TIA:        Zone air dry-bulb temperature (C) -----------------T1
QISW:       Internal (short wave) radiant gain from lights(kW)--Q1
QILW:       Internal (long wave) radiant gain (kW) -------------Q2
TIS(1):     Inner  surface temperature (C) ---------------------T2
TIS(2):     Inner  surface temperature (C) ---------------------T3
TIS(3):     Inner  surface temperature (C) ---------------------T4
TIS(4):     Inner  surface temperature (C) ---------------------T5
TIS(5):     Inner  surface temperature (C) ---------------------T6
TIS(6):     Inner  surface temperature (C) ---------------------T7
TIS(7):     Inner  surface temperature (C) ---------------------T8
TIS(8):     Inner  surface temperature (C) ---------------------T8
TIS(9):     Inner  surface temperature (C) ---------------------T8
TIS(10):    Inner  surface temperature (C) ---------------------T8

OUTPUTS:
TMR:        Mean radiant temperature (C) ----------------------T10
QWALL:      Convective heat gain from building surfaces (kW) ---Q3

PARAMETERS:
1 IZN:      Identification number of zone ---------------------1
2 NS:       Number of surfaces of zone ------------------------7

NOTE: When the number of surfaces is less than 10, an index of
      the last surface may be used for the remaining temperature
      inputs.
```

************************************************************************

TYPE 51 BUILDING SURFACE *ceiling* UNIT= 2

INPUTS:

| | | |
|---|---|---|
| TIA: | Indoor air dry-bulb temperature (C) ----------------T | 1 |
| TMR: | Mean radiant temperature (C) -----------------------T | 10 |
| TOSINF: | Outer surface temperature of unexposed wall(C)------T | 9 |
| FSHADW: | Shaded fraction of exposed outer surface (-) -------C | 5 |

OUTPUTS:

| | | |
|---|---|---|
| TIS: | Inner surface temperature (C) ----------------------T | 4 |
| SOLINT: | Integrated solar flux incident on surface (W/m2) ---Q | 0 |

PARAMETERS:

| | | | |
|---|---|---|---|
| 1 | IZN: | Identification number of zone ---------------------- | 1 |
| 2 | ID: | Identification number of surface ------------------- | 1 |
| 3 | IEXPSO: | 0=W/in zone, 1=betw. zones, 2=exposed to sun (-) --- | 1 |
| 4 | ISTR: | Identification number of the construct ------------- | 1 |
| 5 | AS: | Surface area (m2) ---------------------------------- | 37.21 |
| 6 | ORIENT: | Azimuth angle between normal to surface & south ---- | 0 |
| 7 | TILT: | Tilt angle : flat roof=0, floor=180 (degree) ------- | 0 |
| 8 | GRF: | Ground reflectivity (-) ---------------------------- | 0 |
| 9 | IROFS: | Outer surface roughness index [1,6] (-) ------------ | 0 |
| 10 | ABSOS: | Solar absorptance of the outer surface (-) --------- | 0 |
| 11 | ABSIS: | Short wave absorptance of the inner surface -------- | 0.6 |
| 12 | EMITIS: | Emissivity of the inner surface (-) ---------------- | 0.9 |
| 13 | TRANSM: | Transmittance of the glass window (-) -------------- | 0 |
| 14 | SC: | Shading coefficient of the glass window (-) -------- | 0 |

NOTE: If outer surface is exposed to outside air (IEXPOS=2), the index of TOSINF may be the same index of TIS.

The orintation angle of an west facing surface is 90 degrees, while an east facing surface is 270 degrees.

The surface roughness index, IROFS, is defined as follows:

IROFS = 1 Stucco
2 Brick, rough plaster
3 Concrete
4 Clear pine
5 Smooth plaster
6 Glass, paint on pine

```
**************************************************************************

TYPE 51   BUILDING SURFACE       Floor          UNIT=3

INPUTS:
TIA:        Indoor air dry-bulb temperature (C) ----------------T1
TMR:        Mean radiant temperature (C) -----------------------T10
TOSINF:     Outer surface temperature of unexposed wall(C)------T9
FSHADW:     Shaded fraction of exposed outer surface (-) -------C5

OUTPUTS:
TIS:        Inner surface temperature (C) ----------------------T3
SOLINT:     Integrated solar flux incident on surface (W/m2) ---Q0

PARAMETERS:
 1 IZN:     Identification number of zone ---------------------- 1
 2 ID:      Identification number of surface ------------------- 2
 3 IEXPSO:  0=W/in zone, 1=betw. zones, 2=exposed to sun (-) --- 1
 4 ISTR:    Identification number of the construct ------------- 2
 5 AS:      Surface area  (m2) --------------------------------- 37.21
 6 ORIENT:  Azimuth angle between normal to surface & south ---- 0
 7 TILT:    Tilt angle : flat roof=0, floor=180 (degree) ------- 180
 8 GRF:     Ground reflectivity (-) ---------------------------- 0
 9 IROFS:   Outer surface roughness index [1,6] (-) ------------ 0
10 ABSOS:   Solar absorptance of the outer surface (-) --------- 0
11 ABSIS:   Short wave absorptance of the inner surface -------- 0.6
12 EMITIS:  Emissivity of the inner surface (-) ---------------- 0.9
13 TRANSM:  Transmittance of the glass window (-) -------------- 0
14 SC:      Shading coefficient of the glass window (-) -------- 0


NOTE: If outer surface is exposed to outside air (IEXPOS=2),
      the index of TOSINF may be the same index of TIS.

      The orintation angle of an  west facing surface is 90
      degrees, while an east facing surface is 270 degrees.

      The surface roughness index, IROFS, is defined as follows:
      IROFS = 1   Stucco
              2   Brick, rough plaster
              3   Concrete
              4   Clear pine
              5   Smooth plaster
              6   Glass, paint on pine
```

***********************************************************************

TYPE 51    BUILDING SURFACE    West Wall    UNIT= 4

INPUTS:

| | | |
|---|---|---|
| TIA: | Indoor air dry-bulb temperature (C) ---------------- | T 1 |
| TMR: | Mean radiant temperature (C) ----------------------- | T 10 |
| TOSINF: | Outer surface temperature of unexposed wall(C)------ | T 9 |
| FSHADW: | Shaded fraction of exposed outer surface (-) ------- | C 5 |

OUTPUTS:

| | | |
|---|---|---|
| TIS: | Inner surface temperature (C) ---------------------- | T 2 |
| SOLINT: | Integrated solar flux incident on surface (W/m2) --- | Q 0 |

PARAMETERS:

| | | | |
|---|---|---|---|
| 1 | IZN: | Identification number of zone ---------------------- | 1 |
| 2 | ID: | Identification number of surface ------------------- | 3 |
| 3 | IEXPSO: | 0=W/in zone, 1=betw. zones, 2=exposed to sun (-) --- | 1 |
| 4 | ISTR: | Identification number of the construct ------------- | 3 |
| 5 | AS: | Surface area (m2) ---------------------------------- | 24.4 |
| 6 | ORIENT: | Azimuth angle between normal to surface & south ---- | 90 |
| 7 | TILT: | Tilt angle : flat roof=0, floor=180 (degree) ------- | 90 |
| 8 | GRF: | Ground reflectivity (-) ---------------------------- | 0 |
| 9 | IROFS: | Outer surface roughness index [1,6] (-) ------------ | 0 |
| 10 | ABSOS: | Solar absorptance of the outer surface (-) --------- | 0 |
| 11 | ABSIS: | Short wave absorptance of the inner surface -------- | 0.6 |
| 12 | EMITIS: | Emissivity of the inner surface (-) ---------------- | 0.9 |
| 13 | TRANSM: | Transmittance of the glass window (-) -------------- | 0 |
| 14 | SC: | Shading coefficient of the glass window (-) -------- | 0 |

NOTE: If outer surface is exposed to outside air (IEXPOS=2), the index of TOSINF may be the same index of TIS.

The orintation angle of an west facing surface is 90 degrees, while an east facing surface is 270 degrees.

The surface roughness index, IROFS, is defined as follows:

IROFS = 1 Stucco
2 Brick, rough plaster
3 Concrete
4 Clear pine
5 Smooth plaster
6 Glass, paint on pine

***********************************************************************

TYPE 51   BUILDING SURFACE   East Wall   UNIT= 5

INPUTS:

| | | |
|---|---|---|
| TIA: | Indoor air dry-bulb temperature (C) ---------------- | T 1 |
| TMR: | Mean radiant temperature (C) ----------------------- | T 10 |
| TOSINF: | Outer surface temperature of unexposed wall(C)------ | T 9 |
| FSHADW: | Shaded fraction of exposed outer surface (-) ------- | C 5 |

OUTPUTS:

| | | |
|---|---|---|
| TIS: | Inner surface temperature (C) ---------------------- | T 5 |
| SOLINT: | Integrated solar flux incident on surface (W/m2) --- | Q 0 |

PARAMETERS:

| | | | |
|---|---|---|---|
| 1 | IZN: | Identification number of zone ---------------------- | 1 |
| 2 | ID: | Identification number of surface ------------------- | 4 |
| 3 | IEXPSO: | 0=W/in zone, 1=betw. zones, 2=exposed to sun (-) --- | 1 |
| 4 | ISTR: | Identification number of the construct ------------- | 3 |
| 5 | AS: | Surface area (m2) ---------------------------------- | 24.4 |
| 6 | ORIENT: | Azimuth angle between normal to surface & south ---- | 270 |
| 7 | TILT: | Tilt angle : flat roof=0, floor=180 (degree) ------- | 90 |
| 8 | GRF: | Ground reflectivity (-) ---------------------------- | 0 |
| 9 | IROFS: | Outer surface roughness index [1,6] (-) ------------ | 0 |
| 10 | ABSOS: | Solar absorptance of the outer surface (-) --------- | 0 |
| 11 | ABSIS: | Short wave absorptance of the inner surface -------- | 0.6 |
| 12 | EMITIS: | Emissivity of the inner surface (-) ---------------- | 0.9 |
| 13 | TRANSM: | Transmittance of the glass window (-) -------------- | 0 |
| 14 | SC: | Shading coefficient of the glass window (-) -------- | 0 |

NOTE: If outer surface is exposed to outside air (IEXPOS=2), the index of TOSINF may be the same index of TIS.

The orintation angle of an west facing surface is 90 degrees, while an east facing surface is 270 degrees.

The surface roughness index, IROFS, is defined as follows:

IROFS = 1 Stucco
2 Brick, rough plaster
3 Concrete
4 Clear pine
5 Smooth plaster
6 Glass, paint on pine

************************************************************************

TYPE 51   BUILDING SURFACE   North Wall   UNIT= 6

INPUTS:

| | | |
|---|---|---|
| TIA: | Indoor air dry-bulb temperature (C) ----------------T | 1 |
| TMR: | Mean radiant temperature (C) -----------------------T | 10 |
| TOSINF: | Outer surface temperature of unexposed wall(C)------T | 9 |
| FSHADW: | Shaded fraction of exposed outer surface (-) -------C | 5 |

OUTPUTS:

| | | |
|---|---|---|
| TIS: | Inner surface temperature (C) ----------------------T | 7 |
| SOLINT: | Integrated solar flux incident on surface (W/m2) ---Q | 0 |

PARAMETERS:

| | | |
|---|---|---|
| 1 IZN: | Identification number of zone --------------------- | 1 |
| 2 ID: | Identification number of surface ------------------ | 5 |
| 3 IEXPSO: | 0=W/in zone, 1=betw. zones, 2=exposed to sun (-) --- | 1 |
| 4 ISTR: | Identification number of the construct ------------- | 3 |
| 5 AS: | Surface area (m2) ----------------------------------- | 24.4 |
| 6 ORIENT: | Azimuth angle between normal to surface & south ---- | 180 |
| 7 TILT: | Tilt angle : flat roof=0, floor=180 (degree) ------- | 90 |
| 8 GRF: | Ground reflectivity (-) ----------------------------- | 0 |
| 9 IROFS: | Outer surface roughness index [1,6] (-) ------------ | 0 |
| 10 ABSOS: | Solar absorptance of the outer surface (-) --------- | 0 |
| 11 ABSIS: | Short wave absorptance of the inner surface -------- | 0.6 |
| 12 EMITIS: | Emissivity of the inner surface (-) ---------------- | 0.9 |
| 13 TRANSM: | Transmittance of the glass window (-) -------------- | 0 |
| 14 SC: | Shading coefficient of the glass window (-) -------- | 0 |

NOTE: If outer surface is exposed to outside air (IEXPOS=2), the index of TOSINF may be the same index of TIS.

The orintation angle of an west facing surface is 90 degrees, while an east facing surface is 270 degrees.

The surface roughness index, IROFS, is defined as follows:

IROFS = 1 Stucco
2 Brick, rough plaster
3 Concrete
4 Clear pine
5 Smooth plaster
6 Glass, paint on pine

************************************************************************

TYPE 51   BUILDING SURFACE   South Wall   UNIT= 7

INPUTS:

```
TIA:        Indoor air dry-bulb temperature (C) ----------------T1
TMR:        Mean radiant temperature (C) -----------------------T10
TOSINF:     Outer surface temperature of unexposed wall(C)------T6
FSHADW:     Shaded fraction of exposed outer surface (-) -------C4
```

OUTPUTS:

```
TIS:        Inner surface temperature (C) ----------------------T6
SOLINT:     Integrated solar flux incident on surface (W/m2) ---O5
```

PARAMETERS:

```
 1 IZN:     Identification number of zone ---------------------- 1
 2 ID:      Identification number of surface ------------------- 6
 3 IEXPSO:  0=W/in zone, 1=betw. zones, 2=exposed to sun (-) --- 2
 4 ISTR:    Identification number of the construct ------------- 4
 5 AS:      Surface area  (m2) ---------------------------------- 18.4
 6 ORIENT:  Azimuth angle between normal to surface & south ---- 0
 7 TILT:    Tilt angle : flat roof=0, floor=180 (degree) ------- 90
 8 GRF:     Ground reflectivity (-) ---------------------------- 0.2
 9 IROFS:   Outer surface roughness index [1,6] (-) ------------ 2
10 ABSOS:   Solar absorptance of the outer surface (-) --------- 0.6
11 ABSIS:   Short wave absorptance of the inner surface -------- 0.6
12 EMITIS:  Emissivity of the inner surface (-) ---------------- 0.9
13 TRANSM:  Transmittance of the glass window (-) -------------- 0
14 SC:      Shading coefficient of the glass window (-) -------- 0
```

NOTE: If outer surface is exposed to outside air (IEXPOS=2), the index of TOSINF may be the same index of TIS.

The orintation angle of an west facing surface is 90 degrees, while an east facing surface is 270 degrees.

The surface roughness index, IROFS, is defined as follows:

```
IROFS = 1   Stucco
        2   Brick, rough plaster
        3   Concrete
        4   Clear pine
        5   Smooth plaster
        6   Glass, paint on pine
```

*************************************************************************

TYPE 51 BUILDING SURFACE South Window UNIT= 8

INPUTS:

| | | |
|---|---|---|
| TIA: | Indoor air dry-bulb temperature (C) ----------------- | T 1 |
| TMR: | Mean radiant temperature (C) ------------------------ | T 10 |
| TOSINF: | Outer surface temperature of unexposed wall(C)------ | T 8 |
| FSHADW: | Shaded fraction of exposed outer surface (-) ------- | C 4 |

OUTPUTS:

| | | |
|---|---|---|
| TIS: | Inner surface temperature (C) ----------------------- | T 8 |
| SOLINT: | Integrated solar flux incident on surface (W/m2) --- | Q 4 |

PARAMETERS:

| | | |
|---|---|---|
| 1 IZN: | Identification number of zone ---------------------- | 1 |
| 2 ID: | Identification number of surface ------------------- | 7 |
| 3 IEXPSO: | 0=W/in zone, 1=betw. zones, 2=exposed to sun (-) --- | 2 |
| 4 ISTR: | Identification number of the construct ------------- | 5 |
| 5 AS: | Surface area (m2) ---------------------------------- | 6.0 |
| 6 ORIENT: | Azimuth angle between normal to surface & south ---- | 0 |
| 7 TILT: | Tilt angle : flat roof=0, floor=180 (degree) ------- | 90 |
| 8 GRF: | Ground reflectivity (-) ---------------------------- | 0.2 |
| 9 IROFS: | Outer surface roughness index [1,6] (-) ------------ | 6 |
| 10 ABSOS: | Solar absorptance of the outer surface (-) --------- | 0 |
| 11 ABSIS: | Short wave absorptance of the inner surface -------- | 0 |
| 12 EMITIS: | Emissivity of the inner surface (-) ---------------- | 0 |
| 13 TRANSM: | Transmittance of the glass window (-) -------------- | 0.95 |
| 14 SC: | Shading coefficient of the glass window (-) -------- | 0.85 |

NOTE: If outer surface is exposed to outside air (IEXPOS=2), the index of TOSINF may be the same index of TIS.

The orintation angle of an west facing surface is 90 degrees, while an east facing surface is 270 degrees.

The surface roughness index, IROFS, is defined as follows:

IROFS = 1 Stucco
2 Brick, rough plaster
3 Concrete
4 Clear pine
5 Smooth plaster
6 Glass, paint on pine

```
*************************************************************************

TYPE 53   WEATHER INPUT                               UNIT= 9

INPUTS:
TAMB:        Ambient (outdoor) air temperature (C)---------------T/2
HUMRAT:      Outdoor air humidity ratio (-) ----------------------H3
PBAR:        Barometric pressure (kPa) ---------------------------P3
IDN:         Direct normal solar radiation (W/m2) ----------------Q6
ISKY:        Diffuse (sky) solar radiation (W/m2) ----------------Q7
IHOR:        Total horizontal solar radiation (W/m2) -------------Q8

OUTPUTS:     none

PARAMETERS:
 1 Index for ambient temperature  (e.g. 5 if TAMB= T5) ---------/2
 2 Index for outdoor air humidity ratio ------------------------ 3
 3 Index for barometric pressure ------------------------------- 3
 4 Index for direct normal solar radiation --------------------- 6
 5 Index for diffuse (sky) solar radiation --------------------- 7
 6 Index for total horizontal solar radiation ------------------ 8
```

```
**********************************************************************

TYPE 52    ZONE MODEL                                   UNIT= 10

INPUTS:
PIAG:      Gage pressure of zone air (kPa) ---------------------P1
TIA:       Zone air dry-bulb temperature (C) -------------------T1
WIA:       Humidiy ratio of zone air (-) -----------------------H1
PSAG:      Gage pressure of supply air (kPa) -------------------P2
MSA:       Mass flow rate of supply air (kg/s) -----------------M1
TSA:       Supply air dry-bulb temperature (C) -----------------T11
WSA:       Humidity ratio of supply air (-) --------------------H2
QWALL:     Convective heat gain from building surfaces (kW) ---Q3
NUMPEP:    Number of people (occupant in the zone) ------------C1
UTCEQP:    Equipment utilization coeff. (-) --------------------C2
UTCLIT:    Lighting utilization coeff. (-) ---------------------C3

OUTPUTS:
TIA:       Zone air dry-bulb temperature [diff. eq.] (C) ------T1
WIA:       Humidiy ratio of zone air [diff. eq.] ---------------H1
QISW:      Internal (short wave) radiant gain from lights(kW)--Q1
QILW:      Internal (long wave) radiant gain (kW) -------------Q2

PARAMETER:
 1 IZN:     Identification number of zone ---------------------- 1
 2 CFUR:    Effective thermal capacitance of furnishing (kJ/K) - 200
 3 EFFMIA:  Air mass multiplier for zone moisture capacitance -- 4
 4 VOLUME:  Volume of zone air (interior space of zone) (m3) --- 148.84
 5 SAIREX:  Std air exchange rate (0.5=tight,1.0=std,1.5=leaky)- 1.0
 6 WPEPS:   Sensible heat gain from a person (kW)  ------------- 0.07176
 7 WPEPL:   Latent heat gain from a person (kW)  --------------- 0.0454
 8 WLIT:    Heat gain due to lighting in the zone (kW) --------- 0.2
 9 LIGHT:   1 = Fluorescent, 2 = Incandescent ------------------ 1
10 WEQPS:   Sensible heat gain due to equipment (kW) ----------- 0.15
11 WEQPL:   Latent heat gain due to equipment (kW) ------------- 0.02
12 REQP:    Radiative to sensible heat from equipment (-)------- 0.3
```

---------------------------------------
* Initial Conditions of State Variables
---------------------------------------

| | | |
|---|---|---|
| P1 | Zone air pressure, gage | 0.0 kPa |
| P2 | Supply air pressure, gage | 0.0 kPa |
| P3 | Barometric pressure of ambient air | 101.3 kPa |
| M1 | Supply air mass flow rate | 0.0 kg/s |
| T1 | Zone air dry-bulb temperature | 20.0 C |
| T2 | Inner surface temperature of west wall | 20.0 C |
| T3 | Inner surface temperature of floor | 20.0 C |
| T4 | Inner surface temperature of ceiling | 20.0 C |
| T5 | Inner surface temperature of east wall | 20.0 C |
| T6 | Inner surface temperature of south wall | 20.0 C |
| T7 | Inner surface temperature of north wall | 20.0 C |
| T8 | Inner surface temperature of south window | 20.0 C |
| T9 | Outer surface temperature of unexposed surfaces | 20.0 C |
| T10 | Mean radiant temperature | 20.0 C |
| T11 | Supply air dry-bulb temperature | 20.0 C |
| T12 | Ambient temperature | 20.0 C |
| C1 | Number of people | 1.0 |
| C2 | Equipment utilization coefficient | 1.0 |
| C3 | Light utilization coefficient | 1.0 |
| C4 | Shaded fraction of exposed outer surface | 0.0 |
| C5 | Shaded fraction of unexposed surfaces | 1.0 |
| Q1 | Short wave radiant heat gain | 0.0 kW |
| Q2 | Long wave radiant heat gain | 0.0 kW |
| Q3 | Convective heat gain from building surfaces | 0.0 kW |
| Q4 | Average solar radiation influx of window | 0.0 kW |
| Q5 | Average solar radiation influx of exposed wall | 0.0 kW |
| Q6 | Direct solar radiation | 0.0 kW |
| Q7 | Diffuse solar radiation | 0.0 kW |
| Q8 | Total horizontal solar radiation | 0.0 kW |
| H1 | Zone air humidity ratio | 0.0074 |
| H2 | Supply air humidity ratio | 0.0074 |
| H3 | Ambient air humidity ratio | 0.0074 |

```
-----------------------
* Execution of HVACGEN
-----------------------
 HVACGEN - Simulation GENeration Program
 Version 1.8 (08-16 1985)

 Choose from the list below:

 CReate (SImulation,BLock,UNit)

 EDit (SImulation,UNit)

 VIew (SImulation,BLock,UNit)

 HElp

 ENd

 Selection ?
VI SI ONEZONE

 reading from work file....
 INITIALIZING TYPES INFORMATION...

  What part of the simulation would you like to view:

 ALl the simulation information (for documentation)

 STructure (superblock,block, and unit Information)

 VAriable initial values

 ERror tolerances, variable scan and freeze options

 BOundary variables

 REported variables

 COntinue with the previous menu

AL

 ONE ZONE MODEL

 SUPERBLOCK 1
      BLOCK 1
           UNIT  1     TYPE 50 - ZONE ENVELOPE
           UNIT  2     TYPE 51 - BUILDING SURFACE
           UNIT  3     TYPE 51 - BUILDING SURFACE
           UNIT  4     TYPE 51 - BUILDING SURFACE
           UNIT  5     TYPE 51 - BUILDING SURFACE
           UNIT  6     TYPE 51 - BUILDING SURFACE
           UNIT  7     TYPE 51 - BUILDING SURFACE
           UNIT  8     TYPE 51 - BUILDING SURFACE
      BLOCK 2
           UNIT  9     TYPE 53 - WEATHER INPUT
```

```
SUPERBLOCK 2
    BLOCK 3
        UNIT 10     TYPE 52 - ZONE MODEL
----------------------------------------------------

UNIT   1      TYPE  50
ZONE ENVELOPE

1      INPUTS:
        TEMPERATURE       1 - TIA:     Zone air dry-bulb temperature
        POWER             1 - QISW:    Internal (short wave) radiant gain
        POWER             2 - QILW:    Internal (long wave) radiant gain
        TEMPERATURE       2 - TIS(1):  Inner  surface temperature
        TEMPERATURE       3 - TIS(2):  Inner  surface temperature
        TEMPERATURE       4 - TIS(3):  Inner  surface temperature
        TEMPERATURE       5 - TIS(4):  Inner  surface temperature
        TEMPERATURE       6 - TIS(5):  Inner  surface temperature
        TEMPERATURE       7 - TIS(6):  Inner  surface temperature
        TEMPERATURE       8 - TIS(7):  Inner  surface temperature
        TEMPERATURE       8 - TIS(8):  Inner  surface temperature
        TEMPERATURE       8 - TIS(9):  Inner  surface temperature
        TEMPERATURE       8 - TIS(10):Inner  surface temperature

2      OUTPUTS:
        TEMPERATURE      10 - TMR:     Mean radiant temperature
        POWER             3 - QWALL:   Convective heat gain from  surfaces

3      PARAMETERS:
           1.00000     IZN:     Identification number of zone
           7.00000     NS:      Number of surfaces of zone
----------------------------------------------------

UNIT   2      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE       1 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      10 - TMR:     Mean radiant temperature
        TEMPERATURE       9 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL           5 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       4 - TIS:     Inner surface temperature
        POWER             0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
           1.00000     IZN:     Identification number of zone
           1.00000     ID:      Identification number of surface
           1.00000     IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
           1.00000     ISTR:    Identification number of the construct
           37.2100     AS:      Surface area (m2)
          0.000000     ORIENT:  Azimuth angle of normal to surface & south
          0.000000     TILT:    Tilt angle: flat roof=0, floor=180 (degree)
          0.000000     GRF:     Ground reflectivity (-)
          0.000000     IROFS:   Outer surface roughness index: 1=stucco,...
          0.000000     ABSOS:   Solar absorptance of outer surface (-)
          0.600000     ABSIS:   Short wave absorptance of inner surface(-)
          0.900000     EMITIS:  Emissivity of the inner surface (-)
          0.000000     TRANSM:  Transmittance of the glass window (-)
          0.000000     SC:      Shading coeff. of the glass window (-)
```

```
---------------------------------------------------

UNIT   3      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE       1 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      10 - TMR:     Mean radiant temperature
        TEMPERATURE       9 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL           5 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       3 - TIS:     Inner surface temperature
        POWER             0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
           1.00000      IZN:     Identification number of zone
           2.00000      ID:      Identification number of surface
           1.00000      IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
           2.00000      ISTR:    Identification number of the construct
           37.2100      AS:      Surface area (m2)
          0.000000      ORIENT:  Azimuth angle of normal to surface & south
           180.000      TILT:    Tilt angle: flat roof=0, floor=180 (degree)
          0.000000      GRF:     Ground reflectivity (-)
          0.000000      IROFS:   Outer surface roughness index: 1=stucco,...
          0.000000      ABSOS:   Solar absorptance of outer surface (-)
          0.600000      ABSIS:   Short wave absorptance of inner surface(-)
          0.900000      EMITIS:  Emissivity of the inner surface (-)
          0.000000      TRANSM:  Transmittance of the glass window (-)
          0.000000      SC:      Shading coeff. of the glass window (-)
---------------------------------------------------

UNIT   4      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE       1 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      10 - TMR:     Mean radiant temperature
        TEMPERATURE       9 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL           5 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       2 - TIS:     Inner surface temperature
        POWER             0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
           1.00000      IZN:     Identification number of zone
           3.00000      ID:      Identification number of surface
           1.00000      IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
           3.00000      ISTR:    Identification number of the construct
           24.4000      AS:      Surface area (m2)
           90.0000      ORIENT:  Azimuth angle of normal to surface & south
           90.0000      TILT:    Tilt angle: flat roof=0, floor=180 (degree)
          0.000000      GRF:     Ground reflectivity (-)
          0.000000      IROFS:   Outer surface roughness index: 1=stucco,...
          0.000000      ABSOS:   Solar absorptance of outer surface (-)
          0.600000      ABSIS:   Short wave absorptance of inner surface(-)
          0.900000      EMITIS:  Emissivity of the inner surface (-)
          0.000000      TRANSM:  Transmittance of the glass window (-)
          0.000000      SC:      Shading coeff. of the glass window (-)
```

---

UNIT 5 TYPE 51
BUILDING SURFACE

```
1      INPUTS:
        TEMPERATURE         1 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE        10 - TMR:     Mean radiant temperature
        TEMPERATURE         9 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL             5 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE         5 - TIS:     Inner surface temperature
        POWER               0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
            1.00000     IZN:     Identification number of zone
            4.00000     ID:      Identification number of surface
            1.00000     IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
            3.00000     ISTR:    Identification number of the construct
            24.4000     AS:      Surface area (m2)
            270.000     ORIENT:  Azimuth angle of normal to surface & south
            90.0000     TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.000000     GRF:     Ground reflectivity (-)
           0.000000     IROFS:   Outer surface roughness index: 1=stucco,...
           0.000000     ABSOS:   Solar absorptance of outer surface (-)
           0.600000     ABSIS:   Short wave absorptance of inner surface(-)
           0.900000     EMITIS:  Emissivity of the inner surface (-)
           0.000000     TRANSM:  Transmittance of the glass window (-)
           0.000000     SC:      Shading coeff. of the glass window (-)
```

---

UNIT 6 TYPE 51
BUILDING SURFACE

```
1      INPUTS:
        TEMPERATURE         1 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE        10 - TMR:     Mean radiant temperature
        TEMPERATURE         9 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL             5 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE         7 - TIS:     Inner surface temperature
        POWER               0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
            1.00000     IZN:     Identification number of zone
            5.00000     ID:      Identification number of surface
            1.00000     IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
            3.00000     ISTR:    Identification number of the construct
            24.4000     AS:      Surface area (m2)
            180.000     ORIENT:  Azimuth angle of normal to surface & south
            90.0000     TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.000000     GRF:     Ground reflectivity (-)
           0.000000     IROFS:   Outer surface roughness index: 1=stucco,...
           0.000000     ABSOS:   Solar absorptance of outer surface (-)
           0.600000     ABSIS:   Short wave absorptance of inner surface(-)
           0.900000     EMITIS:  Emissivity of the inner surface (-)
           0.000000     TRANSM:  Transmittance of the glass window (-)
           0.000000     SC:      Shading coeff. of the glass window (-)
```

---

```
UNIT   7      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE       1 - TIA:    Indoor air dry-bulb temperature
        TEMPERATURE      10 - TMR:    Mean radiant temperature
        TEMPERATURE       6 - TOSINF: Outer surface temp. of unexposed wall
        CONTROL           4 - FSHADW: Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       6 - TIS:    Inner surface temperature
        POWER             5 - SOLINT: Integrated solar influx  on surface

3      PARAMETERS:
            1.00000     IZN:     Identification number of zone
            6.00000     ID:      Identification number of surface
            2.00000     IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
            4.00000     ISTR:    Identification number of the construct
            18.4000     AS:      Surface area (m2)
           0.000000     ORIENT:  Azimuth angle of normal to surface & south
            90.0000     TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.200000     GRF:     Ground reflectivity (-)
            2.00000     IROFS:   Outer surface roughness index: 1=stucco,...
           0.600000     ABSOS:   Solar absorptance of outer surface (-)
           0.600000     ABSIS:   Short wave absorptance of inner surface(-)
           0.900000     EMITIS:  Emissivity of the inner surface (-)
           0.000000     TRANSM:  Transmittance of the glass window (-)
           0.000000     SC:      Shading coeff. of the glass window (-)
```

---

```
UNIT   8      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE       1 - TIA:    Indoor air dry-bulb temperature
        TEMPERATURE      10 - TMR:    Mean radiant temperature
        TEMPERATURE       8 - TOSINF: Outer surface temp. of unexposed wall
        CONTROL           4 - FSHADW: Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       8 - TIS:    Inner surface temperature
        POWER             4 - SOLINT: Integrated solar influx  on surface

3      PARAMETERS:
            1.00000     IZN:     Identification number of zone
            7.00000     ID:      Identification number of surface
            2.00000     IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
            5.00000     ISTR:    Identification number of the construct
            6.00000     AS:      Surface area (m2)
           0.000000     ORIENT:  Azimuth angle of normal to surface & south
            90.0000     TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.200000     GRF:     Ground reflectivity (-)
            6.00000     IROFS:   Outer surface roughness index: 1=stucco,...
           0.000000     ABSOS:   Solar absorptance of outer surface (-)
           0.000000     ABSIS:   Short wave absorptance of inner surface(-)
           0.000000     EMITIS:  Emissivity of the inner surface (-)
           0.950000     TRANSM:  Transmittance of the glass window (-)
           0.850000     SC:      Shading coeff. of the glass window (-)
```

```
---------------------------------------------------------

UNIT   9       TYPE  53
WEATHER INPUT

1      INPUTS:
        TEMPERATURE      12 - TAMB:    Ambient (outdoor) air temperature (C)
        ABS. HUMIDITY     3 - HUMRAT:  Outdoor air humidity ratio (-)
        PRESSURE          3 - PBAR:    Barometric pressure (kPa)
        POWER             6 - IDN:     Direct normal solar radiation (W/m2)
        POWER             7 - ISKY:    Diffuse (sky) solar radiation (W/m2)
        POWER             8 - IHOR:    Total horizontal solar radiation (W/m2)

2      OUTPUTS:

3      PARAMETERS:
           12.0000      Index for ambient temperature (e.g. 5 if TAMB=T5)
           3.00000      Index for outdoor air humidity ratio
           3.00000      Index for barometric pressure
           6.00000      Index for direct normal solar radiation
           7.00000      Index for diffuse (sky) solar radiation
           8.00000      Index for total horizontal solar radiation
---------------------------------------------------------

UNIT  10       TYPE  52
ZONE MODEL

1      INPUTS:
        PRESSURE          1 - PIAG:    Gage pressure of zone air
        TEMPERATURE       1 - TIA:     Zone air dry-bulb temperature
        ABS. HUMIDITY     1 - WIA:     Humidiy ratio of zone air
        PRESSURE          2 - PSAG:    Gage pressure of supply air
        FLOW              1 - MSA:     Mass flow rate of supply air
        TEMPERATURE      11 - TSA:     Supply air dry-bulb temperature
        ABS. HUMIDITY     2 - WSA:     Humidity ratio of supply air
        POWER             3 - QWALL:   Convective heat gain from surfaces
        CONTROL           1 - NUMPEP:  Number of people (occupant in the zone)
        CONTROL           2 - UTCEQP:  Equipment utilization coefficient
        CONTROL           3 - UTCLIT:  Lighting utilization coefficient

2      OUTPUTS:
        TEMPERATURE       1 - TIA:     Zone air dry-bulb temp. [diff. eq.]
        ABS. HUMIDITY     1 - WIA:     Humidity ratio of zone air [diff. eq.]
        POWER             1 - QISW:    Internal (short wave) radiant gain
        POWER             2 - QILW:    Internal (long wave) radiant gain

3      PARAMETERS:
           1.00000      IZN:     Identification number of zone
           200.000      CFUR:    Effective capacitance of furnishings (kJ/K)
           4.00000      EFFMIA:  Multiplier for zone moisture capacitance(-)
           148.840      VOLUME:  Volume of zone air (interior space ) (m3)
           1.00000      SAIREX:  Standard air exchange rate (1/h)
         0.717600E-01   WPEPS:   Sensible heat gain from a person (kW)
         0.454000E-01   WPEPL:   Latent heat gain from a person (kW)
         0.200000       WLIT:    Heat gain due to lighting in the zone (kW)
           1.00000      LIGHT:   1 = Fluorescent, 2 = Incandescent (-)
         0.150000       WEQPS:   Sensible heat gain due to equipment (kW)
         0.200000E-01   WEQPL:   Latent heat gain due to equipment (kW)
         0.300000       REQP:    Radiative to sensible heat from equipment(-)
---------------------------------------------------------
```

```
Initial Variable Values:

PRESSURE          1 ->     0.000000     (kPa)
PRESSURE          2 ->     0.000000     (kPa)
PRESSURE          3 ->      101.300     (kPa)
FLOW              1 ->     0.000000     (kg/s)
TEMPERATURE       1 ->      20.0000     (C)
TEMPERATURE       2 ->      20.0000     (C)
TEMPERATURE       3 ->      20.0000     (C)
TEMPERATURE       4 ->      20.0000     (C)
TEMPERATURE       5 ->      20.0000     (C)
TEMPERATURE       6 ->      20.0000     (C)
TEMPERATURE       7 ->      20.0000     (C)
TEMPERATURE       8 ->      20.0000     (C)
TEMPERATURE       9 ->      20.0000     (C)
TEMPERATURE      10 ->      20.0000     (C)
TEMPERATURE      11 ->      20.0000     (C)
TEMPERATURE      12 ->      20.0000     (C)
CONTROL           1 ->      1.00000     (-)
CONTROL           2 ->      1.00000     (-)
CONTROL           3 ->      1.00000     (-)
CONTROL           4 ->     0.000000     (-)
CONTROL           5 ->      1.00000     (-)
POWER             1 ->     0.000000     (kW)
POWER             2 ->     0.000000     (kW)
POWER             3 ->     0.000000     (kW)
POWER             4 ->     0.000000     (kW)
POWER             5 ->     0.000000     (kW)
POWER             6 ->     0.000000     (kW)
POWER             7 ->     0.000000     (kW)
POWER             8 ->     0.000000     (kW)
ABS. HUMIDITY     1 ->     0.740000E-02(kg(water)/kg(air))
ABS. HUMIDITY     2 ->     0.740000E-02(kg(water)/kg(air))
ABS. HUMIDITY     3 ->     0.740000E-02(kg(water)/kg(air))
-----------------------------------------------------
Simulation Error Tolerances:

1       RTOLX=    0.100000E-03      ATOLX=    0.100000E-04
        XTOL=     0.200000E-03      TTIME=     1.00000

SUPERBLOCK 1
2       FREEZE OPTION 0       SCAN OPTION 0

SUPERBLOCK 2
3       FREEZE OPTION 0       SCAN OPTION 0
-----------------------------------------------------
The following are Boundary Variables in the simulation:

-----------------------------------------------------
The following are the reported variables:


SUPERBLOCK 1         REPORTING INTERVAL     3600.00
TEMPERATURE       2
TEMPERATURE       3
TEMPERATURE       4
TEMPERATURE       5
TEMPERATURE       6
TEMPERATURE       7
TEMPERATURE       8
```

```
 TEMPERATURE     10
 TEMPERATURE     12
 POWER            3
 POWER            6
 POWER            7
 POWER            8

 SUPERBLOCK 2       REPORTING INTERVAL     3600.00
 TEMPERATURE      1
 ABS. HUMIDITY    1

 Selection ?
END
STOP
```

```
--------------------------------------------
* File: ONEZONE.SIM (Simulation Work File)
--------------------------------------------
```

```
ONE ZONE MODEL
    2
    0.100000E-03   0.100000E-04   0.200000E-03   0.100000E+01
    2
    8
    1  50
    1   1   2   2   3   4   5   6   7   8   8   8   8
   10   3
    0.100000E+01   0.700000E+01
    2  51
    1  10   9   5
    4   0
    0.100000E+01   0.100000E+01   0.100000E+01   0.100000E+01   0.372100E+02
    0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
    0.600000E+00   0.900000E+00   0.000000E+00   0.000000E+00
    3  51
    1  10   9   5
    3   0
    0.100000E+01   0.200000E+01   0.100000E+01   0.200000E+01   0.372100E+02
    0.000000E+00   0.180000E+03   0.000000E+00   0.000000E+00   0.000000E+00
    0.600000E+00   0.900000E+00   0.000000E+00   0.000000E+00
    4  51
    1  10   9   5
    2   0
    0.100000E+01   0.300000E+01   0.100000E+01   0.300000E+01   0.244000E+02
    0.900000E+02   0.900000E+02   0.000000E+00   0.000000E+00   0.000000E+00
    0.600000E+00   0.900000E+00   0.000000E+00   0.000000E+00
    5  51
    1  10   9   5
    5   0
    0.100000E+01   0.400000E+01   0.100000E+01   0.300000E+01   0.244000E+02
    0.270000E+03   0.900000E+02   0.000000E+00   0.000000E+00   0.000000E+00
    0.600000E+00   0.900000E+00   0.000000E+00   0.000000E+00
    6  51
    1  10   9   5
    7   0
    0.100000E+01   0.500000E+01   0.100000E+01   0.300000E+01   0.244000E+02
    0.180000E+03   0.900000E+02   0.000000E+00   0.000000E+00   0.000000E+00
    0.600000E+00   0.900000E+00   0.000000E+00   0.000000E+00
    7  51
    1  10   6   4
```

```
 6    5
 0.100000E+01   0.600000E+01   0.200000E+01   0.400000E+01   0.184000E+02
 0.000000E+00   0.900000E+02   0.200000E+00   0.200000E+01   0.600000E+00
 0.600000E+00   0.900000E+00   0.000000E+00   0.000000E+00
 8   51
 1   10    8    4
 8    4
 0.100000E+01   0.700000E+01   0.200000E+01   0.500000E+01   0.600000E+01
 0.000000E+00   0.900000E+02   0.200000E+00   0.600000E+01   0.000000E+00
 0.000000E+00   0.000000E+00   0.950000E+00   0.850000E+00
 1
 9   53
12    3    3    6    7    8

 0.120000E+02   0.300000E+01   0.300000E+01   0.600000E+01   0.700000E+01
 0.800000E+01
 1
 1
10   52
 1    1    1    2    1   11    2    3    1    2    3
 1    1    1    2
 0.100000E+01   0.200000E+03   0.400000E+01   0.148840E+03   0.100000E+01
 0.717600E-01   0.454000E-01   0.200000E+00   0.100000E+01   0.150000E+00
 0.200000E-01   0.300000E+00
 0.000000E+00   0.000000E+00   0.101300E+03   0.000000E+00   0.200000E+02
 0.200000E+02   0.200000E+02   0.200000E+02   0.200000E+02   0.200000E+02
 0.200000E+02   0.200000E+02   0.200000E+02   0.200000E+02   0.200000E+02
 0.200000E+02   0.100000E+01   0.100000E+01   0.100000E+01   0.000000E+00
 0.100000E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.740000E-02
 0.740000E-02   0.740000E-02
 0

13    0.360000E+04
 6    7    8    9   10   11   12   14   16   24   27   28   29
 3    3    3    3    3    3    3    3    3    7    7    7    7
 2    3    4    5    6    7    8   10   12    3    6    7    8
 2    0.360000E+04
 5   30
 3    8
 1    1
 0    0
 0    0
****************OLD****WORK****FILE****ENDS****HERE***************
 2    3   10
 2    1
 3    1   12    5    0    0    8    3
32
13    2
```

(2) Creation of Model Definition File

```
-------------------------
* Execution of SLIMCON
-------------------------
 Simulation Work File to Model Definition File Converter
 Version 2.1 (November 13, 1984)
 Enter the simulation filename (Up to 8 characters) or carriage return to end.
ONEZONE
              2 superblocks in the simulation .......... MAXIMUM =  10 ( 20.0%)
              3 blocks in the simulation ............... MAXIMUM =  50 (  6.0%)
              2 differential equations in the simulation MAXIMUM =  50 (  4.0%)
            399 saved variables in the simulation ...... MAXIMUM =6000 (  6.7%)
             10 units in the simulation ................ MAXIMUM = 200 (  5.0%)
              8 units in a single block ................ MAXIMUM =  20 ( 40.0%)
              2 differential equations in one unit ..... MAXIMUM =  10 ( 20.0%)
             13 inputs or outputs in a single unit ..... MAXIMUM =  20 ( 65.0%)
             14 parameters in a single unit ............ MAXIMUM =  30 ( 46.7%)
              2 blocks in the largest superblock ....... MAXIMUM =  10 ( 20.0%)
              2 differential equations in one superblock MAXIMUM =  20 ( 10.0%)
             32 state variables in the simulation ...... MAXIMUM = 600 (  5.3%)
             14 inputs or outputs in a single block .... MAXIMUM =  50 ( 28.0%)
            118 unit parameters in the simulation ...... MAXIMUM =1000 ( 11.8%)
              8 simultaneous equations in a single block MAXIMUM =  30 ( 26.7%)
              0 simultaneous equations in one superblock MAXIMUM =  20 (  0.0%)
              0 time dependent boundary variables ...... MAXIMUM =  30 (  0.0%)
              0 boundary conditions in one superblock .. MAXIMUM =  20 (  0.0%)
             13 reported variables in one superblock ... MAXIMUM =  30 ( 43.3%)
 Model Definition File Complete
```

```
-------------------------------------------------------------
* File: ONEZONE.DAT ==> MODELDEF.DAT (Model Definition File)
-------------------------------------------------------------

 ONE ZONE MODEL
  32   2
   2   1
   0.000000E+00   0.000000E+00   0.101300E+03   0.000000E+00   0.200000E+02
   0.200000E+02   0.200000E+02   0.200000E+02   0.200000E+02   0.200000E+02
   0.200000E+02   0.200000E+02   0.200000E+02   0.200000E+02   0.200000E+02
   0.200000E+02   0.100000E+01   0.100000E+01   0.100000E+01   0.000000E+00
   0.100000E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.740000E-02
   0.740000E-02   0.740000E-02
   0   3   4  16  -1  -1  21  29
   8   1   1
   0   0
   8   0   2
   1   2
   3
   1   2   3   4   5   6   7   8
   9
  10
  50  51  51  51  51  51  51  51  53  52
  13   4   4   4   4   4   4   4   6  11
   5  22  23   6   7   8   9  10  11  12  12  12  12
   5  14  13  21
```

```
   5  14  13  21
   5  14  13  21
   5  14  13  21
   5  14  13  21
   5  14  10  20
   5  14  12  20
  16  32   3  27  28  29
   1   5  30   2   4  15  31  24  17  18  19
   2   2   2   2   2   2   2   2   0   4
  14  24
   8   0
   7   0
   6   0
   9   0
  11   0
  10  26
  12  25

   5  30  22  23
   0
   0
   8   7   6   9  11  10  12  14
   0
   5  30
   0   0   0   0   0   0   0   0   0   2
   0
   0
   0
   0
   0
   0
   0
   0
   0
   1   2
   5  30
   1   1  58 115 172 229 286 343 400 400
   1   3  17  31  45  59  73  87 101 107
 118 399
   0.100000E+01   0.700000E+01   0.100000E+01   0.100000E+01   0.100000E+01
   0.100000E+01   0.372100E+02   0.000000E+00   0.000000E+00   0.000000E+00
   0.000000E+00   0.000000E+00   0.600000E+00   0.900000E+00   0.000000E+00
   0.000000E+00   0.100000E+01   0.200000E+01   0.100000E+01   0.200000E+01
   0.372100E+02   0.000000E+00   0.180000E+03   0.000000E+00   0.000000E+00
   0.000000E+00   0.600000E+00   0.900000E+00   0.000000E+00   0.000000E+00
   0.100000E+01   0.300000E+01   0.100000E+01   0.300000E+01   0.244000E+02
   0.900000E+02   0.900000E+02   0.000000E+00   0.000000E+00   0.000000E+00
   0.600000E+00   0.900000E+00   0.000000E+00   0.000000E+00   0.100000E+01
   0.400000E+01   0.100000E+01   0.300000E+01   0.244000E+02   0.270000E+03
   0.900000E+02   0.000000E+00   0.000000E+00   0.000000E+00   0.600000E+00
   0.900000E+00   0.000000E+00   0.000000E+00   0.100000E+01   0.500000E+01
   0.100000E+01   0.300000E+01   0.244000E+02   0.180000E+03   0.900000E+02
   0.000000E+00   0.000000E+00   0.000000E+00   0.600000E+00   0.900000E+00
   0.000000E+00   0.000000E+00   0.100000E+01   0.600000E+01   0.200000E+01
   0.400000E+01   0.184000E+02   0.000000E+00   0.900000E+02   0.200000E+00
   0.200000E+01   0.600000E+00   0.600000E+00   0.900000E+00   0.000000E+00
   0.000000E+00   0.100000E+01   0.700000E+01   0.200000E+01   0.500000E+01
   0.600000E+01   0.000000E+00   0.900000E+02   0.200000E+00   0.600000E+01
   0.000000E+00   0.000000E+00   0.000000E+00   0.950000E+00   0.850000E+00
   0.120000E+02   0.300000E+01   0.300000E+01   0.600000E+01   0.700000E+01
```

```
0.800000E+01   0.100000E+01   0.200000E+03   0.400000E+01   0.148840E+03
0.100000E+01   0.717600E-01   0.454000E-01   0.200000E+00   0.100000E+01
0.150000E+00   0.200000E-01   0.300000E+00
0

13   2
0.360000E+04   0.360000E+04
6   7   8   9   10   11   12   14   16   24   27   28   29
3   3   3   3    3    3    3    3    3    7    7    7    7
2   3   4   5    6    7    8   10   12    3    6    7    8
5   30
3   8
1   1
0.100000E-03   0.100000E-04   0.200000E-03   0.100000E+01
0   0
0   0
```

(3) Creation of Boundary Variable File

No file for boundary variables is created in this example.

(4) Creation of Conduction Transfer Function File

```
------------------------------
* Composition of constructs
------------------------------

CONSTRUCT #1 (Ceiling)

                         (Outside)
              ------------------------------------
Layer 1          Acoustic tile                      (47): [material I.D. #
              ------------------------------------          in THERM.DAT file]
      2          Ceiling air space                  (46)
              ------------------------------------
      3          Concrete, 4-in.                    (36)
              ------------------------------------
      4          Vinyle tile, 3/32-in.              (48)*
              ------------------------------------
                         (Inside)

* Data for vinyle tile should be added to THERM.DAT file.

   Vinyle tile   L=0.002 m, k=0.27 W/mK,   = 1552.2 kg/m3, Cp=1.004 KJ/kg-K


CONSTRUCT #2 (Floor)

                         (Outside)
              ------------------------------------
Layer 1          Vinyle tile, 3/32-in.              (48)*
              ------------------------------------
      2          Concrete, 4-in.                    (36)
              ------------------------------------
      3          Ceiling air space                  (46)
              ------------------------------------
      4          Acoustic tile                      (47)
              ------------------------------------
                         (Inside)


CONSTRUCT #3 (Interior Walls)

                         (Outside)
              ------------------------------------
 Layer 1         Plaster, 3/4-in.                   (43)
              ------------------------------------
       2         Air space                           (8)
              ------------------------------------
       3         Plaster, 3/4-in.                   (43)
              ------------------------------------
                         (Inside)


CONSTRUCT #4  (Exposed Wall)
```

```
                      (Outside)
              -----------------------------------
Layer 1            Face Brick, 4-in.                 (2)
              -----------------------------------
      2            Fiberglass insulation, R-11       (10)
              -----------------------------------
      3            Air space                         (8)
              -----------------------------------
      4            Plaster, 3/4-in.                  (43)
              -----------------------------------
                      (Inside)


CONSTRUCT #5 (Exposed Glass Window)

                      (Outside)
              -----------------------------------
Layer 1            Glass, 3/32-in.                   (49)*
              -----------------------------------
      2            Air space                         (8)
              -----------------------------------
      3            Glass, 3/32-in.                   (49)*
              -----------------------------------
                      (Inside)

    Data for glass:  L=k=Cp=0 R=0.26 m2-K/W


------------------------
* Execution of CTFGEN
------------------------
                 Enter your choice:
 ****************************************************
 A => Add thermal property data to the construction
      materials database (THERM.DAT)
 B => Print the contents of the data file THERM.DAT
      to Logical Unit 6
 C => Create a CTF data file
 D => Change time interval in an existing CTF data file
 E => END
A
 *************************************************
 *                                               *
 *   YOU ARE NOW ADDING THERMAL PROPERTY DATA    *
 *   INTO THE EXISTING FILE (THERM.DAT)          *
 *   PLEASE ENTER YOUR DATA WITH CARE.           *
 *   METRIC UNITS MUST BE USED.                  *
 *                                               *
 *************************************************

  Enter the name of the construction material
  (up to 60 characters)
Vinyle tile
    Thickness (meters) =
0.002
    Conductivity (W/m.C) =
0.27
    Density (kg/m**3) =
1552.2
    Specific heat (kJ/kg.C) =
```

```
1.004
    Thermal resistance (m**2.C/W) =
0
  IDATA=48 LENGTH=2.0E-03 COND=0.27
  DENS=1552.2 SPHT=1.004 RVAL=0.0
 Do you want to continue?  <N>
y
  Enter the name of the construction material
  (up to 60 characters)
Glass
    Thickness (meters) =
0
    Conductivity (W/m.C) =
0
    Density (kg/m**3) =
0
    Specific heat (kJ/kg.C) =
0
    Thermal resistance (m**2.C/W) =
0.26
  IDATA=49 LENGTH=0.0 COND=0.0
  DENS=0.0 SPHT=0.0 RVAL=0.26
 Do you want to continue?  <N>

 -- END OF ADDITION ---
                 Enter your choice:
 ****************************************************
 A => Add thermal property data to the construction
      materials database (THERM.DAT)
 B => Print the contents of the data file THERM.DAT
      to Logical Unit 6
 C => Create a CTF data file
 D => Change time interval in an existing CTF data file
 E => END
C
  Enter the name of the CTF Definition File,
  or carriage return for default name: CTFINPUT.DAT

  Enter the name of the CTF Output File,
  or carriage return for default name: CTFDATA.DAT

 What kind of output do you want?
  0 ==>   for a very simple output,
  1 ==>   for a less simple output,
  2 ==>   for detailed output   or
  3 ==>   for root search
0
 What is the time interval for CTF calculation in s ?
900
 THIS CONSTRUCT ID NUMBER (ISTR) IS  1
 How many layers in this construct? (max. = 10 )
4
 Enter the layer ID numbers with most outer layer first
47,46,36,48
 ISTR: 1
 NCTF: 4  NORD: 2
 UVAL: 0.969606
 CTFX: 2.99057,  -3.713,  1.10035,  -6.3286E-02,  -3.55439E-05
 CTFY: 9.44398E-03,  0.163193,  0.132975,  8.93878E-03,  5.09487E-05
 CTFZ: 9.21826,  -13.4813,  4.86344,  -0.28575,  -8.8593E-05
```

```
 CTFQ: 0.735784,  -6.02473E-02
 Do you want to continue? <N>
Y
 THIS CONSTRUCT ID NUMBER (ISTR) IS  2
 How many layers in this construct? (max. = 10 )
4
 Enter the layer ID numbers with most outer layer first
48,36,46,47
 ISTR: 2
 NCTF: 4  NORD: 2
 UVAL: 0.969606
 CTFX: 9.21826,  -13.4813,  4.86344,  -0.28575,  -8.8593E-05
 CTFY: 9.44398E-03,  0.163193,  0.132975,  8.93878E-03,  5.09487E-05
 CTFZ: 2.99057,  -3.713,  1.10035,  -6.3286E-02,  -3.55439E-05
 CTFQ: 0.735784,  -6.02473E-02
 Do you want to continue? <N>
Y
 THIS CONSTRUCT ID NUMBER (ISTR) IS  3
 How many layers in this construct? (max. = 10 )
3
 Enter the layer ID numbers with most outer layer first
43,8,43
 ISTR: 3
 NCTF: 1  NORD: 1
 UVAL: 4.71099
 CTFX: 11.6962,  -6.9852
 CTFY: 3.82101,  0.88995
 CTFZ: 11.6962,  -6.9852
 CTFQ: 6.21576E-06
 Do you want to continue? <N>
Y
 THIS CONSTRUCT ID NUMBER (ISTR) IS  4
 How many layers in this construct? (max. = 10 )
4
 Enter the layer ID numbers with most outer layer first
2,10,8,43
 ISTR: 4
 NCTF: 3  NORD: 2
 UVAL: 0.691656
 CTFX: 31.2398,  -37.7555,  6.8351,  -3.14559E-02
 CTFY: 3.03452E-02,  0.199088,  5.80254E-02,  5.05029E-04
 CTFZ: 8.55491,  -12.8833,  4.6573,  -4.09825E-02
 CTFQ: 0.588904,  -5.24332E-03
 Do you want to continue? <N>
Y
 THIS CONSTRUCT ID NUMBER (ISTR) IS  5
 How many layers in this construct? (max. = 10 )
3
 Enter the layer ID numbers with most outer layer first
49,8,49

  LAYER            L        K        CP       D        R        RC
 Glass           0.000    0.000    0.000    0.000    0.260    0.000
 Air Space       0.000    0.000    0.000    0.000    0.160    0.000
 Glass           0.000    0.000    0.000    0.000    0.260    0.000

 SUMRC =   0.00000  CND =    1.47059  TINC =     900.00

  NUMBER OF ROOTS =  7;  SEARCH INCREMENT =0.020026
```

```
   N         ROOT
   1     0.024607256
   2     0.072309779
   3     0.111355003
   4     0.120292539
   5     0.136468904
   6     0.169175402
   7     0.216991657

 NUMBER OF RESPONSE FACTORS =  3;  ORDER =  2

   N         0 0          0 1          0 2          0 3          0 4          0 5

   0      31.239817    31.239817    31.239817    31.239817    31.239817    31.239817
   1     -19.358236   -37.473015   -37.755497   -37.755942   -37.756010   -37.756012
   2      -4.728849     6.496254     6.835099     6.835637     6.835720     6.835722
   3      -2.714793     0.027286    -0.031456     0.000000     0.000000     0.000000

   0       0.030345     0.030345     0.030345     0.030345     0.030345     0.030345
   1       0.216958     0.199362     0.199088     0.199087     0.199087     0.199087
   2       0.185634     0.059828     0.058025     0.058023     0.058022     0.058022
   3       0.108688     0.001046     0.000505     0.000000     0.000000     0.000000

   0       8.554926     8.554926     8.554926     8.554926     8.554926     8.554926
   1      -7.845255   -12.805930   -12.883287   -12.883409   -12.883428   -12.883428
   2      -0.007653     4.541511     4.657307     4.657491     4.657519     4.657520
   3      -0.004354     0.000083    -0.040983     0.000000     0.000000     0.000000

   2       0.588904    -0.005243     0.000000     0.000000     0.000000
 ** SEVERE   RESPONSE FACTORS NOT COMPUTED (RESPNS)
 ISTR: 5
 NCTF: 0  NORD: 0
 UVAL: 1.47059
 CTFX: 1.47059
 CTFY: 1.47059
 CTFZ: 1.47059
 CTFQ:
 Do you want to continue? <N>
N
STOP ----------- END OF CTF RUN ------------------

-----------------------------------------------------------------------
* File: THERM.DAT ( Thermal Property Data Bank for Building Materials)
-----------------------------------------------------------------------
  1  Stucco/asbestos cement/wood siding plaster, 25.4-mm (1-in.)
 0.0254  0.692 1858. 0.233 0.036  47.2 A1
  2  Facebrick (dense concrete), 101.6-mm (4-in.)
 0.1016  1.298 2082. 0.256 0.078 211.4 A2
  3  Steel siding (aluminum or other lightweight cladding)
 0.0015 44.99  7689. 0.116 0.000  11.7 A3
  4  Slag, membrane, 12.7-mm (0.5-in.)
 0.0127  1.143  881. 0.465 0.011  11.2 A4
  5  Felt, 9.5-mm (0.375-in.)
 0.0095  0.190 1121. 0.465 0.050  10.6 A5
  6  Finish
 0.0127  0.415 1249. 0.302 0.031  15.9 A6
  7  Facebrick, 101.6-mm (4-in.)
 0.1016  1.332 2002. 0.256 0.076 203.1 A7
  8  Air Space Resistance
 0.0000  0.000     0. 0.000 0.160   0.  B1
```

```
 9  Insulation, 25.4-mm (1-in.)
0.0254  0.043   32. 0.233 0.585   0.8 B2
10  Insulation, 50.8-mm (2-in.)
0.0508  0.043   32. 0.233 1.176   1.6 B3
11  Insulation,  76.2-mm (3-in.)
0.0762  0.043   32. 0.233 1.766   2.4 B4
12  Insulation, 25.4-mm (1-in.)
0.0254  0.043   91. 0.233 0.586   2.3 B5
13  Insulation, 50.8-mm (2-in.)
0.0508  0.043   91. 0.233 1.176   4.6 B6
14  Wood, 25.4-mm (1-in.)
0.0254  0.116  592. 0.699 0.209  15.0 B7
15  Wood, 63.5-mm (2.5-in.)
0.0635  0.116  592. 0.699 0.525  37.6 B8
16  Wood, 101.6-mm (4-in.)
0.1016  0.116  592. 0.699 0.838  60.0 B9
17  Wood,  50.8-mm (2-in.)
0.0508  0.116  592. 0.699 0.421  30.2 B10
18  Wood, 76.2-mm (3-in.)
0.0762  0.116  592. 0.699 0.631  45.2 B11
19  Insulation,  76.2-mm (3-in.)
0.0762  0.043   91. 0.233 1.761   6.9 B12
20  Insulation, 101.6-mm (4-in.)
0.1016  0.043   91. 0.233 2.346   9.3 B13
21  Insulation, 127.0-mm (5-in.)
0.1270  0.043   91. 0.233 2.934  11.6 B14
22  Insulation, 152.4-mm (6-in.)
0.1524  0.043   91. 0.233 3.520  13.9 B15
23  Clay tile, 101.6-mm (4-in.)
0.1016  0.571 1121. 0.233 0.178 113.7 C1
24  Concrete block, l.w., 101.6-mm (4-in.)
0.1016  0.381  608. 0.233 0.266  62.0 C2
25  Concrete block, h.w., 101.6-mm (4-in.)
0.1016  0.813  977. 0.233 0.125  99 1 C3
26  Common brick, 101.6-mm (4-in.)
0.1016  0.727 1922. 0.233 0.139 195.3 C4
27  Concrete, l.w., 101.6-mm (4-in.)
0.1016  1.730 2242. 0.233 0.059 227.5 C5
28  Clay tile, 203.2-mm (8-in.)
0.2032  0.571 1121. 0.233 0.356 227.9 C6
29  Concrete block, l.w., 203.2-mm (8-in.)
0.2032  0.571  608. 0.233 0.356 124.0 C7
30  Concrete block, h.w., 203.2-mm (8-in.)
0.2032  1.038  977. 0.233 0.195 198.7 C8
31  Common brick, 203.2-mm (8-in.)
0.2032  0.727 1922. 0.233 0.280 390.6 C9
32  Concrete, h.w., 203.2-mm (8-in.)
0.2032  1.730 2242. 0.233 0.117 455.9 C10
33  Concrete, h.w., 304.8-mm (12-in.)
0.3048  1.730 2242. 0.233 0.176 683.5 C11
34  Concrete, h.w., 50.8-mm (2-in.)
0.0508  1.730 2242. 0.233 0.029 114.2 C12
35  Concrete, h.w., 152.4-mm (6-in.)
0.1524  1.730 2242. 0.233 0.088 341.7 C13
36  Concrete, l.w., 101.6-mm (4-in.)
0.1016  0.173  640. 0.233 0.586  64.9 C14
37  Concrete, l.w., 152.4-mm (6-in.)
0.1524  0.173  640. 0.233 0.088  97.6 C15
38  Concrete, l.w., 203.2-mm (8-in.)
0.2032  0.173  640. 0.233 1.174 130.3 C16
```

```
39  Concrete block (filled insulation), l.w., 203.2-mm (8-in.)
0.2032  0.138  288.  0.233 1.584  58.6 C17
40  Concrete block (filled insulation), l.w., 203.2-mm (8-in.)
0.2032  0.588  849.  0.233 0.348 172.8 C18
41  Concrete block (filled insulation), l.w., 304.8-mm (12-in.)
0.3048  0.138  304.  0.233 2.376  92.8 C19
42  Concrete block (filled insulation), l.w, 304.8-mm (12-in.)
0.3048  0.675  897.  0.233 0.456 273.4 C20
43  Plaster/gypsum/similar finishing layer, 19.0-mm (0.75-in.)
0.0190  0.727 1601.  0.233 0.026  30.5 E1
44  Slag or stone, 12.7-mm (0.5-in.)
0.0127  1.436  881.  0.465 0.009  11.2 E2
45  Felt & membrane, 9.5-mm (0.375-in.)
0.0095  0.190 1121.  0.465 0.050  10.7 E3
46  Ceiling air space
0.0000  0.000     0.  0.000 0.176   0.0 E4
47  Acoustic tile
0.0159  0.061  480.  0.233 0.315   9.2 E5
48  Vinyle tile
0.0020  0.270 1552.  1.004 0.000   3.1 XXX
49  Glass
0.0000  0.000     0.  0.000 0.260   0.0 XXX
```

---

*** File: CTFDATA.DAT (Conduction Transfer Function File)**

---

```
   900.000
   1    4    2    0.969606
   2.99057        -3.71300        1.10035       -0.632860E-01   -0.355439E-04
  0.944398E-02    0.163193       0.132975        0.893878E-02    0.509487E-04
   9.21826       -13.4813         4.86344       -0.285750       -0.885930E-04
  0.735784        -0.602473E-01
   2    4    2    0.969606
   9.21826       -13.4813         4.86344       -0.285750       -0.885930E-04
  0.944398E-02    0.163193       0.132975        0.893878E-02    0.509487E-04
   2.99057        -3.71300        1.10035       -0.632860E-01   -0.355439E-04
  0.735784        -0.602473E-01
   3    1    1    4.71099
   11.6962        -6.98520
   3.82101         0.889950
   11.6962        -6.98520
  0.621576E-05
   4    3    2    0.691656
   31.2398       -37.7555         6.83510       -0.314559E-01
  0.303452E-01    0.199088       0.580254E-01    0.505029E-03
   8.55491       -12.8833         4.65730       -0.409825E-01
  0.588904        -0.524332E-02
   5    0    1    1.47059
   1.47059
   1.47059
   1.47059
  0.000000
```

---

*** File: CTFINPUT.DAT ( CTF Input Data File)**

---

```
   900.000
  4   47   46   36   48
  4   48   36   46   47
```

| | | | | |
|---|---|---|---|---|
| 3 | 43 | 8 | 43 | |
| 4 | 2 | 10 | 8 | 43 |
| 3 | 49 | 8 | 49 | |

(5) <u>Creation of Weather Data File</u>

```
----------------------
* Execution of CRWDTA
----------------------
    **************************************************
    *                                                *
    *          CREATING A WEATHER DATA FILE          *
    *                                                *
    **************************************************

  Enter LATITUDE, LONGITUDE, and TIME ZONE:
38.85
77.03
5
  Enter one of the following:
  1 - to process the weather data in file WTPOUT.DAT
    (previously read from weather tape by program RDTAPE)
  2 - to generate clear sky design data
  3 - to generate cloudy sky design data
2
  Enter output file name (up to 12 characters)
  or carriage return for default name: WEATHER.DAT

  Enter initial day and month, and number of days
  for which weather calculations will be made:
7,7,2
  Enter pressure (kPa), wind speed (m/s), and
  relative humidity (from 0.0 to 1.0):
101.3,0,0.8
  Enter minimum and maximum temperatures:
20,30
  Enter visibility (km); if value unknown use 0:
0
  Enter geographic correction factor
  [ASHRAE Fund. 1981, p.27.8]; if value unknown use 1:
1
STOP ---- END OF CREATING WEATHER FILE ------
```

```
---------------------
* File: WEATHER.DAT
---------------------
     7    7      38.85      77.03      5.00     2
     7    7  0.0    21.8000    0.0133  101.3000    0.0000    0.0000    0.0000
     7    7  1.0    21.3000    0.0128  101.3000    0.0000    0.0000    0.0000
     7    7  2.0    20.8000    0.0124  101.3000    0.0000    0.0000    0.0000
     7    7  3.0    20.4000    0.0121  101.3000    0.0000    0.0000    0.0000
     7    7  4.0    20.1000    0.0119  101.3000    0.0000    0.0000    0.0000
     7    7  5.0    20.0000    0.0118  101.3000    0.0000    0.0000    0.0000
     7    7  6.0    20.2000    0.0120  101.3000    0.0000  194.7809   26.8798   4
     7    7  7.0    20.7000    0.0124  101.3000    0.0000  582.1411   80.3355  25
     7    7  8.0    21.6000    0.0131  101.3000    0.0000  741.2583  102.2937  45
     7    7  9.0    22.9000    0.0142  101.3000    0.0000  819.7222  113.1217  64
     7    7 10.0    24.4000    0.0156  101.3000    0.0000  862.7646  119.0615  79
     7    7 11.0    26.1000    0.0173  101.3000    0.0000  886.6650  122.3598  91
     7    7 12.0    27.7000    0.0190  101.3000    0.0000  898.1992  123.9515  97
     7    7 13.0    28.9000    0.0205  101.3000    0.0000  900.1130  124.2156  98
     7    7 14.0    29.7000    0.0215  101.3000    0.0000  892.8298  123.2105  94
     7    7 15.0    30.0000    0.0218  101.3000    0.0000  874.6892  120.7071  85
```

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7 | 7 | 16.0 | 29.7000 | 0.0215 | 101.3000 | 0.0000 | 840.9761 | 116.0547 | 71 |
| 7 | 7 | 17.0 | 29.0000 | 0.0206 | 101.3000 | 0.0000 | 780.5696 | 107.7186 | 53 |
| 7 | 7 | 18.0 | 27.9000 | 0.0193 | 101.3000 | 0.0000 | 664.8452 | 91.7486 | 34 |
| 7 | 7 | 19.0 | 26.6000 | 0.0178 | 101.3000 | 0.0000 | 403.6780 | 55.7076 | 13 |
| 7 | 7 | 20.0 | 25.3000 | 0.0165 | 101.3000 | 0.0000 | 19.7814 | 2.7298 | |
| 7 | 7 | 21.0 | 24.2000 | 0.0154 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 7 | 22.0 | 23.2000 | 0.0145 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 7 | 23.0 | 22.4000 | 0.0138 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 7 | 24.0 | 21.8000 | 0.0133 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 8 | 1.0 | 21.3000 | 0.0128 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 8 | 2.0 | 20.8000 | 0.0124 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 8 | 3.0 | 20.4000 | 0.0121 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 8 | 4.0 | 20.1000 | 0.0119 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 8 | 5.0 | 20.0000 | 0.0118 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 8 | 6.0 | 20.2000 | 0.0120 | 101.3000 | 0.0000 | 189.4358 | 26.1422 | 4 |
| 7 | 8 | 7.0 | 20.7000 | 0.0124 | 101.3000 | 0.0000 | 580.1868 | 80.0658 | 25 |
| 7 | 8 | 8.0 | 21.6000 | 0.0131 | 101.3000 | 0.0000 | 740.4182 | 102.1777 | 45 |
| 7 | 8 | 9.0 | 22.9000 | 0.0142 | 101.3000 | 0.0000 | 819.2832 | 113.0611 | 64 |
| 7 | 8 | 10.0 | 24.4000 | 0.0156 | 101.3000 | 0.0000 | 862.5037 | 119.0255 | 79 |
| 7 | 8 | 11.0 | 26.1000 | 0.0173 | 101.3000 | 0.0000 | 886.4949 | 122.3363 | 90 |
| 7 | 8 | 12.0 | 27.7000 | 0.0190 | 101.3000 | 0.0000 | 898.0789 | 123.9349 | 97 |
| 7 | 8 | 13.0 | 28.9000 | 0.0205 | 101.3000 | 0.0000 | 900.0195 | 124.2027 | 98 |
| 7 | 8 | 14.0 | 29.7000 | 0.0215 | 101.3000 | 0.0000 | 892.7478 | 123.1992 | 94 |
| 7 | 8 | 15.0 | 30.0000 | 0.0218 | 101.3000 | 0.0000 | 874.6021 | 120.6951 | 85 |
| 7 | 8 | 16.0 | 29.7000 | 0.0215 | 101.3000 | 0.0000 | 840.8579 | 116.0384 | 71 |
| 7 | 8 | 17.0 | 29.0000 | 0.0206 | 101.3000 | 0.0000 | 780.3618 | 107.6899 | 53 |
| 7 | 8 | 18.0 | 27.9000 | 0.0193 | 101.3000 | 0.0000 | 664.3657 | 91.6825 | 33 |
| 7 | 8 | 19.0 | 26.6000 | 0.0178 | 101.3000 | 0.0000 | 402.1970 | 55.5032 | 13 |
| 7 | 8 | 20.0 | 25.3000 | 0.0165 | 101.3000 | 0.0000 | 19.1445 | 2.6419 | |
| 7 | 8 | 21.0 | 24.2000 | 0.0154 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 8 | 22.0 | 23.2000 | 0.0145 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 8 | 23.0 | 22.4000 | 0.0138 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 8 | 24.0 | 21.8000 | 0.0133 | 101.3000 | 0.0000 | 0.0000 | 0.0000 | |

NOTE: Data in columns from 1 to 80 are only shown here.

B. Simulation

(1) Allocation of Output Files

The output files of the MODSIM program are automatically allocated. Default file names are MODSUM.DAT, MODOUT.DAT, and INITOUT.DAT.

(2) Execution of MODSIM for Initialization

```
     *********************************************
     *                                           *
     *          MODSIM      Version 5.0          *
     *                                           *
     *********************************************

  Enter MINIMUM TIME STEP, MAXIMUM TIME STEP, and SIMULATION STOPPING TIME:
1,1000,86400
   Is the Building Shell Model used? <N>
Y
   Will the Initialization File be called? <N>
N
  Simulate Building Shell ONLY? <N>
Y
    Only the superblock containing the building model will be called.

   What is the INDEX NUMBER of the SUPERBLOCK for the Building Shell?
1
   ISSHEL =1

  Enter the time of day (in hours after midnight)
  at which the simulation is to begin
0
  Use default file names for all files? (Y/N) <Y>

   Do you want Diagnostic Information to be written <N>?

  Would you like to monitor the Simulation on Screen? <N>
Y
  Enter the INDEX NUMBER of the SUPERBLOCK to monitor
  or zero (0) to monitor all superblocks.
0
  --During the simulation, up to five State Variables can be viewed--
  Enter the NUMBER of STATE VARIABLES to be viewed.
5
  1 = PRES
  2 = FLOW
  3 = TEMP
  4 = CTRL
  5 = RVPS
  6 = ENRG
  7 = POWR
  8 = AHUM

  Enter the CATEGORY NUMBER (above) and INDEX NUMBER
  for each of the 5 variables to be viewed.
3,1
3,2
3,3
3,4
3,10
    ------- SIMULATION BEGINS ---------
```

```
-- FIRST WEATHER DATA SET HAS BEEN READ
SB 1:  TIME =1.0    NTIME =1    TSTEP =1.0    PSTEP=1000.0
   20.0000        20.1286       20.1634       20.0601        20.1227
SB 2:  TIME =1.0    NTIME =2    TSTEP =1.0    PSTEP=5.37683
   20.0007        20.1286       20.1634       20.0601        20.1227
SB 1:  TIME =900.0    NTIME =3    TSTEP =899.0    PSTEP=1000.0
   20.0007        20.1753       20.3496       20.2146        20.3603
SB 1:  TIME =1800.0    NTIME =4    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.2086       20.3931       20.2858        20.4108
SB 1:  TIME =2700.0    NTIME =5    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.2298       20.4062       20.3219        20.4387
SB 1:  TIME =3600.0    NTIME =6    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.2432       20.4121       20.3429        20.4557
SB 1:  TIME =4500.0    NTIME =7    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.2516       20.4156       20.3566        20.4666
SB 1:  TIME =5400.0    NTIME =8    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.2570       20.4178       20.3662        20.4736
SB 1:  TIME =6300.0    NTIME =9    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.2604       20.4193       20.3733        20.4780
SB 1:  TIME =7200.0    NTIME =10    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.2625       20.4201       20.3784        20.4806
SB 1:  TIME =8100.0    NTIME =11    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.2637       20.4204       20.3822        20.4819
SB 1:  TIME =9000.0    NTIME =12    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.2642       20.4202       20.3848        20.4821

   -----( OUTPUTS FROM TIME=9900 TO  80100 ARE DELETED )----

 SB 1:  TIME =81000.0    NTIME =92    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.4094       20.6504       20.6317        20.7577
SB 1:  TIME =81900.0    NTIME =93    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.3949       20.6269       20.6050        20.7303
SB 1:  TIME =82800.0    NTIME =94    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.3820       20.6061       20.5819        20.7060
SB 1:  TIME =83700.0    NTIME =95    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.3706       20.5877       20.5618        20.6843
SB 1:  TIME =84600.0    NTIME =96    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.3604       20.5713       20.5441        20.6648
SB 1:  TIME =85500.0    NTIME =97    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.3512       20.5566       20.5285        20.6472
SB 1:  TIME =86400.0    NTIME =98    TSTEP =900.0    PSTEP=1000.0
   20.0007        20.3429       20.5433       20.5147        20.6313
 ----- INITIALIZATION FILE HAS BEEN WRITTEN -----
STOP    ------------END OF SIMULATION ---------

--------------------------------------------------
* File: MODSUM.DAT (for the initialization run)
--------------------------------------------------

          ***** PROGRAM MODSIM *****
        a MODular SIMulation program

 ONE ZONE MODEL

  2 SUPERBLOCKS       3 BLOCKS       10 UNITS

   32 STATE VARIABLES:
    3 PRES    1 FLOW   12 TEMP    5 CTRL    8 POWR    3 AHUM

 INITIAL STATE VECTOR:
```

```
 PRES:
    0.000000         0.000000          101.300

 FLOW:
    0.000000

 TEMP:
     20.0000         20.0000          20.0000         20.0000          20.0000
     20.0000         20.0000          20.0000         20.0000          20.0000
     20.0000         20.0000

 CTRL:
     1.00000         1.00000          1.00000        0.000000          1.00000

 POWR:
    0.000000        0.000000         0.000000        0.000000         0.000000
    0.000000        0.000000         0.000000

 AHUM:
    7.399999E-03   7.399999E-03   7.399999E-03

 0 TIME DEPENDENT BOUNDARY VARIABLES:

ERROR TOLERANCES:  RTOLX, ATOLX, XTOL, TTIME:
    1.00000E-04    1.00000E-05    2.00000E-04     1.0000

***** SUPERBLOCK  1 *****

 SUPERBLOCK SIMULTANEOUS EQUATION UNFREEZING OPTION, IFZOPT =  0
 SUPERBLOCK INPUT SCAN OPTION, INSOPT =  0

13 REPORTED VARIABLES:
TEMP 2    TEMP 3    TEMP 4    TEMP 5    TEMP 6    TEMP 7    TEMP 8    TEMP10
TEMP12    POWR 3    POWR 6    POWR 7    POWR 8

 0 SIMULTANEOUS EQUATIONS; VARIABLES:

***** BLOCK  1 *****

 8 SIMULTANEOUS EQUATIONS; VARIABLES:
TEMP 4    TEMP 3    TEMP 2    TEMP 5    TEMP 7    TEMP 6    TEMP 8    TEMP10

UNIT   1     TYPE 50

 13 INPUTS:
TEMP 1    POWR 1    POWR 2    TEMP 2    TEMP 3    TEMP 4    TEMP 5    TEMP 6
TEMP 7    TEMP 8    TEMP 8    TEMP 8    TEMP 8

  2 OUTPUTS:
TEMP10    POWR 3

PARAMETERS:
     1.0000          7.0000

UNIT   2     TYPE 51

  4 INPUTS:
TEMP 1    TEMP10    TEMP 9    CTRL 5
```

2 OUTPUTS:
TEMP 4 NULL 0

PARAMETERS:

| | | | | |
|---|---|---|---|---|
| 1.0000 | 1.0000 | 1.0000 | 1.0000 | 37.210 |
| 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 0.60000 | 0.90000 | 0.00000 | 0.00000 | |

UNIT 3 TYPE 51

4 INPUTS:
TEMP 1 TEMP10 TEMP 9 CTRL 5

2 OUTPUTS:
TEMP 3 NULL 0

PARAMETERS:

| | | | | |
|---|---|---|---|---|
| 1.0000 | 2.0000 | 1.0000 | 2.0000 | 37.210 |
| 0.00000 | 180.00 | 0.00000 | 0.00000 | 0.00000 |
| 0.60000 | 0.90000 | 0.00000 | 0.00000 | |

UNIT 4 TYPE 51

4 INPUTS:
TEMP 1 TEMP10 TEMP 9 CTRL 5

2 OUTPUTS:
TEMP 2 NULL 0

PARAMETERS:

| | | | | |
|---|---|---|---|---|
| 1.0000 | 3.0000 | 1.0000 | 3.0000 | 24.400 |
| 90.000 | 90.000 | 0.00000 | 0.00000 | 0.00000 |
| 0.60000 | 0.90000 | 0.00000 | 0.00000 | |

UNIT 5 TYPE 51

4 INPUTS:
TEMP 1 TEMP10 TEMP 9 CTRL 5

2 OUTPUTS:
TEMP 5 NULL 0

PARAMETERS:

| | | | | |
|---|---|---|---|---|
| 1.0000 | 4.0000 | 1.0000 | 3.0000 | 24.400 |
| 270.00 | 90.000 | 0.00000 | 0.00000 | 0.00000 |
| 0.60000 | 0.90000 | 0.00000 | 0.00000 | |

UNIT 6 TYPE 51

4 INPUTS:
TEMP 1 TEMP10 TEMP 9 CTRL 5

2 OUTPUTS:
TEMP 7 NULL 0

PARAMETERS:

| | | | | |
|---|---|---|---|---|
| 1.0000 | 5.0000 | 1.0000 | 3.0000 | 24.400 |
| 180.00 | 90.000 | 0.00000 | 0.00000 | 0.00000 |
| 0.60000 | 0.90000 | 0.00000 | 0.00000 | |

```
UNIT    7      TYPE 51

  4 INPUTS:
TEMP 1     TEMP10     TEMP 6     CTRL 4

  2 OUTPUTS:
TEMP 6     POWR 5

PARAMETERS:
     1.0000          6.0000          2.0000          4.0000          18.400
    0.00000          90.000         0.20000          2.0000         0.60000
    0.60000         0.90000         0.00000         0.00000

UNIT    8      TYPE 51

  4 INPUTS:
TEMP 1     TEMP10     TEMP 8     CTRL 4

  2 OUTPUTS:
TEMP 8     POWR 4

PARAMETERS:
     1.0000          7.0000          2.0000          5.0000          6.0000
    0.00000          90.000         0.20000          6.0000         0.00000
    0.00000         0.00000         0.95000         0.85000

***** BLOCK   2 *****

 0 SIMULTANEOUS EQUATIONS; VARIABLES:

UNIT    9      TYPE 53

  6 INPUTS:
TEMP12     AHUM 3     PRES 3     POWR 6     POWR 7     POWR 8

  0 OUTPUTS:

PARAMETERS:
     12.000          3.0000          3.0000          6.0000          7.0000
     8.0000

***** SUPERBLOCK   2 *****

 SUPERBLOCK SIMULTANEOUS EQUATION UNFREEZING OPTION, IFZOPT =  0
 SUPERBLOCK INPUT SCAN OPTION, INSOPT =  0

 2 REPORTED VARIABLES:
TEMP 1     AHUM 1

 0 SIMULTANEOUS EQUATIONS; VARIABLES:

***** BLOCK   3 *****

 2 SIMULTANEOUS EQUATIONS; VARIABLES:
TEMP 1     AHUM 1

UNIT   10      TYPE 52

 11 INPUTS:
PRES 1     TEMP 1     AHUM 1     PRES 2     FLOW 1     TEMP11     AHUM 2     POWR 3
```

```
CTRL 1    CTRL 2    CTRL 3

  4 OUTPUTS:
TEMP 1    AHUM 1    POWR 1    POWR 2

PARAMETERS:
     1.0000          200.00          4.0000          148.84          1.0000
    7.17600E-02    4.54000E-02    0.20000          1.0000          0.15000
    2.00000E-02    0.30000

-----------------------------------------------------------------
TMIN =       1.000  TMAX =    1000.000  TSTOP =   86400.000
-----------------------------------------------------------------

BUILDING SHELL MODEL IN SUPERBLOCK  1:
  CONSTANT TIME STEP    TSHELL =   900.00

WEATHER DATA:  LATITUDE =  38.850  LONGITUDE =  77.030
STARTING DATE:    7 JUL.
SOURCE:  CLEAR SKY DESIGN DAY METHOD



********** SUPERBLOCK  1 **********
TIME=   3600.00
 TEMP 2     TEMP 3     TEMP 4     TEMP 5     TEMP 6     TEMP 7     TEMP 8     TEMP10
  20.2       20.4       20.3       20.2       20.4       20.2       20.5       20.5
 TEMP12     POWR 3     POWR 6     POWR 7     POWR 8
  21.3      4.711E-02 0.000      0.000      0.000

********** SUPERBLOCK  1 **********
TIME=   7200.00
 TEMP 2     TEMP 3     TEMP 4     TEMP 5     TEMP 6     TEMP 7     TEMP 8     TEMP10
  20.3       20.4       20.4       20.3       20.5       20.3       20.5       20.5
 TEMP12     POWR 3     POWR 6     POWR 7     POWR 8
  20.8      5.145E-02 0.000      0.000      0.000

********** SUPERBLOCK  1 **********
TIME=  10800.00
 TEMP 2     TEMP 3     TEMP 4     TEMP 5     TEMP 6     TEMP 7     TEMP 8     TEMP10
  20.3       20.4       20.4       20.3       20.5       20.3       20.4       20.5
 TEMP12     POWR 3     POWR 6     POWR 7     POWR 8
  20.4      5.097E-02 0.000      0.000      0.000


---------( OUTPUTS FROM TIME=14400 TO 79200 ARE DELETED)--------------


********** SUPERBLOCK  1 **********
TIME=  82800.00
 TEMP 2     TEMP 3     TEMP 4     TEMP 5     TEMP 6     TEMP 7     TEMP 8     TEMP10
  20.4       20.6       20.6       20.4       21.1       20.4       20.8       20.7
 TEMP12     POWR 3     POWR 6     POWR 7     POWR 8
  22.4      9.917E-02 0.000      0.000      0.000

********** SUPERBLOCK  1 **********
TIME=  86400.00
 TEMP 2     TEMP 3     TEMP 4     TEMP 5     TEMP 6     TEMP 7     TEMP 8     TEMP10
  20.3       20.5       20.5       20.3       20.9       20.3       20.7       20.6
```

```
TYPE WORK

TEMP12    POWR 3     POWR 6    POWR 7    POWR 8
 21.8     8.252E-02  0.000     0.000     0.000


----------------------------------------------------------
* File: INITOUT.DAT => INITIN.DAT (Initialization File)
----------------------------------------------------------
      1.00    1000.00  86400.00  86400.00   32   399
   0.000000       0.000000        101.300       0.000000       20.0007
    20.3429        20.5433        20.5147        20.3472       20.9149
    20.3471        20.7106        20.0000        20.6313       20.0000
    21.8000        1.00000        1.00000        1.00000      0.000000
    1.00000       4.000000E-02   0.135232      8.252382E-02   0.000000
   0.000000       0.000000       0.000000       0.000000      7.400133E-03
   7.399999E-03   1.330000E-02
  1  1 -1  1  1 -1 -1 -1 -1 -1 -1 -1  1 -1  1 -1  1  1  1  1  1  1  1 -1 -1
 -1 -1 -1 -1  1  1 -1
    86400.0        20.5147        20.5285        20.5441       20.5618
    20.5819        20.0000        20.0000        20.0000       20.0000
    20.0000      -0.293930      -0.279144      -0.260101      0.562424
   0.585342       0.611954        188.627        60.1801      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000        86400.0        20.5433       20.5566
    20.5713        20.5877        20.6061        20.0000       20.0000
    20.0000        20.0000        20.0000      -0.472382     -0.478424
  -0.484512       0.587433       0.608215       0.632095       60.7750
    184.759       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000       86400.0
    20.3429        20.3512        20.0000        20.0000      -1.55827
   -1.59109        1.62202        1.66194        159.956       157.816
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000        86400.0        20.3472        20.3557       20.0000
    20.0000       -1.57761       -1.61086        1.64243       1.68301
    159.987        157.820       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
   0.000000       0.000000       0.000000       0.000000      0.000000
```

| | | | | |
|---|---|---|---|---|
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 86400.0 | 20.3471 |
| 20.3555 | 20.0000 | 20.0000 | -1.57727 | -1.61057 |
| 1.64198 | 1.68248 | 159.987 | 157.819 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 86400.0 | 20.9149 | 20.9599 | 21.0094 | 21.0640 |
| 22.9142 | 23.1523 | 23.4117 | 23.6951 | 2.21538 |
| 2.42876 | 2.66360 | 13.9172 | 15.2017 | 16.6440 |
| 180.445 | 729.118 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 86400.0 | 20.7106 | 21.6348 |
| 1.35913 | 0.000000 | -1.35913 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 0.000000 | 0.000000 | 0.000000 | 0.000000 | |

(3) Continuation of Simulation

```
----------------------------------------------------------------------
* Execution of MODSIM for Simulation using the Initialization File
----------------------------------------------------------------------
     ************************************************
     *                                              *
     *           MODSIM       Version 5.0           *
     *                                              *
     ************************************************


  Enter MINIMUM TIME STEP, MAXIMUM TIME STEP, and SIMULATION STOPPING TIME:
1,1000,172800
   Is the Building Shell Model used? (N)
Y
   Will the Initialization File be called? (N)
Y

   What is the INDEX NUMBER of the SUPERBLOCK for the Building Shell?
```

```
1
   ISSHEL =1

  Enter the time of day (in hours after midnight)
  at which the simulation is to begin
0
  Use default file names for all files? (Y/N) <Y>
N
 Enter the name of the Model Definition File,
 or Carriage Return for default name:  MODELDEF.DAT

 Enter the name of the Boundary Variable File,
 or Carriage Return for default name:  BOUNDARY.DAT

 Enter the name of the Initial State File,
 or Carriage Return for default name:  INITIN.DAT

 Enter the name of the Final State File,
 or Carriage Return for default name:  INITOUT.DAT

 Enter the name of the Output Data File,
 or Carriage Return for default name:  MODOUT.DAT

 Enter the name of the Simulation Summary File,
 or Carriage Return for default name:  MODSUM.DAT
MODSUM2.DAT
 Enter the name of the CTF File,
 or Carriage Return for default name:  CTFDATA.DAT

 Enter the name of the Weather Data File,
 or Carriage Return for default name:  WEATHER.DAT

   Do you want Diagnostic Information to be written <N>?
N
  Would you like to monitor the Simulation on Screen? <N>
N
    ------- SIMULATION BEGINS ---------
 --  FIRST WEATHER DATA SET HAS BEEN READ
  -----  INITIALIZATION FILE HAS BEEN WRITTEN -----
STOP    ------------END OF SIMULATION ---------

----------------------------------------------
* File: MODSUM2.DAT (for the second run)
----------------------------------------------
          ***** PROGRAM MODSIM *****
        a MODular SIMulation program

 ONE ZONE MODEL

  2 SUPERBLOCKS       3 BLOCKS       10 UNITS

   32 STATE VARIABLES:
    3 PRES    1 FLOW   12 TEMP    5 CTRL    8 POWR    3 AHUM

 INITIAL STATE VECTOR:

  PRES:
     0.000000        0.000000         101.300

  FLOW:
```

```
   0.000000

  TEMP:
     20.0007       20.3429       20.5433       20.5147       20.3472
     20.9149       20.3471       20.7106       20.0000       20.6313
     20.0000       21.8000

  CTRL:
     1.00000       1.00000       1.00000       0.000000      1.00000

  POWR:
    4.000000E-02   0.135232      8.252382E-02  0.000000      0.000000
    0.000000       0.000000      0.000000

  AHUM:
    7.400133E-03   7.399999E-03  1.330000E-02

  0 TIME DEPENDENT BOUNDARY VARIABLES:

 ERROR TOLERANCES:  RTOLX, ATOLX, XTOL, TTIME:
    1.00000E-04    1.00000E-05    2.00000E-04     1.0000

 ----------------------------------------------------------
 TMIN =        1.000  TMAX =     1000.000  TSTOP =  172800.000
 ----------------------------------------------------------

 BUILDING SHELL MODEL IN SUPERBLOCK  1:
   CONSTANT TIME STEP    TSHELL =   900.00

 WEATHER DATA:  LATITUDE =  38.850  LONGITUDE =  77.030
 STARTING DATE:    7 JUL.
 SOURCE:  CLEAR SKY DESIGN DAY METHOD


 ********** SUPERBLOCK  1 **********
 TIME=   3600.00
  TEMP 2    TEMP 3    TEMP 4    TEMP 5    TEMP 6    TEMP 7    TEMP 8    TEMP10
   20.7      21.0      20.9      20.7      21.3      20.7      21.1      21.0
  TEMP12    POWR 3    POWR 6    POWR 7    POWR 8
   21.3     -0.183     0.000     0.000     0.000

 ********** SUPERBLOCK  2 **********
 TIME=   3600.00
  TEMP 1    AHUM 1
   21.9     7.831E-03

 ********** SUPERBLOCK  1 **********
 TIME=   7200.00
  TEMP 2    TEMP 3    TEMP 4    TEMP 5    TEMP 6    TEMP 7    TEMP 8    TEMP10
   20.8      21.2      21.1      20.8      21.4      20.8      21.2      21.2
  TEMP12    POWR 3    POWR 6    POWR 7    POWR 8
   20.8     -0.224     0.000     0.000     0.000

 ********** SUPERBLOCK  2 **********
 TIME=   7200.00
  TEMP 1    AHUM 1
   22.1     8.223E-03

--------(OUTPUTS FROM TIME=10800 TO 169200 ARE DELETED)-----------
```

```
********** SUPERBLOCK  1 **********
TIME= 172800.00
 TEMP 2    TEMP 3    TEMP 4    TEMP 5    TEMP 6    TEMP 7    TEMP 8    TEMP10
  21.1      21.7      21.7      21.2      22.1      21.2      21.8      21.6
 TEMP12    POWR 3    POWR 6    POWR 7    POWR 8
  21.8     -0.258    0.000     0.000     0.000

********** SUPERBLOCK  2 **********
TIME= 172800.00
 TEMP 1    AHUM 1
  22.6     1.820E-02
```

```
-------------------------------------------
* File: MODOUT.DAT (for the second run)
-------------------------------------------
```

```
SUPERBLOCK 1      1.00
    20.2917       20.5139       20.5405       20.2846       21.1066
    20.2843       21.0060       21.2797       21.8000       8.404082E-02
   0.000000      0.000000      0.000000
SUPERBLOCK 2      1.00
    20.0016       7.400267E-03
SUPERBLOCK 2      5.00
    20.0054       7.400803E-03
SUPERBLOCK 2     13.00
    20.0128       7.401876E-03
SUPERBLOCK 2     29.00
    20.0277       7.404022E-03
SUPERBLOCK 2     61.00
    20.0574       7.408317E-03
SUPERBLOCK 2    125.00
    20.1168       7.416867E-03
SUPERBLOCK 2    253.00
    20.2349       7.433806E-03
SUPERBLOCK 2    509.00
    20.4688       7.467050E-03
SUPERBLOCK 1    900.00
    20.5530       20.9868       20.8029       20.5515       21.2674
    20.5513       21.2203       20.6367       21.6776       1.849874E-03
   0.000000      0.000000      0.000000
SUPERBLOCK 2   1021.00
    20.8193       7.531371E-03
SUPERBLOCK 1   1800.00
    20.5248       20.7980       20.7678       20.5321       21.1843
    20.5319       20.9597       20.8542       21.5535      -1.177248E-02
   0.000000      0.000000      0.000000
SUPERBLOCK 2   2021.00
    21.4451       7.649470E-03
SUPERBLOCK 1   2700.00
    20.5797       20.8906       20.8064       20.5900       21.1941
    20.5897       21.0495       20.9111       21.4276      -0.116937
   0.000000      0.000000      0.000000
SUPERBLOCK 2   3021.00
    21.7804       7.765420E-03
SUPERBLOCK 1   3600.00
    20.6530       21.0056       20.8754       20.6659       21.2501
    20.6655       21.1431       20.9923       21.3000      -0.182925
   0.000000      0.000000      0.000000
```

```
SUPERBLOCK 2   4021.00
    21.9328       7.879067E-03
SUPERBLOCK 1   4500.00
    20.7129        21.0866        20.9417        20.7276        21.3079
    20.7271        21.1954        21.0578        21.1710       -0.207124
   0.000000       0.000000       0.000000
SUPERBLOCK 2   5021.00
    22.0143       7.990129E-03
SUPERBLOCK 1   5400.00
    20.7564        21.1417        20.9970        20.7721        21.3539
    20.7715        21.2228        21.1055        21.0429       -0.216749
   0.000000       0.000000       0.000000
SUPERBLOCK 2   6021.00
    22.0642       8.098528E-03
SUPERBLOCK 1   6300.00
    20.7868        21.1799        21.0412        20.8031        21.3862
    20.8026        21.2357        21.1394        20.9184       -0.221382
   0.000000       0.000000       0.000000
SUPERBLOCK 2   7021.00
    22.0962       8.204252E-03
SUPERBLOCK 1   7200.00
    20.8078        21.2065        21.0757        20.8246        21.4067
    20.8240        21.2395        21.1629        20.8000       -0.223880
   0.000000       0.000000       0.000000
SUPERBLOCK 2   8021.00
    22.1167       8.307319E-03
SUPERBLOCK 1   8100.00
    20.8220        21.2247        21.1021        20.8391        21.4177
    20.8384        21.2374        21.1788        20.6898       -0.225273
   0.000000       0.000000       0.000000
SUPERBLOCK 1   9000.00
    20.8295        21.2332        21.1203        20.8466        21.4193
    20.8460        21.2272        21.1866        20.5871       -0.223120
   0.000000       0.000000       0.000000
SUPERBLOCK 2   9021.00
    22.1346       8.407805E-03

---------(OUTPUTS FROM TIME=9900 TO 171000 ARE DELETED)------------

SUPERBLOCK 2 171021.00
    22.7579       1.824510E-02
SUPERBLOCK 1 171900.00
    21.1762        21.7274        21.7091        21.2018        22.2095
    21.2008        21.8538        21.6709        21.9322       -0.263855
   0.000000       0.000000       0.000000
SUPERBLOCK 2 172021.00
    22.6839       1.822144E-02
SUPERBLOCK 1 172800.00
    21.1395        21.6742        21.6508        21.1642        22.1230
    21.1632        21.7881        21.6196        21.8000       -0.257617
   0.000000       0.000000       0.000000
SUPERBLOCK 2 172800.00
    22.6373       1.820225E-02
```

C. Postprocessing - Output Data Analysis

```
-----------------------
* Execution of SORTSB
-----------------------

  Enter input file name
MODOUT.DAT
  Enter output file name
SORTSB.DAT
  Superblock # ?
1

 SUPERBLOCK 1        1.00
     20.2917          20.5139         20.5405         20.2846         21.1066
     20.2843          21.0060         21.2797         21.8000         8.404082E-02
    0.000000         0.000000        0.000000
 SUPERBLOCK 2        1.00
     20.0016         7.400267E-03
 SUPERBLOCK 2        5.00
  Number of seconds per unit time?
3600
  Extract another superblock? <N>
N
STOP ---- END OF SORTSB -----


---------------------------------------
* File: SORTSB.DAT (for SUPERBLOCK #1)
---------------------------------------

   0.277778E-03   20.2917       20.5139       20.5405       20.2846
    21.1066       20.2843       21.0060       21.2797       21.8000
   0.840408E-01  0.000000      0.000000      0.000000
   0.250000       20.5530       20.9868       20.8029       20.5515
    21.2674       20.5513       21.2203       20.6367       21.6776
   0.184987E-02  0.000000      0.000000      0.000000
   0.500000       20.5248       20.7980       20.7678       20.5321
    21.1843       20.5319       20.9597       20.8542       21.5535
  -0.117725E-01  0.000000      0.000000      0.000000
   0.750000       20.5797       20.8906       20.8064       20.5900
    21.1941       20.5897       21.0495       20.9111       21.4276
  -0.116937      0.000000      0.000000      0.000000
    1.00000       20.6530       21.0056       20.8754       20.6659
    21.2501       20.6655       21.1431       20.9923       21.3000
  -0.182925      0.000000      0.000000      0.000000
    1.25000       20.7129       21.0866       20.9417       20.7276
    21.3079       20.7271       21.1954       21.0578       21.1710
  -0.207124      0.000000      0.000000      0.000000
    1.50000       20.7564       21.1417       20.9970       20.7721
    21.3539       20.7715       21.2228       21.1055       21.0429
  -0.216749      0.000000      0.000000      0.000000
    1.75000       20.7868       21.1799       21.0412       20.8031
    21.3862       20.8026       21.2357       21.1394       20.9184
  -0.221382      0.000000      0.000000      0.000000

 --------(OUTPUTS FROM TIME=2.00 HOUR TO 45.75 HOUR ARE DELETED)-----
```

| | | | | |
|---|---|---|---|---|
| 46.0000 | 21.5826 | 22.2978 | 22.3858 | 21.6182 |
| 23.1710 | 21.6167 | 22.5207 | 22.2371 | 23.2000 |
| -0.300409 | 0.000000 | 0.000000 | 0.000000 | |
| 46.2500 | 21.4953 | 22.1766 | 22.2449 | 21.5287 |
| 22.9737 | 21.5273 | 22.3873 | 22.1180 | 22.9789 |
| -0.291503 | 0.000000 | 0.000000 | 0.000000 | |
| 46.5000 | 21.4200 | 22.0715 | 22.1218 | 21.4517 |
| 22.8010 | 21.4504 | 22.2689 | 22.0144 | 22.7725 |
| -0.283895 | 0.000000 | 0.000000 | 0.000000 | |
| 46.7500 | 21.3547 | 21.9798 | 22.0139 | 21.3847 |
| 22.6490 | 21.3835 | 22.1632 | 21.9239 | 22.5798 |
| -0.277311 | 0.000000 | 0.000000 | 0.000000 | |
| 47.0000 | 21.2977 | 21.8994 | 21.9193 | 21.3263 |
| 22.5147 | 21.3251 | 22.0686 | 21.8445 | 22.4000 |
| -0.271551 | 0.000000 | 0.000000 | 0.000000 | |
| 47.2500 | 21.2476 | 21.8286 | 21.8360 | 21.2750 |
| 22.3954 | 21.2739 | 21.9836 | 21.7744 | 22.2322 |
| -0.266488 | 0.000000 | 0.000000 | 0.000000 | |
| 47.5000 | 21.2160 | 21.7894 | 21.7731 | 21.2427 |
| 22.3032 | 21.2416 | 21.9335 | 21.7279 | 22.0762 |
| -0.281198 | 0.000000 | 0.000000 | 0.000000 | |
| 47.7500 | 21.1762 | 21.7274 | 21.7091 | 21.2018 |
| 22.2095 | 21.2008 | 21.8538 | 21.6709 | 21.9322 |
| -0.263855 | 0.000000 | 0.000000 | 0.000000 | |
| 48.0000 | 21.1395 | 21.6742 | 21.6508 | 21.1642 |
| 22.1230 | 21.1632 | 21.7881 | 21.6196 | 21.8000 |
| -0.257617 | 0.000000 | 0.000000 | 0.000000 | |

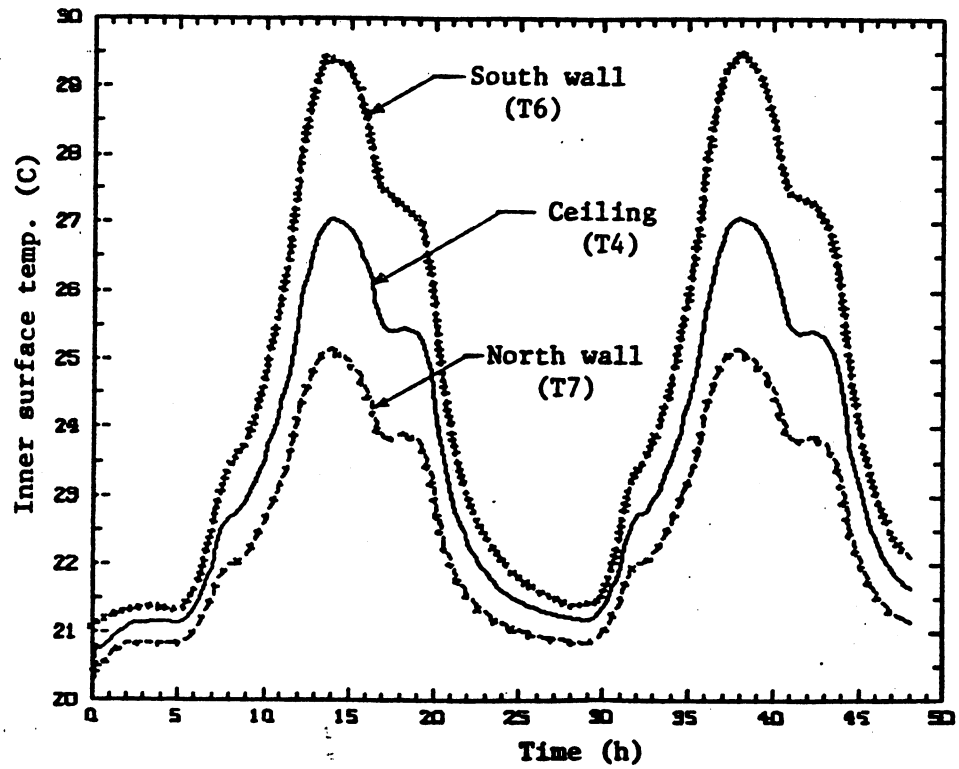


Figure C-3. Inner surface temperatures of the single-zone model

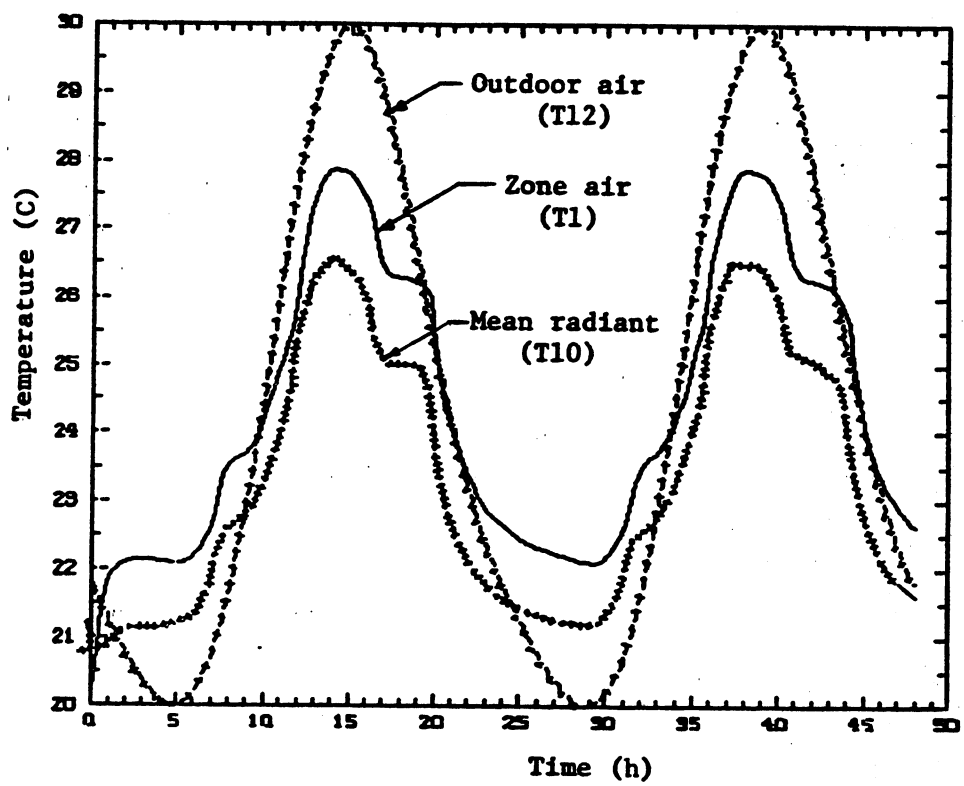


Figure C-4. Outdoor air, zone air, and mean radiant temperatures of the single-zone model

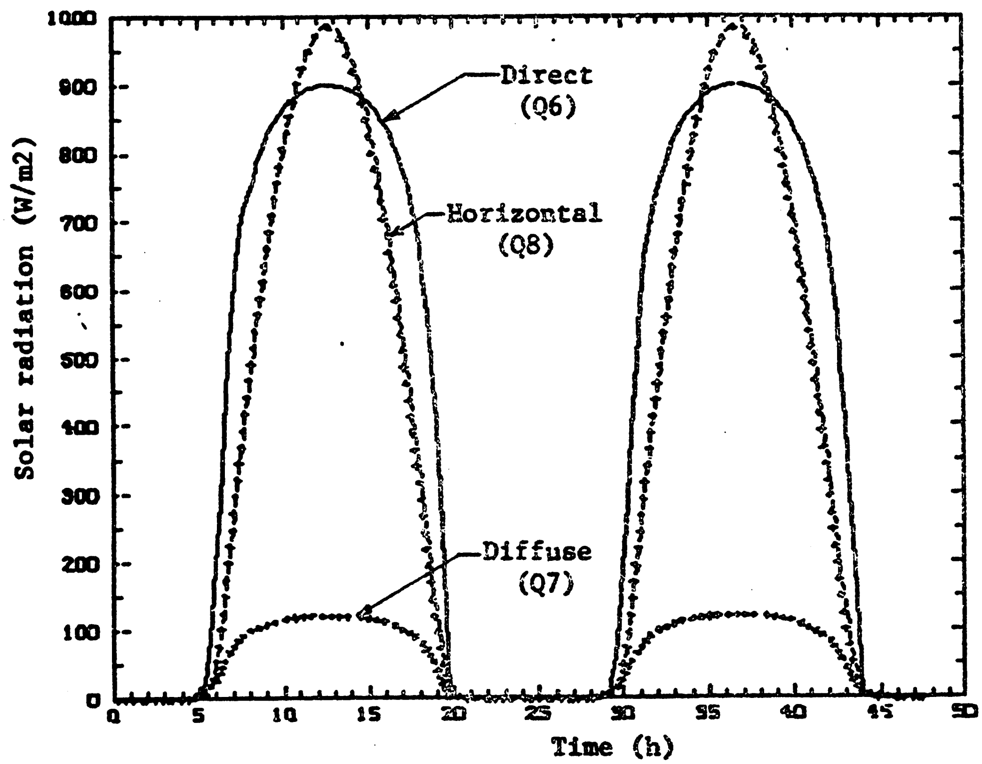


Figure C-5. Artificially generated solar radiation influxes

================================================================================
APPENDIX D: Example 2 Three-zone Building Model
================================================================================

A three-zone building model is simulated in this example, following the Simulation Procedure outlined in Chapter 9 of this report. The purpose of the example is to demonstrate how to use HVACSIM+ with a multizone building model. Selected data files are listed. The weather data file is created by using the weather tape information. The inlet temperature of the inlet duct is selected as a boundary variable. The machine precisons used in this example are the same as those used in Example 1.

A. Preprocessing - Input Data Generation

(1) Creation of Simulation Work File

As shown in Figure D-1, the example model is a single-story building with three zones. A simple system (inlet duct-fan-duct) is connected to one of zones, Zone 3 (see Figure D-2).

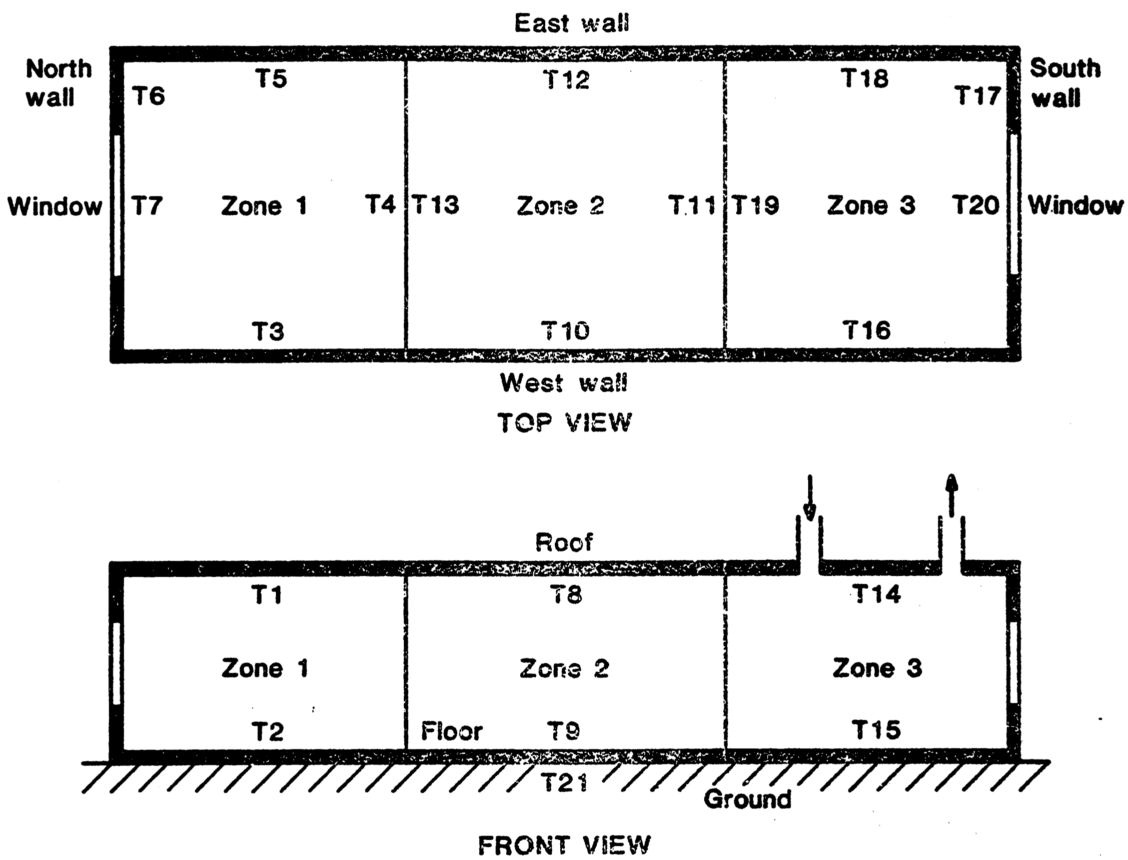


Figure D-1. A three-zone model

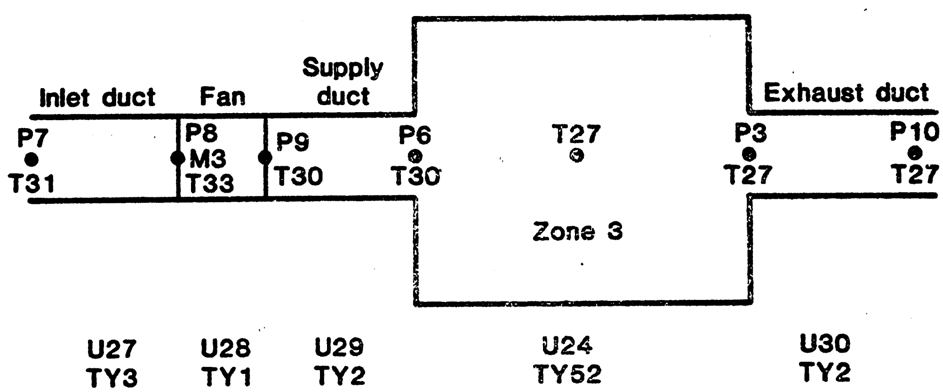


Figure D-2. A simple system (fan and ducts) for Zone 3

---

* Initial Conditions of State Variables

---

| | | |
|---|---|---|
| P1 | Zone air pressure, gage (IZN=1) | 0.0 kPa |
| P2 | Zone air pressure, gage (IZN=2) | 0.0 kPa |
| P3 | Zone air pressure, gage (IZN=3) | 0.3 kPa |
| P4 | Supply air pressure, gage (IZN=1) | 0.0 kPa |
| P5 | Supply air pressure, gage (IZN=2) | 0.0 kPa |
| P6 | Supply air pressure, gage (IZN=3) | 0.5 kPa |
| P7 | Inlet pressure of the inlet duct | 0.0 kPa |
| P8 | Outlet pressure of the inlet duct | -0.8 kPa |
| P9 | Outlet pressure of the fan | 1.0 kPa |
| P10 | Outlet pressure of the exhaust duct | -0.5 kPa |
| P11 | Outdoor air barometric pressure | 0.0 kPa |
| M1 | Supply air mass flow rate (IZN=1) | 0.0 kg/s |
| M2 | Supply air mass flow rate (IZN=2) | 0.0 kg/s |
| M3 | Supply air mass flow rate (IZN=3) | 2.5 kg/s |
| T1 | Inner surface temp. of roof (IZN=1) | 20.0 C |
| T2 | Inner surface temp. of floor | 20.0 C |
| T3 | Inner surface temp. of west wall | 20.0 C |
| T4 | Inner surface temp. of south wall | 20.0 C |
| T5 | Inner surface temp. of east wall | 20.0 C |
| T6 | Inner surface temp. of north wall | 20.0 C |
| T7 | Inner surface temp. of north window | 20.0 C |
| T8 | Inner surface temp. of roof (IZN=2) | 20.0 C |
| T9 | Inner surface temp. of floor | 20.0 C |
| T10 | Inner surface temp. of west wall | 20.0 C |
| T11 | Inner surface temp. of south wall | 20.0 C |
| T12 | Inner surface temp. of east wall | 20.0 C |
| T13 | Inner surface temp. of north wall | 20.0 C |
| T14 | Inner surface temp. of roof (IZN=3) | 20.0 C |
| T15 | Inner surface temp. of floor | 20.0 C |
| T16 | Inner surface temp. of west wall | 20.0 C |
| T17 | Inner surface temp. of south wall | 20.0 C |
| T18 | Inner surface temp. of east wall | 20.0 C |
| T19 | Inner surface temp. of north wall | 20.0 C |
| T20 | Inner surface temp. of south window | 20.0 C |
| T21 | Ground temp. | 15.0 C |
| T22 | Mean radiant temperature (IZN=1) | 20.0 C |
| T23 | Mean radiant temperature (IZN=2) | 20.0 C |
| T24 | Mean radiant temperature (IZN=3) | 20.0 C |
| T25 | Zone air dry-bulb temp. (IZN=1) | 20.0 C |
| T26 | Zone air dry-bulb temp. (IZN=2) | 20.0 C |
| T27 | Zone air dry-bulb temp. (IZN=3) | 20.0 C |
| T28 | Supply air temp. (IZN=1) | 20.0 C |
| T29 | Supply air temp. (IZN=2) | 20.0 C |
| T30 | Supply air temp. (IZN=3) | 20.0 C |
| T31 | Inlet air temp. of the inlet duct (B.C.) | 20.0 C |
| T32 | Outdoor air dry-bulb temp. | 20.0 C |
| T33 | Outlet air temp. of the inlet duct | 20.0 C |
| C1 | Number of people (IZN=1) | 1.0 |
| C2 | Equipment utilization coefficient | 1.0 |
| C3 | Light utilization coefficient | 1.0 |
| C4 | Shaded fraction of outer surface | 0.0 |
| C5 | Number of people (IZN=2) | 1.0 |

| | | |
|---|---|---|
| C6 | Equipment utilization coefficient | 1.0 |
| C7 | Light utilization coefficient | 1.0 |
| C8 | Shaded fraction of outer surface | 0.0 |
| C9 | Number of people (IZN=3) | 1.0 |
| C10 | Equipment utilization coefficient | 1.0 |
| C11 | Light utilization coefficient | 1.0 |
| C12 | Shaded fraction of outer surface | 0.0 |
| | | |
| R1 | Fan roataional speed | 60.0 rev/s |
| | | |
| Q1 | Convective heat gain from surfaces (IZN=1) | 0.0 kW |
| Q2 | Short wave radiant heat gain | 0.0 kW |
| Q3 | Long wave radiant heat gain | 0.0 kW |
| Q4 | Convective heat gain from surfaces (IZN=2) | 0.0 kW |
| Q5 | Short wave radiant heat gain | 0.0 kW |
| Q6 | Long wave radiant heat gain | 0.0 kW |
| Q7 | Convective heat gain from surfaces (IZN=3) | 0.0 kW |
| Q8 | Short wave radiant heat gain | 0.0 kW |
| Q9 | Long wave radiant heat gain | 0.0 kW |
| Q10 | Fan power consumption | 0.0 kW |
| Q11 | Direct solar radiation | 0.0 kW |
| Q12 | Diffuse solar radiation | 0.0 kW |
| Q13 | Total horizontal solar radiation | 0.0 kW |
| | | |
| H1 | Zone air humidity ratio (IZN=1) | 0.0074 |
| H2 | Zone air humidity ratio (IZN=2) | 0.0074 |
| H3 | Zone air humidity ratio (IZN=3) | 0.0074 |
| H4 | Supply air humidity ratio (IZN=1) | 0.0074 |
| H5 | Supply air humidity ratio (IZN=2) | 0.0074 |
| H6 | Supply air humidity ratio (IZN=3) | 0.0074 |
| H7 | Outdoor air humidity ratio | 0.0 |

```
------------------------
* Execution of HVACGEN
------------------------
 HVACGEN - Simulation GENeration Program
 Version 1.8 (08-16 1985)

 Choose from the list below:

 CReate (SImulation,BLock,UNit)

 EDit (SImulation,UNit)

 VIew (SImulation,BLock,UNit)

 HElp

 ENd

 Selection ?
VI

 View a:

 SImulation
 BLock
 UNit
 Enter Selection
SI

 Enter the filename (Maximum of 8 characters)
THRIZONE
 reading from work file....
 INITIALIZING TYPES INFORMATION...

  What part of the simulation would you like to view:

 ALl the simulation information (for documentation)

 STructure (superblock,block, and unit Information)

 VAriable initial values

 ERror tolerances, variable scan and freeze options

 BOundary variables

 REported variables

 COntinue with the previous menu

AL

 THREE ZONE BUILDING MODEL --A SINGLE STORY BUILDING

 SUPERBLOCK 1
      BLOCK 1
           UNIT  1      TYPE 50 - ZONE ENVELOPE
```

```
        UNIT  2      TYPE 51 - BUILDING SURFACE
        UNIT  3      TYPE 51 - BUILDING SURFACE
        UNIT  4      TYPE 51 - BUILDING SURFACE
        UNIT  5      TYPE 51 - BUILDING SURFACE
        UNIT  6      TYPE 51 - BUILDING SURFACE
        UNIT  7      TYPE 51 - BUILDING SURFACE
        UNIT  8      TYPE 51 - BUILDING SURFACE
    BLOCK 2
        UNIT  9      TYPE 50 - ZONE ENVELOPE
        UNIT 10      TYPE 51 - BUILDING SURFACE
        UNIT 11      TYPE 51 - BUILDING SURFACE
        UNIT 12      TYPE 51 - BUILDING SURFACE
        UNIT 13      TYPE 51 - BUILDING SURFACE
        UNIT 14      TYPE 51 - BUILDING SURFACE
        UNIT 15      TYPE 51 - BUILDING SURFACE
        UNIT 16      TYPE 51 - BUILDING SURFACE
    BLOCK 3
        UNIT 17      TYPE 50 - ZONE ENVELOPE
        UNIT 18      TYPE 51 - BUILDING SURFACE
        UNIT 19      TYPE 51 - BUILDING SURFACE
        UNIT 20      TYPE 51 - BUILDING SURFACE
        UNIT 21      TYPE 51 - BUILDING SURFACE
        UNIT 22      TYPE 51 - BUILDING SURFACE
        UNIT 23      TYPE 51 - BUILDING SURFACE
    BLOCK 4
        UNIT 31      TYPE 53 - WEATHER INPUT

SUPERBLOCK 2
    BLOCK 5
        UNIT 24      TYPE 52 - ZONE MODEL
    BLOCK 6
        UNIT 25      TYPE 52 - ZONE MODEL
    BLOCK 7
        UNIT 26      TYPE 52 - ZONE MODEL
    BLOCK 8
        UNIT 27      TYPE  3 - INLET CONDUIT (DUCT OR PIPE)
        UNIT 28      TYPE  1 - FAN OR PUMP
        UNIT 29      TYPE  2 - CONDUIT (DUCT OR PIPE)
        UNIT 30      TYPE  2 - CONDUIT (DUCT OR PIPE)
------------------------------------------------------

UNIT   1      TYPE  50
ZONE ENVELOPE

1      INPUTS:
        TEMPERATURE      27 - TIA:     Zone air dry-bulb temperature
        POWER             8 - QISW:    Internal (short wave) radiant gain
        POWER             9 - QILW:    Internal (long wave) radiant gain
        TEMPERATURE      14 - TIS(1):  Inner  surface temperature
        TEMPERATURE      15 - TIS(2):  Inner  surface temperature
        TEMPERATURE      16 - TIS(3):  Inner  surface temperature
        TEMPERATURE      17 - TIS(4):  Inner  surface temperature
        TEMPERATURE      18 - TIS(5):  Inner  surface temperature
        TEMPERATURE      19 - TIS(6):  Inner  surface temperature
        TEMPERATURE      20 - TIS(7):  Inner  surface temperature
        TEMPERATURE      20 - TIS(8):  Inner  surface temperature
        TEMPERATURE      20 - TIS(9):  Inner  surface temperature
        TEMPERATURE      20 - TIS(10): Inner  surface temperature

2      OUTPUTS:
```

```
        TEMPERATURE      24 - TMR:    Mean radiant temperature
        POWER             7 - QWALL:  Convective heat gain from  surfaces

3       PARAMETERS:
            3.00000      IZN:     Identification number of zone
            7.00000      NS:      Number of surfaces of zone
--------------------------------------------------------

UNIT   2       TYPE  51
BUILDING SURFACE

1       INPUTS:
        TEMPERATURE      27 - TIA:    Indoor air dry-bulb temperature
        TEMPERATURE      24 - TMR:    Mean radiant temperature
        TEMPERATURE      14 - TOSINF: Outer surface temp. of unexposed wall
        CONTROL          12 - FSHADW: Shaded fraction of exposed surface

2       OUTPUTS:
        TEMPERATURE      14 - TIS:    Inner surface temperature
        POWER             0 - SOLINT: Integrated solar influx  on surface

3       PARAMETERS:
            3.00000      IZN:     Identification number of zone
            1.00000      ID:      Identification number of surface
            2.00000      IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
            1.00000      ISTR:    Identification number of the construct
            37.2100      AS:      Surface area (m2)
           0.000000      ORIENT:  Azimuth angle of normal to surface & south
           0.000000      TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.200000      GRF:     Ground reflectivity (-)
            1.00000      IROFS:   Outer surface roughness index: 1=stucco,...
           0.600000      ABSOS:   Solar absorptance of outer surface (-)
           0 650000      ABSIS:   Short wave absorptance of inner surface(-)
           0.900000      EMITIS:  Emissivity of the inner surface (-)
           0.000000      TRANSM:  Transmittance of the glass window (-)
           0.000000      SC:      Shading coeff. of the glass window (-)
--------------------------------------------------------

UNIT   3       TYPE  51
BUILDING SURFACE

1       INPUTS:
        TEMPERATURE      27 - TIA:    Indoor air dry-bulb temperature
        TEMPERATURE      24 - TMR:    Mean radiant temperature
        TEMPERATURE      21 - TOSINF: Outer surface temp. of unexposed wall
        CONTROL          12 - FSHADW: Shaded fraction of exposed surface

2       OUTPUTS:
        TEMPERATURE      15 - TIS:    Inner surface temperature
        POWER             0 - SOLINT: Integrated solar influx  on surface

3       PARAMETERS:
            3.00000      IZN:     Identification number of zone
            2.00000      ID:      Identification number of surface
            1.00000      IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
            2.00000      ISTR:    Identification number of the construct
            37.2100      AS:      Surface area (m2)
           0.000000      ORIENT:  Azimuth angle of normal to surface & south
            180.000      TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.200000      GRF:     Ground reflectivity (-)
```

```
        0.000000      IROFS:  Outer surface roughness index: 1=stucco,...
        0.000000      ABSOS:  Solar absorptance of outer surface (-)
        0.650000      ABSIS:  Short wave absorptance of inner surface(-)
        0.900000      EMITIS: Emissivity of the inner surface (-)
        0.000000      TRANSM: Transmittance of the glass window (-)
        0.000000      SC:     Shading coeff. of the glass window (-)
-----------------------------------------------------

UNIT   4      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE       27 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE       24 - TMR:     Mean radiant temperature
        TEMPERATURE       16 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL           12 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       16 - TIS:     Inner surface temperature
        POWER              0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
            3.00000     IZN:    Identification number of zone
            3.00000     ID:     Identification number of surface
            2.00000     IEXPOS: 0=W/in zone, 1=betw.zones, 2=exposed to sun
            3.00000     ISTR:   Identification number of the construct
            24.4000     AS:     Surface area (m2)
            90.0000     ORIENT: Azimuth angle of normal to surface & south
            90.0000     TILT:   Tilt angle: flat roof=0, floor=180 (degree)
           0.200000     GRF:    Ground reflectivity (-)
            5.00000     IROFS:  Outer surface roughness index: 1=stucco,...
           0.400000     ABSOS:  Solar absorptance of outer surface (-)
           0.650000     ABSIS:  Short wave absorptance of inner surface(-)
           0.900000     EMITIS: Emissivity of the inner surface (-)
           0.000000     TRANSM: Transmittance of the glass window (-)
           0.000000     SC:     Shading coeff. of the glass window (-)
-----------------------------------------------------

UNIT   5      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE       27 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE       24 - TMR:     Mean radiant temperature
        TEMPERATURE       17 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL           12 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       17 - TIS:     Inner surface temperature
        POWER              0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
            3.00000     IZN:    Identification number of zone
            4.00000     ID:     Identification number of surface
            2.00000     IEXPOS: 0=W/in zone, 1=betw.zones, 2=exposed to sun
            3.00000     ISTR:   Identification number of the construct
            18.4000     AS:     Surface area (m2)
           0.000000     ORIENT: Azimuth angle of normal to surface & south
            90.0000     TILT:   Tilt angle: flat roof=0, floor=180 (degree)
           0.200000     GRF:    Ground reflectivity (-)
```

```
        5.00000     IROFS:  Outer surface roughness index: 1=stucco,...
       0.400000     ABSOS:  Solar absorptance of outer surface (-)
       0.650000     ABSIS:  Short wave absorptance of inner surface(-)
       0.900000     EMITIS: Emissivity of the inner surface (-)
       0.000000     TRANSM: Transmittance of the glass window (-)
       0.000000     SC:     Shading coeff. of the glass window (-)
------------------------------------------------------

UNIT   6      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      27 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      24 - TMR:     Mean radiant temperature
        TEMPERATURE      18 - TOSINF: Outer surface temp. of unexposed wall
        CONTROL          12 - FSHADW: Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE      18 - TIS:     Inner surface temperature
        POWER             0 - SOLINT: Integrated solar influx  on surface

3      PARAMETERS:
        3.00000     IZN:    Identification number of zone
        5.00000     ID:     Identification number of surface
        2.00000     IEXPOS: 0=W/in zone, 1=betw.zones, 2=exposed to sun
        3.00000     ISTR:   Identification number of the construct
        24.4000     AS:     Surface area (m2)
        270.000     ORIENT: Azimuth angle of normal to surface & south
        90.0000     TILT:   Tilt angle: flat roof=0, floor=180 (degree)
       0.200000     GRF:    Ground reflectivity (-)
        5.00000     IROFS:  Outer surface roughness index: 1=stucco,...
       0.400000     ABSOS:  Solar absorptance of outer surface (-)
       0.650000     ABSIS:  Short wave absorptance of inner surface(-)
       0.900000     EMITIS: Emissivity of the inner surface (-)
       0.000000     TRANSM: Transmittance of the glass window (-)
       0.000000     SC:     Shading coeff. of the glass window (-)
------------------------------------------------------

UNIT   7      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      27 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      24 - TMR:     Mean radiant temperature
        TEMPERATURE      11 - TOSINF: Outer surface temp. of unexposed wall
        CONTROL          12 - FSHADW: Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE      19 - TIS:     Inner surface temperature
        POWER             0 - SOLINT: Integrated solar influx  on surface

3      PARAMETERS:
        3.00000     IZN:    Identification number of zone
        6.00000     ID:     Identification number of surface
        1.00000     IEXPOS: 0=W/in zone, 1=betw.zones, 2=exposed to sun
        5.00000     ISTR:   Identification number of the construct
        24.4000     AS:     Surface area (m2)
       0.000000     ORIENT: Azimuth angle of normal to surface & south
        90.0000     TILT:   Tilt angle: flat roof=0, floor=180 (degree)
       0.200000     GRF:    Ground reflectivity (-)
```

```
        5.00000      IROFS:  Outer surface roughness index: 1=stucco,...
       0.600000      ABSOS:  Solar absorptance of outer surface (-)
       0.650000      ABSIS:  Short wave absorptance of inner surface(-)
       0.900000      EMITIS: Emissivity of the inner surface (-)
       0.000000      TRANSM: Transmittance of the glass window (-)
       0.000000      SC:     Shading coeff. of the glass window (-)
-----------------------------------------------------

UNIT   8      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      27 - TIA:    Indoor air dry-bulb temperature
        TEMPERATURE      24 - TMR:    Mean radiant temperature
        TEMPERATURE      20 - TOSINF: Outer surface temp. of unexposed wall
        CONTROL          12 - FSHADW: Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE      20 - TIS:    Inner surface temperature
        POWER             0 - SOLINT: Integrated solar influx  on surface

3      PARAMETERS:
          3.00000      IZN:    Identification number of zone
          7.00000      ID:     Identification number of surface
          2.00000      IEXPOS: 0=W/in zone, 1=betw.zones, 2=exposed to sun
          4.00000      ISTR:   Identification number of the construct
          6.00000      AS:     Surface area (m2)
         0.000000      ORIENT: Azimuth angle of normal to surface & south
          90.0000      TILT:   Tilt angle: flat roof=0, floor=180 (degree)
         0.200000      GRF:    Ground reflectivity (-)
          6.00000      IROFS:  Outer surface roughness index: 1=stucco,...
         0.000000      ABSOS:  Solar absorptance of outer surface (-)
         0.000000      ABSIS:  Short wave absorptance of inner surface(-)
         0.000000      EMITIS: Emissivity of the inner surface (-)
         0.850000      TRANSM: Transmittance of the glass window (-)
         0.800000      SC:     Shading coeff. of the glass window (-)
-----------------------------------------------------

UNIT   9      TYPE  50
ZONE ENVELOPE

1      INPUTS:
        TEMPERATURE      25 - TIA:    Zone air dry-bulb temperature
        POWER             2 - QISW:   Internal (short wave) radiant gain
        POWER             3 - QILW:   Internal (long wave) radiant gain
        TEMPERATURE       1 - TIS(1): Inner  surface temperature
        TEMPERATURE       2 - TIS(2): Inner  surface temperature
        TEMPERATURE       3 - TIS(3): Inner  surface temperature
        TEMPERATURE       4 - TIS(4): Inner  surface temperature
        TEMPERATURE       5 - TIS(5): Inner  surface temperature
        TEMPERATURE       6 - TIS(6): Inner  surface temperature
        TEMPERATURE       7 - TIS(7): Inner  surface temperature
        TEMPERATURE       7 - TIS(8): Inner  surface temperature
        TEMPERATURE       7 - TIS(9): Inner  surface temperature
        TEMPERATURE       7 - TIS(10):Inner  surface temperature

2      OUTPUTS:
        TEMPERATURE      22 - TMR:    Mean radiant temperature
        POWER             1 - QWALL:  Convective heat gain from  surfaces
```

```
3      PARAMETERS:
           1.00000     IZN:     Identification number of zone
           7.00000     NS:      Number of surfaces of zone
----------------------------------------------------

UNIT  10       TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      25 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      22 - TMR:     Mean radiant temperature
        TEMPERATURE       1 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL           4 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       1 - TIS:     Inner surface temperature
        POWER             0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
           1.00000     IZN:     Identification number of zone
           1.00000     ID:      Identification number of surface
           2.00000     IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
           1.00000     ISTR:    Identification number of the construct
           37.2100     AS:      Surface area (m2)
          0.000000     ORIENT:  Azimuth angle of normal to surface & south
          0.000000     TILT:    Tilt angle: flat roof=0, floor=180 (degree)
          0.200000     GRF:     Ground reflectivity (-)
           1.00000     IROFS:   Outer surface roughness index: 1=stucco,...
          0.600000     ABSOS:   Solar absorptance of outer surface (-)
          0.650000     ABSIS:   Short wave absorptance of inner surface(-)
          0.900000     EMITIS:  Emissivity of the inner surface (-)
          0.000000     TRANSM:  Transmittance of the glass window (-)
          0.000000     SC:      Shading coeff. of the glass window (-)
----------------------------------------------------

UNIT  11       TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      25 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      22 - TMR:     Mean radiant temperature
        TEMPERATURE      21 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL           4 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       2 - TIS:     Inner surface temperature
        POWER             0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
           1.00000     IZN:     Identification number of zone
           2.00000     ID:      Identification number of surface
           1.00000     IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
           2.00000     ISTR:    Identification number of the construct
           37.2100     AS:      Surface area (m2)
          0.000000     ORIENT:  Azimuth angle of normal to surface & south
           180.000     TILT:    Tilt angle: flat roof=0, floor=180 (degree)
          0.000000     GRF:     Ground reflectivity (-)
          0.000000     IROFS:   Outer surface roughness index: 1=stucco,...
          0.000000     ABSOS:   Solar absorptance of outer surface (-)
          0.650000     ABSIS:   Short wave absorptance of inner surface(-)
```

```
      0.900000     EMITIS: Emissivity of the inner surface (-)
      0.000000     TRANSM: Transmittance of the glass window (-)
      0.000000     SC:     Shading coeff. of the glass window (-)
-------------------------------------------------------

UNIT  12      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      25 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      22 - TMR:     Mean radiant temperature
        TEMPERATURE       3 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL           4 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       3 - TIS:     Inner surface temperature
        POWER             0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
            1.00000     IZN:     Identification number of zone
            3.00000     ID:      Identification number of surface
            2.00000     IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
            3.00000     ISTR:    Identification number of the construct
            24.4000     AS:      Surface area (m2)
            90.0000     ORIENT:  Azimuth angle of normal to surface & south
            90.0000     TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.200000     GRF:     Ground reflectivity (-)
            5.00000     IROFS:   Outer surface roughness index: 1=stucco,...
           0.400000     ABSOS:   Solar absorptance of outer surface (-)
           0.650000     ABSIS:   Short wave absorptance of inner surface(-)
           0.900000     EMITIS:  Emissivity of the inner surface (-)
           0.000000     TRANSM:  Transmittance of the glass window (-)
           0.000000     SC:      Shading coeff. of the glass window (-)
-------------------------------------------------------

UNIT  13      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      25 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      22 - TMR:     Mean radiant temperature
        TEMPERATURE      13 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL           4 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       4 - TIS:     Inner surface temperature
        POWER             0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
            1.00000     IZN:     Identification number of zone
            4.00000     ID:      Identification number of surface
            1.00000     IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
            5.00000     ISTR:    Identification number of the construct
            24.4000     AS:      Surface area (m2)
            180.000     ORIENT:  Azimuth angle of normal to surface & south
            90.0000     TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.200000     GRF:     Ground reflectivity (-)
           0.000000     IROFS:   Outer surface roughness index: 1=stucco,...
           0.000000     ABSOS:   Solar absorptance of outer surface (-)
           0.650000     ABSIS:   Short wave absorptance of inner surface(-)
```

```
        0.900000     EMITIS: Emissivity of the inner surface (-)
        0.000000     TRANSM: Transmittance of the glass window (-)
        0.000000     SC:     Shading coeff. of the glass window (-)
----------------------------------------------------

UNIT  14      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      25 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      22 - TMR:     Mean radiant temperature
        TEMPERATURE       5 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL           4 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       5 - TIS:     Inner surface temperature
        POWER             0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
            1.00000      IZN:     Identification number of zone
            5.00000      ID:      Identification number of surface
            2.00000      IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
            3.00000      ISTR:    Identification number of the construct
            24.4000      AS:      Surface area (m2)
            270.000      ORIENT:  Azimuth angle of normal to surface & south
            90.0000      TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.200000      GRF:     Ground reflectivity (-)
            5.00000      IROFS:   Outer surface roughness index: 1=stucco,...
           0.400000      ABSOS:   Solar absorptance of outer surface (-)
           0.650000      ABSIS:   Short wave absorptance of inner surface(-)
           0.900000      EMITIS:  Emissivity of the inner surface (-)
           0.000000      TRANSM:  Transmittance of the glass window (-)
           0.000000      SC:      Shading coeff. of the glass window (-)
----------------------------------------------------

UNIT  15      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      25 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      22 - TMR:     Mean radiant temperature
        TEMPERATURE       6 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL           4 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       6 - TIS:     Inner surface temperature
        POWER             0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
            1.00000      IZN:     Identification number of zone
            6.00000      ID:      Identification number of surface
            2.00000      IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
            3.00000      ISTR:    Identification number of the construct
            18.4000      AS:      Surface area (m2)
            180.000      ORIENT:  Azimuth angle of normal to surface & south
            90.0000      TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.200000      GRF:     Ground reflectivity (-)
            5.00000      IROFS:   Outer surface roughness index: 1=stucco,...
           0.400000      ABSOS:   Solar absorptance of outer surface (-)
           0.650000      ABSIS:   Short wave absorptance of inner surface(-)
```

```
        0.900000     EMITIS: Emissivity of the inner surface (-)
        0.000000     TRANSM: Transmittance of the glass window (-)
        0.000000     SC:     Shading coeff. of the glass window (-)
-----------------------------------------------------------

UNIT 16       TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE     25 - TIA:    Indoor air dry-bulb temperature
        TEMPERATURE     22 - TMR:    Mean radiant temperature
        TEMPERATURE      7 - TOSINF: Outer surface temp. of unexposed wall
        CONTROL          4 - FSHADW: Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE      7 - TIS:    Inner surface temperature
        POWER            0 - SOLINT: Integrated solar influx  on surface

3      PARAMETERS:
          1.00000     IZN:    Identification number of zone
          7.00000     ID:     Identification number of surface
          2.00000     IEXPOS: 0=W/in zone, 1=betw.zones, 2=exposed to sun
          4.00000     ISTR:   Identification number of the construct
          6.00000     AS:     Surface area (m2)
          180.000     ORIENT: Azimuth angle of normal to surface & south
          90.0000     TILT:   Tilt angle: flat roof=0, floor=180 (degree)
         0.200000     GRF:    Ground reflectivity (-)
          6.00000     IROFS:  Outer surface roughness index: 1=stucco,...
         0.000000     ABSOS:  Solar absorptance of outer surface (-)
         0.000000     ABSIS:  Short wave absorptance of inner surface(-)
         0.000000     EMITIS: Emissivity of the inner surface (-)
         0.850000     TRANSM: Transmittance of the glass window (-)
         0.800000     SC:     Shading coeff. of the glass window (-)
-----------------------------------------------------------
```

```
UNIT  17       TYPE  50
ZONE ENVELOPE

1      INPUTS:
        TEMPERATURE      26 - TIA:     Zone air dry-bulb temperature
        POWER             5 - QISW:    Internal (short wave) radiant gain
        POWER             6 - QILW:    Internal (long wave) radiant gain
        TEMPERATURE       8 - TIS(1):  Inner  surface temperature
        TEMPERATURE       9 - TIS(2):  Inner  surface temperature
        TEMPERATURE      10 - TIS(3):  Inner  surface temperature
        TEMPERATURE      11 - TIS(4):  Inner  surface temperature
        TEMPERATURE      12 - TIS(5):  Inner  surface temperature
        TEMPERATURE      13 - TIS(6):  Inner  surface temperature
        TEMPERATURE      13 - TIS(7):  Inner  surface temperature
        TEMPERATURE      13 - TIS(8):  Inner  surface temperature
        TEMPERATURE      13 - TIS(9):  Inner  surface temperature
        TEMPERATURE      13 - TIS(10):Inner  surface temperature

2      OUTPUTS:
        TEMPERATURE      23 - TMR:     Mean radiant temperature
        POWER             4 - QWALL:   Convective heat gain from  surfaces

3      PARAMETERS:
            2.00000     IZN:    Identification number of zone
            6.00000     NS:     Number of surfaces of zone
-----------------------------------------------------

UNIT  18       TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      26 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      23 - TMR:     Mean radiant temperature
        TEMPERATURE       4 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL           8 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE      13 - TIS:     Inner surface temperature
        POWER             0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
            2.00000     IZN:    Identification number of zone
            6.00000     ID:     Identification number of surface
            1.00000     IEXPOS: 0=W/in zone, 1=betw.zones, 2=exposed to sun
            5.00000     ISTR:   Identification number of the construct
            24.4000     AS:     Surface area (m2)
           0.000000     ORIENT: Azimuth angle of normal to surface & south
            90.0000     TILT:   Tilt angle: flat roof=0, floor=180 (degree)
           0.200000     GRF:    Ground reflectivity (-)
           0.000000     IROFS:  Outer surface roughness index: 1=stucco,...
           0.000000     ABSOS:  Solar absorptance of outer surface (-)
           0.650000     ABSIS:  Short wave absorptance of inner surface(-)
           0.900000     EMITIS: Emissivity of the inner surface (-)
           0.000000     TRANSM: Transmittance of the glass window (-)
           0.000000     SC:     Shading coeff. of the glass window (-)
-----------------------------------------------------
```

```
UNIT  19      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE     26 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE     23 - TMR:     Mean radiant temperature
        TEMPERATURE     12 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL          8 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE     12 - TIS:     Inner surface temperature
        POWER            0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
            2.00000    IZN:     Identification number of zone
            5.00000    ID:      Identification number of surface
            2.00000    IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
            3.00000    ISTR:    Identification number of the construct
            24.4000    AS:      Surface area (m2)
            270.000    ORIENT:  Azimuth angle of normal to surface & south
            90.0000    TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.200000    GRF:     Ground reflectivity (-)
            5.00000    IROFS:   Outer surface roughness index: 1=stucco,...
           0.400000    ABSOS:   Solar absorptance of outer surface (-)
           0.650000    ABSIS:   Short wave absorptance of inner surface(-)
           0.900000    EMITIS:  Emissivity of the inner surface (-)
           0.000000    TRANSM:  Transmittance of the glass window (-)
           0.000000    SC:      Shading coeff. of the glass window (-)
-----------------------------------------------------

UNIT  20      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE     26 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE     23 - TMR:     Mean radiant temperature
        TEMPERATURE     19 - TOSINF:  Outer surface temp. of unexposed wall
        CONTROL          8 - FSHADW:  Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE     11 - TIS:     Inner surface temperature
        POWER            0 - SOLINT:  Integrated solar influx  on surface

3      PARAMETERS:
            2.00000    IZN:     Identification number of zone
            4.00000    ID:      Identification number of surface
            1.00000    IEXPOS:  0=W/in zone, 1=betw.zones, 2=exposed to sun
            5.00000    ISTR:    Identification number of the construct
            24.4000    AS:      Surface area (m2)
            180.000    ORIENT:  Azimuth angle of normal to surface & south
            90.0000    TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.000000    GRF:     Ground reflectivity (-)
           0.000000    IROFS:   Outer surface roughness index: 1=stucco,...
           0.000000    ABSOS:   Solar absorptance of outer surface (-)
           0.650000    ABSIS:   Short wave absorptance of inner surface(-)
           0.900000    EMITIS:  Emissivity of the inner surface (-)
           0.000000    TRANSM:  Transmittance of the glass window (-)
           0.000000    SC:      Shading coeff. of the glass window (-)
-----------------------------------------------------
```

```
UNIT  21      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      26 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      23 - TMR:     Mean radiant temperature
        TEMPERATURE      10 - TOSINF: Outer surface temp. of unexposed wall
        CONTROL           8 - FSHADW: Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE      10 - TIS:     Inner surface temperature
        POWER             0 - SOLINT: Integrated solar influx  on surface

3      PARAMETERS:
            2.00000      IZN:     Identification number of zone
            3.00000      ID:      Identification number of surface
            2.00000      IEXPOS: 0=W/in zone, 1=betw.zones, 2=exposed to sun
            3.00000      ISTR:    Identification number of the construct
            24.4000      AS:      Surface area (m2)
            90.0000      ORIENT: Azimuth angle of normal to surface & south
            90.0000      TILT:    Tilt angle: flat roof=0, floor=180 (degree)
          0.200000      GRF:     Ground reflectivity (-)
            5.00000      IROFS:   Outer surface roughness index: 1=stucco,...
          0.400000      ABSOS:   Solar absorptance of outer surface (-)
          0.650000      ABSIS:   Short wave absorptance of inner surface(-)
          0.900000      EMITIS: Emissivity of the inner surface (-)
          0.000000      TRANSM: Transmittance of the glass window (-)
          0.000000      SC:      Shading coeff. of the glass window (-)
--------------------------------------------------------------

UNIT  22      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      26 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      23 - TMR:     Mean radiant temperature
        TEMPERATURE      21 - TOSINF: Outer surface temp. of unexposed wall
        CONTROL           8 - FSHADW: Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       9 - TIS:     Inner surface temperature
        POWER             0 - SOLINT: Integrated solar influx  on surface

3      PARAMETERS:
            2.00000      IZN:     Identification number of zone
            2.00000      ID:      Identification number of surface
            1.00000      IEXPOS: 0=W/in zone, 1=betw.zones, 2=exposed to sun
            2.00000      ISTR:    Identification number of the construct
            37.2100      AS:      Surface area (m2)
          0.000000      ORIENT: Azimuth angle of normal to surface & south
            180.000      TILT:    Tilt angle: flat roof=0, floor=180 (degree)
          0.000000      GRF:     Ground reflectivity (-)
          0.000000      IROFS:   Outer surface roughness index: 1=stucco,...
          0.000000      ABSOS:   Solar absorptance of outer-surface (-)
          0.650000      ABSIS:   Short wave absorptance of inner surface(-)
          0.900000      EMITIS: Emissivity of the inner surface (-)
          0.000000      TRANSM: Transmittance of the glass window (-)
          0.000000      SC:      Shading coeff. of the glass window (-)
--------------------------------------------------------------
```

```
UNIT  23      TYPE  51
BUILDING SURFACE

1      INPUTS:
        TEMPERATURE      26 - TIA:     Indoor air dry-bulb temperature
        TEMPERATURE      23 - TMR:     Mean radiant temperature
        TEMPERATURE       8 - TOSINF: Outer surface temp. of unexposed wall
        CONTROL           8 - FSHADW: Shaded fraction of exposed surface

2      OUTPUTS:
        TEMPERATURE       8 - TIS:     Inner surface temperature
        POWER             0 - SOLINT: Integrated solar influx  on surface

3      PARAMETERS:
            2.00000     IZN:     Identification number of zone
            1.00000     ID:      Identification number of surface
            2.00000     IEXPOS: 0=W/in zone, 1=betw.zones, 2=exposed to sun
            1.00000     ISTR:    Identification number of the construct
            37.2100     AS:      Surface area (m2)
           0.000000     ORIENT: Azimuth angle of normal to surface & south
           0.000000     TILT:    Tilt angle: flat roof=0, floor=180 (degree)
           0.200000     GRF:     Ground reflectivity (-)
            1.00000     IROFS:   Outer surface roughness index: 1=stucco,...
           0.600000     ABSOS:   Solar absorptance of outer surface (-)
           0.650000     ABSIS:   Short wave absorptance of inner surface(-)
           0.900000     EMITIS: Emissivity of the inner surface (-)
           0.000000     TRANSM: Transmittance of the glass window (-)
           0.000000     SC:      Shading coeff. of the glass window (-)
--------------------------------------------------------

UNIT  31      TYPE  53
WEATHER INPUT

1      INPUTS:
        TEMPERATURE      32 - TAMB:    Ambient (outdoor) air temperature (C)
        ABS. HUMIDITY     7 - HUMRAT: Outdoor air humidity ratio (-)
        PRESSURE         11 - PBAR:    Barometric pressure (kPa)
        POWER            11 - IDN:     Direct normal solar radiation (W/m2)
        POWER            12 - ISKY:    Diffuse (sky) solar radiation (W/m2)
        POWER            13 - IHOR:    Total horizontal solar radiation (W/m2)

2      OUTPUTS:

3      PARAMETERS:
            32.0000     Index for ambient temperature (e.g. 5 if TAMB=T5)
            7.00000     Index for outdoor air humidity ratio
            11.0000     Index for barometric pressure
            11.0000     Index for direct normal solar radiation
            12.0000     Index for diffuse (sky) solar radiation
            13.0000     Index for total horizontal solar radiation
--------------------------------------------------------

UNIT  24      TYPE  52
ZONE MODEL

1      INPUTS:
        PRESSURE          3 - PIAG:    Gage pressure of zone air
        TEMPERATURE      27 - TIA:     Zone air dry-bulb temperature
        ABS. HUMIDITY     3 - WIA:     Humidiy ratio of zone air
```

```
        PRESSURE          6 - PSAG:   Gage pressure of supply air
        FLOW              3 - MSA:    Mass flow rate of supply air
        TEMPERATURE      30 - TSA:    Supply air dry-bulb temperature
        ABS. HUMIDITY     6 - WSA:    Humidity ratio of supply air
        POWER             7 - QWALL:  Convective heat gain from surfaces
        CONTROL           9 - NUMPEP: Number of people (occupant in the zone)
        CONTROL          10 - UTCEQP: Equipment utilization coefficient
        CONTROL          11 - UTCLIT: Lighting utilization coefficient

2      OUTPUTS:
        TEMPERATURE      27 - TIA:    Zone air dry-bulb temp. [diff. eq.]
        ABS. HUMIDITY     3 - WIA:    Humidity ratio of zone air [diff. eq.]
        POWER             8 - QISW:   Internal (short wave) radiant gain
        POWER             9 - QILW:   Internal (long wave) radiant gain

3      PARAMETERS:
           3.00000      IZN:    Identification number of zone
           400.000      CFUR:   Effective capacitance of furnishings (kJ/K)
           5.00000      EFFMIA: Multiplier for zone moisture capacitance(-)
           148.840      VOLUME: Volume of zone air (interior space ) (m3)
           1.00000      SAIREX: Standard air exchange rate (1/h)
         0.717600E-01 WPEPS:  Sensible heat gain from a person (kW)
         0.455000E-01 WPEPL:  Latent heat gain from a person (kW)
         0.200000     WLIT:   Heat gain due to lighting in the zone (kW)
          2.00000     LIGHT:  1 = Fluorescent, 2 = Incandescent (-)
         0.150000     WEQPS:  Sensible heat gain due to equipment (kW)
         0.200000E-01 WEQPL:  Latent heat gain due to equipment (kW)
         0.300000     REQP:   Radiative to sensible heat from equipment(-)
-----------------------------------------------------

UNIT  25      TYPE  52
ZONE MODEL

1      INPUTS:
        PRESSURE          1 - PIAG:   Gage pressure of zone air
        TEMPERATURE      25 - TIA:    Zone air dry-bulb temperature
        ABS. HUMIDITY     1 - WIA:    Humidiy ratio of zone air
        PRESSURE          4 - PSAG:   Gage pressure of supply air
        FLOW              1 - MSA:    Mass flow rate of supply air
        TEMPERATURE      28 - TSA:    Supply air dry-bulb temperature
        ABS. HUMIDITY     4 - WSA:    Humidity ratio of supply air
        POWER             1 - QWALL:  Convective heat gain from surfaces
        CONTROL           1 - NUMPEP: Number of people (occupant in the zone)
        CONTROL           2 - UTCEQP: Equipment utilization coefficient
        CONTROL           3 - UTCLIT: Lighting utilization coefficient

2      OUTPUTS:
        TEMPERATURE      25 - TIA:    Zone air dry-bulb temp. [diff. eq.]
        ABS. HUMIDITY     1 - WIA:    Humidity ratio of zone air [diff. eq.]
        POWER             2 - QISW:   Internal (short wave) radiant gain
        POWER             3 - QILW:   Internal (long wave) radiant gain

3      PARAMETERS:
           1.00000      IZN:    Identification number of zone
           400.000      CFUR:   Effective capacitance of furnishings (kJ/K)
           5.00000      EFFMIA: Multiplier for zone moisture capacitance(-)
           148.840      VOLUME: Volume of zone air (interior space ) (m3)
           1.00000      SAIREX: Standard air exchange rate (1/h)
         0.717600E-01 WPEPS:  Sensible heat gain from a person (kW)
         0.454000E-01 WPEPL:  Latent heat gain from a person (kW)
```

```
        0.200000     WLIT:   Heat gain due to lighting in the zone (kW)
         2.00000     LIGHT:  1 = Fluorescent, 2 = Incandescent (-)
        0.150000     WEQPS:  Sensible heat gain due to equipment (kW)
        0.200000E-01 WEQPL:  Latent heat gain due to equipment (kW)
        0.300000     REQP:   Radiative to sensible heat from equipment(-)
-----------------------------------------------------

UNIT  26       TYPE  52
ZONE MODEL

1      INPUTS:
        PRESSURE           2 - PIAG:   Gage pressure of zone air
        TEMPERATURE       26 - TIA:    Zone air dry-bulb temperature
        ABS. HUMIDITY      2 - WIA:    Humidiy ratio of zone air
        PRESSURE           5 - PSAG:   Gage pressure of supply air
        FLOW               2 - MSA:    Mass flow rate of supply air
        TEMPERATURE       29 - TSA:    Supply air dry-bulb temperature
        ABS. HUMIDITY      5 - WSA:    Humidity ratio of supply air
        POWER              4 - QWALL:  Convective heat gain from surfaces
        CONTROL            5 - NUMPEP: Number of people (occupant in the zone)
        CONTROL            6 - UTCEQP: Equipment utilization coefficient
        CONTROL            7 - UTCLIT: Lighting utilization coefficient

2      OUTPUTS:
        TEMPERATURE       26 - TIA:    Zone air dry-bulb temp. [diff. eq.]
        ABS. HUMIDITY      2 - WIA:    Humidity ratio of zone air [diff. eq.]
        POWER              5 - QISW:   Internal (short wave) radiant gain
        POWER              6 - QILW:   Internal (long wave) radiant gain

3      PARAMETERS:
          2.00000      IZN:    Identification number of zone
          400.000      CFUR:   Effective capacitance of furnishings (kJ/K)
          5.00000      EFFMIA: Multiplier for zone moisture capacitance(-)
          148.840      VOLUME: Volume of zone air (interior space ) (m3)
          1.00000      SAIREX: Standard air exchange rate (1/h)
        0.717600E-01 WPEPS:  Sensible heat gain from a person (kW)
        0.454000E-01 WPEPL:  Latent heat gain from a person (kW)
        0.200000     WLIT:   Heat gain due to lighting in the zone (kW)
         2.00000     LIGHT:  1 = Fluorescent, 2 = Incandescent (-)
        0.150000     WEQPS:  Sensible heat gain due to equipment (kW)
        0.200000E-01 WEQPL:  Latent heat gain due to equipment (kW)
        0.300000     REQP:   Radiative to sensible heat from equipment(-)
-----------------------------------------------------

UNIT  27       TYPE   3
INLET CONDUIT (DUCT OR PIPE)

1      INPUTS:
        PRESSURE           7 - INLET FLUID PRESSURE
        PRESSURE           8 - OUTLET FLUID PRESSURE
        TEMPERATURE       31 - INLET FLUID TEMPERATURE
        TEMPERATURE       32 - AMBIENT AIR TEMPERATURE
        TEMPERATURE       33 - OUTLET FLUID TEMPERATURE (SAME AS FIRST OUTPUT)

2      OUTPUTS:
        TEMPERATURE       33 - OUTLET FLUID TEMPERATURE (SAME AS FIFTH INPUT)
        FLOW               3 - FLUID MASS FLOW RATE

3      PARAMETERS:
        0.000000     INSIDE HEAT TRANSFER COEFFICIENT X AREA (KW/C)
```

```
        0.000000      OUTSIDE HEAT TRANSFER COEFFICIENT X AREA (KW/C)
        0.000000      THERMAL CAPACITANCE OF CONDUIT MATERIAL (KJ/C)
        0.000000      VOLUME (M3)
        0.125000      FLOW RESISTANCE [0.001/(KG M)]
        0.000000      HEIGHT OF OUTLET ABOVE INLET (M)
         1.00000      MODE: 2=WATER, 1=AIR, NEG.=DETAILED, POS.=SIMPLE DYNAMI
----------------------------------------------------

UNIT  28      TYPE   1
FAN OR PUMP

1      INPUTS:
        FLOW              3 - MASS FLOW RATE OF FLUID
        PRESSURE          9 - OUTLET PRESSURE
        RVPS              1 - FAN OR PUMP ROTATIONAL SPEED
        TEMPERATURE      33 - INLET FLUID TEMPERATURE

2      OUTPUTS:
        PRESSURE          8 - INLET PRESSURE
        TEMPERATURE      30 - OUTLET FLUID TEMPERATURE
        POWER            10 - POWER CONSUMPTION

3      PARAMETERS:
         3.64000      1ST PRESSURE COEFFICIENT
        0.801000      2ND PRESSURE COEFFICIENT
       -0.190000      3RD PRESSURE COEFFICIENT
       -0.444000E-02  4TH PRESSURE COEFFICIENT
        0.000000      5TH PRESSURE COEFFICIENT
        0.000000      1ST EFFICIENCY COEFFICIENT
        0.564000      2ND EFFICIENCY COEFFICIENT
       -0.862000E-01  3RD EFFICIENCY COEFFICIENT
        0.000000      4TH EFFICIENCY COEFFICIENT
        0.000000      5TH EFFICIENCY COEFFICIENT
        0.336500      DIAMETER (M)
         1.00000      MODE: AIR=1, WATER=2
----------------------------------------------------

UNIT  29      TYPE   2
CONDUIT (DUCT OR PIPE)

1      INPUTS:
        FLOW              3 - FLUID MASS FLOW RATE
        PRESSURE          6 - OUTLET PRESSURE
        TEMPERATURE      30 - FLUID INLET TEMPERATURE
        TEMPERATURE      32 - AMBIENT TEMPERATURE
        TEMPERATURE      30 - OUTLET FLUID TEMPERATURE (SAME AS FIRST OUTPUT)

2      OUTPUTS:
        TEMPERATURE       0 - OUTLET FLUID TEMPERATURE (SAME AS FIFTH INPUT)
        PRESSURE          9 - INLET PRESSURE

3      PARAMETERS:
        0.000000      INSIDE HEAT TRANSFER COEFFICIENT X AREA (KW/C)
        0.000000      OUTSIDE HEAT TRANSFER COEFFICIENT X AREA (KW/C)
        0.000000      THERMAL CAPACITANCE OF CONDUIT MATERIAL (KJ/C)
        0.000000      VOLUME (M3)
        0.125000      FLOW RESISTANCE [0.001/(KG M)]
        0.000000      HEIGHT OF OUTLET ABOVE INLET (M)
         1.00000      MODE: 2=WATER, 1=AIR, NEG.=DETAILED, POS.=SIMPLE DYNAMI
----------------------------------------------------
```

UNIT 30 TYPE 2
CONDUIT (DUCT OR PIPE)

1 INPUTS:

| | | |
|---|---|---|
| FLOW | 3 - | FLUID MASS FLOW RATE |
| PRESSURE | 10 - | OUTLET PRESSURE |
| TEMPERATURE | 27 - | FLUID INLET TEMPERATURE |
| TEMPERATURE | 32 - | AMBIENT TEMPERATURE |
| TEMPERATURE | 27 - | OUTLET FLUID TEMPERATURE (SAME AS FIRST OUTPUT) |

2 OUTPUTS:

| | | |
|---|---|---|
| TEMPERATURE | 0 - | OUTLET FLUID TEMPERATURE (SAME AS FIFTH INPUT) |
| PRESSURE | 3 - | INLET PRESSURE |

3 PARAMETERS:

| | |
|---|---|
| 0.000000 | INSIDE HEAT TRANSFER COEFFICIENT X AREA (KW/C) |
| 0.000000 | OUTSIDE HEAT TRANSFER COEFFICIENT X AREA (KW/C) |
| 0.000000 | THERMAL CAPACITANCE OF CONDUIT MATERIAL (KJ/C) |
| 0.000000 | VOLUME (M3) |
| 0.125000 | FLOW RESISTANCE [0.001/(KG M)] |
| 0.000000 | HEIGHT OF OUTLET ABOVE INLET (M) |
| 1.00000 | MODE: 2=WATER, 1=AIR, NEG.=DETAILED, POS.=SIMPLE DYNAMI |

---

Initial Variable Values:

| | | | |
|---|---|---|---|
| PRESSURE | 1 -> | 0.000000 | (kPa) |
| PRESSURE | 2 -> | 0.000000 | (kPa) |
| PRESSURE | 3 -> | 0.300000 | (kPa) |
| PRESSURE | 4 -> | 0.000000 | (kPa) |
| PRESSURE | 5 -> | 0.000000 | (kPa) |
| PRESSURE | 6 -> | 0.500000 | (kPa) |
| PRESSURE | 7 -> | 0.000000 | (kPa) |
| PRESSURE | 8 -> | -0.800000 | (kPa) |
| PRESSURE | 9 -> | 1.00000 | (kPa) |
| PRESSURE | 10 -> | -0.500000 | (kPa) |
| PRESSURE | 11 -> | 0.000000 | (kPa) |
| FLOW | 1 -> | 0.000000 | (kg/s) |
| FLOW | 2 -> | 0.000000 | (kg/s) |
| FLOW | 3 -> | 2.49683 | (kg/s) |
| TEMPERATURE | 1 -> | 20.0000 | (C) |
| TEMPERATURE | 2 -> | 20.0000 | (C) |
| TEMPERATURE | 3 -> | 20.0000 | (C) |
| TEMPERATURE | 4 -> | 20.0000 | (C) |
| TEMPERATURE | 5 -> | 20.0000 | (C) |
| TEMPERATURE | 6 -> | 20.0000 | (C) |
| TEMPERATURE | 7 -> | 20.0000 | (C) |
| TEMPERATURE | 8 -> | 20.0000 | (C) |
| TEMPERATURE | 9 -> | 20.0000 | (C) |
| TEMPERATURE | 10 -> | 20.0000 | (C) |
| TEMPERATURE | 11 -> | 20.0000 | (C) |
| TEMPERATURE | 12 -> | 20.0000 | (C) |
| TEMPERATURE | 13 -> | 20.0000 | (C) |
| TEMPERATURE | 14 -> | 20.0000 | (C) |
| TEMPERATURE | 15 -> | 20.0000 | (C) |
| TEMPERATURE | 16 -> | 20.0000 | (C) |
| TEMPERATURE | 17 -> | 20.0000 | (C) |
| TEMPERATURE | 18 -> | 20.0000 | (C) |
| TEMPERATURE | 19 -> | 20.0000 | (C) |
| TEMPERATURE | 20 -> | 20.0000 | (C) |

```
TEMPERATURE     21 ->      15.0000     (C)
TEMPERATURE     22 ->      20.0000     (C)
TEMPERATURE     23 ->      20.0000     (C)
TEMPERATURE     24 ->      20.0000     (C)
TEMPERATURE     25 ->      20.0000     (C)
TEMPERATURE     26 ->      20.0000     (C)
TEMPERATURE     27 ->      20.0000     (C)
TEMPERATURE     28 ->      20.0000     (C)
TEMPERATURE     29 ->      20.0000     (C)
TEMPERATURE     30 ->      20.0000     (C)
TEMPERATURE     31 ->      20.0000     (C)
TEMPERATURE     32 ->      20.0000     (C)
TEMPERATURE     33 ->      20.0000     (C)
CONTROL          1 ->      1.00000     (-)
CONTROL          2 ->      1.00000     (-)
CONTROL          3 ->      1.00000     (-)
CONTROL          4 ->     0.000000     (-)
CONTROL          5 ->      1.00000     (-)
CONTROL          6 ->      1.00000     (-)
CONTROL          7 ->      1.00000     (-)
CONTROL          8 ->     0.000000     (-)
CONTROL          9 ->      1.00000     (-)
CONTROL         10 ->      1.00000     (-)
CONTROL         11 ->      1.00000     (-)
CONTROL         12 ->     0.000000     (-)
RVPS             1 ->      60.0000     (rev/s)
POWER            1 ->     0.000000     (kW)
POWER            2 ->     0.000000     (kW)
POWER            3 ->     0.000000     (kW)
POWER            4 ->     0.000000     (kW)
POWER            5 ->     0.000000     (kW)
POWER            6 ->     0.000000     (kW)
POWER            7 ->     0.000000     (kW)
POWER            8 ->     0.000000     (kW)
POWER            9 ->     0.000000     (kW)
POWER           10 ->     0.000000     (kW)
POWER           11 ->     0.000000     (kW)
POWER           12 ->     0.000000     (kW)
POWER           13 ->     0.000000     (kW)
ABS. HUMIDITY    1 ->     0.740000E-03(kg(water)/kg(air))
ABS. HUMIDITY    2 ->     0.740000E-03(kg(water)/kg(air))
ABS. HUMIDITY    3 ->     0.740000E-03(kg(water)/kg(air))
ABS. HUMIDITY    4 ->     0.740000E-03(kg(water)/kg(air))
ABS. HUMIDITY    5 ->     0.740000E-03(kg(water)/kg(air))
ABS. HUMIDITY    6 ->     0.740000E-03(kg(water)/kg(air))
ABS. HUMIDITY    7 ->     0.000000    (kg(water)/kg(air))
-----------------------------------------------------
Simulation Error Tolerances:

1       RTOLX=    0.500000E-02       ATOLX=    0.100000E-05
        XTOL=     0.500000E-03       TTIME=     10.0000

SUPERBLOCK 1
2       FREEZE OPTION 0       SCAN OPTION 0

SUPERBLOCK 2
3       FREEZE OPTION 0       SCAN OPTION 0
-----------------------------------------------------
The following are Boundary Variables in the simulation:
```

```
TEMPERATURE     31
-------------------------------------------------------
The following are the reported variables:


SUPERBLOCK 1        REPORTING INTERVAL    3600.00
TEMPERATURE      1
TEMPERATURE      2
TEMPERATURE      3
TEMPERATURE      4
TEMPERATURE      5
TEMPERATURE      6
TEMPERATURE      7
TEMPERATURE      8
TEMPERATURE     14
TEMPERATURE     32
POWER            1
POWER            4
POWER            7
POWER           11
POWER           12
POWER           13

SUPERBLOCK 2        REPORTING INTERVAL    3600.00
TEMPERATURE     25
TEMPERATURE     26
TEMPERATURE     27
TEMPERATURE     30
TEMPERATURE     31
ABS. HUMIDITY    1
ABS. HUMIDITY    2
ABS. HUMIDITY    3

Selection ?
END
STOP
```

(2) <u>Creation of Model Definition File</u>

```
-------------------------
* Execution of SLIMCON
-------------------------

 Simulation Work File to Model Definition File Converter
 Version 2.1 (November 13, 1984)
 Enter the simulation filename (Up to 8 characters) or carriage return to end.
THRIZONE
            2 superblocks in the simulation .......... MAXIMUM =  10 ( 20.0%)
            8 blocks in the simulation ............... MAXIMUM =  50 ( 16.0%)
            6 differential equations in the simulation MAXIMUM =  50 ( 12.0%)
         1173 saved variables in the simulation ...... MAXIMUM =6000 ( 19.6%)
           31 units in the simulation ................ MAXIMUM = 200 ( 15.5%)
            8 units in a single block ................ MAXIMUM =  20 ( 40.0%)
            2 differential equations in one unit ..... MAXIMUM =  10 ( 20.0%)
           13 inputs or outputs in a single unit ..... MAXIMUM =  20 ( 65.0%)
           14 parameters in a single unit ............ MAXIMUM =  30 ( 46.7%)
            4 blocks in the largest superblock ....... MAXIMUM =  10 ( 40.0%)
            6 differential equations in one superblock MAXIMUM =  20 ( 30.0%)
           80 state variables in the simulation ...... MAXIMUM = 600 ( 13.3%)
           14 inputs or outputs in a single block .... MAXIMUM =  50 ( 28.0%)
          361 unit parameters in the simulation ...... MAXIMUM =1000 ( 36.1%)
            8 simultaneous equations in a single block MAXIMUM =  30 ( 26.7%)
            1 simultaneous equations in one superblock MAXIMUM =  20 (  5.0%)
            1 time dependent boundary variables ...... MAXIMUM =  30 (  3.3%)
            1 boundary conditions in one superblock .. MAXIMUM =  20 (  5.0%)
           16 reported variables in one superblock ... MAXIMUM =  30 ( 53.3%)
```

(3) Creation of Boundary Variable File

```
----------------------
* File: BOUNDARY.DAT
----------------------
0        20.0
31800    20.0
32000    20.0
32200    20.0
32400    20.0
32400    15.0
32600    15.0
32800    15.0
33000    15.0
60600    15.0
60800    15.0
61000    15.0
61200    15.0
61200    20.0
61400    20.0
61600    20.0
61800    20.0
118200   20.0
118400   20.0
118600   20.0
118800   20.0
118800   15.0
119000   15.0
119200   15.0
119400   15.0
147000   15.0
147200   15.0
147400   15.0
147600   15.0
147600   20.0
147800   20.0
148000   20.0
148200   20.0
204600   20.0
204800   20.0
205000   20.0
205200   20.0
205200   15.0
205400   15.0
205600   15.0
205800   15.0
233400   15.0
233600   15.0
233800   15.0
234000   15.0
234000   20.0
234200   20.0
234400   20.0
234600   20.0
```

(4) <u>Creation of Conduction Transfer Function File</u>

-----------------------------
* Composition of constructs
-----------------------------

CONSTRUCT #1 (Ceiling)

| | (Outside) | | |
|---|---|---|---|
| Layer 1 | Slag, 1/2-in. | (44): | [material I.D. # in THERM.DAT file] |
| 2 | Felt, 3/8-in. | (45) | |
| 3 | Concrete, 4-in. | (36) | |
| 4 | Insulation, 4-in. | (20) | |
| 5 | Ceiling air space | (46) | |
| 6 | Acoustic tile | (47) | |
| | (Inside) | | |

CONSTRUCT #2 (Floor)

| | (Outside) | |
|---|---|---|
| Layer 1 | Concrete, l.w., 4-in. | (36) |
| 2 | Vinyle tile, 3.32-in. | (48) |
| | (Inside) | |

CONSTRUCT #3 (Interior Walls)

Same as Example 1

CONSTRUCT #4 (Exposed Wall)

Same as Example 1

CONSTRUCT #5 (Exposed Glass Window)

Same as Example 1

```
-----------------------------
* Execution of CTFGEN
-----------------------------
                  Enter your choice:
 ***************************************************
 A => Add thermal property data to the construction
      materials database (THERM.DAT)
 B => Print the contents of the data file THERM.DAT
      to Logical Unit 6
 C => Create a CTF data file
 D => Change time interval in an existing CTF data file
 E => END
C
  Enter the name of the CTF Definition File,
  or carriage return for default name: CTFINPUT.DAT

  Enter the name of the CTF Output File,
  or carriage return for default name: CTFDATA.DAT

 What kind of output do you want?
  0 ==>   for a very simple output,
  1 ==>   for a less simple output,
  2 ==>   for detailed output   or
  3 ==>   for root search
1
 What is the time interval for CTF calculation in s ?
900
 THIS CONSTRUCT ID NUMBER (ISTR) IS  1
 How many layers in this construct? (max. = 10 )
6
 Enter the layer ID numbers with most outer layer first
44,45,36,20,46,47

  LAYER          L        K        CP        D         R        RC
 Slag or st    0.013    1.436    0.465   881.000    0.009    6.783
 Felt & mem    0.010    0.190    0.465  1121.000    0.050   15.735
 Concrete,     0.102    0.173    0.233   640.000    0.586   94.328
 Insulation    0.102    0.043    0.233    91.000    2.346   71.344
 Ceiling ai    0.000    0.000    0.000     0.000    0.176    0.000
 Acoustic t    0.016    0.061    0.233   480.000    0.315   21.529

 SUMRC = 209.71966  CND =   0.29023  TINC =     900.00

  NUMBER OF RESPONSE FACTORS =  6;  ORDER =  3

    N        0 0          0 1          0 2          0 3          0 4          0 5

    0     14.557249    14.557249    14.557249    14.557249    14.557249    14.557249
    1    -11.701724   -23.404494   -28.110588   -30.256600   -30.524282   -30.636338
    2     -0.807326     8.599849    16.166097    20.310126    20.866491    21.101454
    3     -0.404115     0.244905    -2.535270    -4.918456    -5.291923    -5.452545
    4     -0.279811     0.045063    -0.034110     0.339636     0.430078     0.470813
    5     -0.214535     0.010408    -0.004160     0.000869    -0.005377    -0.008687
    6     -0.169705     0.002763    -0.000602     0.000012     0.000000     0.000000
```

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0.000001 | 0.000001 | 0.000001 | 0.000001 | 0.000001 | 0.000001 |
| 1 | 0.001435 | 0.001434 | 0.001433 | 0.001433 | 0.001433 | 0.001433 |
| 2 | 0.015018 | 0.013864 | 0.013401 | 0.013190 | 0.013163 | 0.013152 |
| 3 | 0.033322 | 0.021249 | 0.016767 | 0.014791 | 0.014549 | 0.014447 |
| 4 | 0.039358 | 0.012570 | 0.005701 | 0.003229 | 0.002957 | 0.002845 |
| 5 | 0.036730 | 0.005089 | 0.001025 | 0.000185 | 0.000126 | 0.000103 |
| 6 | 0.031329 | 0.001801 | 0.000156 | 0.000005 | 0.000000 | 0.000000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 2.456216 | 2.456216 | 2.456216 | 2.456216 | 2.456216 | 2.456216 |
| 1 | -1.908972 | -3.883557 | -4.677607 | -5.039699 | -5.084865 | -5.103772 |
| 2 | -0.143329 | 1.391319 | 2.646803 | 3.336370 | 3.429041 | 3.468182 |
| 3 | -0.047651 | 0.067573 | -0.382215 | -0.772404 | -0.833754 | -0.860149 |
| 4 | -0.020781 | 0.017526 | -0.004319 | 0.052027 | 0.066230 | 0.072648 |
| 5 | -0.011357 | 0.005349 | -0.000317 | 0.000320 | -0.000637 | -0.001147 |
| 6 | -0.007443 | 0.001688 | -0.000042 | 0.000005 | 0.000000 | 0.000000 |

| | | | | | |
|---|---|---|---|---|---|
| 3 | 1.274614 | -0.426060 | 0.038313 | 0.000000 | 0.000000 |

```
 ISTR: 1
 NCTF: 6  NORD: 3
 UVAL: 0.290227
 CTFX: 14.5573,  -30.2568,  20.3102,  -4.91848,  0.339638,  8.68591E-04,
 1.171E-05
 CTFY: 1.18807E-06,  1.43323E-03,  1.31896E-02,  1.47913E-02,  3.22913E-03,
 1.8491E-04,  5.0123E-06
 CTFZ: 2.45622,  -5.03971,  3.33638,  -0.772406,  5.2027E-02,  3.19892E-04,
 4.97476E-06
 CTFQ: 1.27461,  -0.42606,  3.83128E-02
 Do you want to continue? <N>
Y
 THIS CONSTRUCT ID NUMBER (ISTR) IS  2
 How many layers in this construct? (max. = 10 )
2
 Enter the layer ID numbers with most outer layer first
36,48
```

| LAYER | L | K | CP | D | R | RC |
|---|---|---|---|---|---|---|
| Concrete, | 0.102 | 0.173 | 0.233 | 640.000 | 0.586 | 94.328 |
| Vinyle til | 0.002 | 0.270 | 1.004 | 1552.000 | 0.000 | 4.805 |

SUMRC = 99.13220  CND = 1.68155  TINC = 900.00

NUMBER OF RESPONSE FACTORS = 3;  ORDER = 2

| N | O 0 | O 1 | O 2 | O 3 | O 4 | O 5 |
|---|---|---|---|---|---|---|
| 0 | 6.041242 | 6.041242 | 6.041242 | 6.041242 | 6.041242 | 6.041242 |
| 1 | -3.530460 | -5.812812 | -5.936175 | -5.937136 | -5.937137 | -5.937137 |
| 2 | -0.522149 | 0.811642 | 0.930340 | 0.931285 | 0.931286 | 0.931286 |
| 3 | -0.191197 | 0.006068 | -0.010506 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | |
| 0 | 0.122326 | 0.122326 | 0.122326 | 0.122326 | 0.122326 | 0.122326 |
| 1 | 0.755747 | 0.709533 | 0.707035 | 0.707016 | 0.707016 | 0.707016 |
| 2 | 0.493480 | 0.207962 | 0.193473 | 0.193361 | 0.193360 | 0.193360 |
| 3 | 0.192747 | 0.006313 | 0.002066 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | |
| 0 | 9.218291 | 9.218291 | 9.218291 | 9.218291 | 9.218291 | 9.218291 |
| 1 | -6.686454 | -10.169080 | -10.357318 | -10.358785 | -10.358787 | -10.358787 |
| 2 | -0.535869 | 1.990241 | 2.197894 | 2.199543 | 2.199544 | 2.199544 |
| 3 | -0.195773 | 0.006676 | -0.033965 | 0.000000 | 0.000000 | 0.000000 |

```
   2       0.398215    -0.007715    0.000000    0.000000    0.000000
 ISTR: 2
 NCTF: 3  NORD: 2
 UVAL: 1.68155
 CTFX: 6.04124,  -5.93617,  0.93034,  -1.05061E-02
 CTFY: 0.122326,  0.707036,  0.193473,  2.06644E-03
 CTFZ: 9.21829,  -10.3573,  2.19789,  -3.39653E-02
 CTFQ: 0.398215,  -7.71461E-03
 Do you want to continue? (N)
Y
 THIS CONSTRUCT ID NUMBER (ISTR) IS  3
 How many layers in this construct? (max. = 10 )
3
 Enter the layer ID numbers with most outer layer first
43,8,43

  LAYER          L        K        CP        D        R       RC
 Plaster/gy    0.019    0.727    0.233 1601.000    0.026   13.610
 Air Space     0.000    0.000    0.000    0.000    0.160    0.000
 Plaster/gy    0.019    0.727    0.233 1601.000    0.026   13.610

 SUMRC =  27.22012  CND =   4.71099  TINC =    900.00

  NUMBER OF RESPONSE FACTORS =  1;  ORDER =  1

    N        O 0         O 1         O 2         O 3         O 4         O 5

    0     11.696103   11.696103   11.696103    0.000000    0.000000    0.000000
    1     -6.985093   -6.985166    0.000000    0.000000    0.000000    0.000000

    0      3.820999    3.820999    3.820999    0.000000    0.000000    0.000000
    1      0.889971    0.889947    0.000000    0.000000    0.000000    0.000000

    0     11.696103   11.696103   11.696103    0.000000    0.000000    0.000000
    1     -6.985093   -6.985166    0.000000    0.000000    0.000000    0.000000

    1      0.000006    0.000000    0.000000    0.000000    0.000000
 ISTR: 3
 NCTF: 1  NORD: 1
 UVAL: 4.71099
 CTFX: 11.6962,  -6.9852
 CTFY: 3.82101,  0.88995
 CTFZ: 11.6962,  -6.9852
 CTFQ: 6.21576E-06
 Do you want to continue? (N)
Y
 THIS CONSTRUCT ID NUMBER (ISTR) IS  4
 How many layers in this construct? (max. = 10 )
4
 Enter the layer ID numbers with most outer layer first
2,10,8,43

  LAYER          L        K        CP        D        R       RC
 Facebrick     0.102    1.298    0.256 2082.000    0.078   65.105
 Insulation    0.051    0.043    0.233   32.000    1.176   21.154
 Air Space     0.000    0.000    0.000    0.000    0.160    0.000
 Plaster/gy    0.019    0.727    0.233 1601.000    0.026   13.610

 SUMRC =  99.86891  CND =   0.69166  TINC =    900.00
```

NUMBER OF RESPONSE FACTORS = 3; ORDER = 2

| N | 0 0 | 0 1 | 0 2 | 0 3 | 0 4 | 0 5 |
|---|---|---|---|---|---|---|
| 0 | 31.239817 | 31.239817 | 31.239817 | 31.239817 | 31.239817 | 31.239817 |
| 1 | -19.358236 | -37.473015 | -37.755497 | -37.755942 | -37.756010 | -37.756012 |
| 2 | -4.728849 | 6.496254 | 6.835099 | 6.835637 | 6.835720 | 6.835722 |
| 3 | -2.714793 | 0.027286 | -0.031456 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | |
| 0 | 0.030345 | 0.030345 | 0.030345 | 0.030345 | 0.030345 | 0.030345 |
| 1 | 0.216958 | 0.199362 | 0.199088 | 0.199087 | 0.199087 | 0.199087 |
| 2 | 0.185634 | 0.059828 | 0.058025 | 0.058023 | 0.058022 | 0.058022 |
| 3 | 0.108688 | 0.001046 | 0.000505 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | |
| 0 | 8.554926 | 8.554926 | 8.554926 | 8.554926 | 8.554926 | 8.554926 |
| 1 | -7.845255 | -12.805930 | -12.883287 | -12.883409 | -12.883428 | -12.883428 |
| 2 | -0.007653 | 4.541511 | 4.657307 | 4.657491 | 4.657519 | 4.657520 |
| 3 | -0.004354 | 0.000083 | -0.040983 | 0.000000 | 0.000000 | 0.000000 |
| | | | | | | |
| 2 | 0.588904 | -0.005243 | 0.000000 | 0.000000 | 0.000000 | |

ISTR: 4
NCTF: 3 NORD: 2
UVAL: 0.691656
CTFX: 31.2398, -37.7555, 6.8351, -3.14559E-02
CTFY: 3.03452E-02, 0.199088, 5.80254E-02, 5.05029E-04
CTFZ: 8.55491, -12.8833, 4.6573, -4.09825E-02
CTFQ: 0.588904, -5.24332E-03
Do you want to continue? <N>
Y
THIS CONSTRUCT ID NUMBER (ISTR) IS 5
How many layers in this construct? (max. = 10 )
3
Enter the layer ID numbers with most outer layer first
49,8,49

| LAYER | L | K | CP | D | R | RC |
|---|---|---|---|---|---|---|
| Glass | 0.000 | 0.000 | 0.000 | 0.000 | 0.260 | 0.000 |
| Air Space | 0.000 | 0.000 | 0.000 | 0.000 | 0.160 | 0.000 |
| Glass | 0.000 | 0.000 | 0.000 | 0.000 | 0.260 | 0.000 |

SUMRC = 0.00000 CND = 1.47059 TINC = 900.00

| LAYER | L | K | CP | D | R | RC |
|---|---|---|---|---|---|---|
| Glass | 0.000 | 0.000 | 0.000 | 0.000 | 0.260 | 0.000 |
| Air Space | 0.000 | 0.000 | 0.000 | 0.000 | 0.160 | 0.000 |
| Glass | 0.000 | 0.000 | 0.000 | 0.000 | 0.260 | 0.000 |

SUMRC = 0.00000 CND = 1.47059 TINC = 900.00

NUMBER OF ROOTS = 7; SEARCH INCREMENT =0.020026

| N | ROOT |
|---|---|
| 1 | 0.024607256 |
| 2 | 0.072309779 |
| 3 | 0.111355003 |
| 4 | 0.120292539 |
| 5 | 0.136468904 |
| 6 | 0.169175402 |
| 7 | 0.216991657 |

```
NUMBER OF RESPONSE FACTORS =  3;  ORDER =  2

  N        0 0          0 1          0 2          0 3          0 4          0 5

  0     31.239817    31.239817    31.239817    31.239817    31.239817    31.239817
  1    -19.358236   -37.473015   -37.755497   -37.755942   -37.756010   -37.756012
  2     -4.728849     6.496254     6.835099     6.835637     6.835720     6.835722
  3     -2.714793     0.027286    -0.031456     0.000000     0.000000     0.000000

  0      0.030345     0.030345     0.030345     0.030345     0.030345     0.030345
  1      0.216958     0.199362     0.199088     0.199087     0.199087     0.199087
  2      0.185634     0.059828     0.058025     0.058023     0.058022     0.058022
  3      0.108688     0.001046     0.000505     0.000000     0.000000     0.000000

  0      8.554926     8.554926     8.554926     8.554926     8.554926     8.554926
  1     -7.845255   -12.805930   -12.883287   -12.883409   -12.883428   -12.883428
  2     -0.007653     4.541511     4.657307     4.657491     4.657519     4.657520
  3     -0.004354     0.000083    -0.040983     0.000000     0.000000     0.000000

  2      0.588904    -0.005243     0.000000     0.000000     0.000000
** SEVERE   RESPONSE FACTORS NOT COMPUTED (RESPNS)
ISTR: 5
NCTF: 0  NORD: 0
UVAL: 1.47059
CTFX: 1.47059
CTFY: 1.47059
CTFZ: 1.47059
CTFQ:
Do you want to continue? (N)
N
STOP ----------- END OF CTF RUN -------------------
```

```
-----------------------------------------------------------
* File: CTFDATA.DAT (Conduction Transfer Function File)
-----------------------------------------------------------
    900.000
    1    6    3    0.290227
    14.5573        -30.2568        20.3102        -4.91848        0.339638
   0.868591E-03    0.117100E-04
   0.118807E-05    0.143323E-02   0.131896E-01   0.147913E-01   0.322913E-02
   0.184910E-03    0.501230E-05
    2.45622        -5.03971        3.33638       -0.772406       0.520270E-01
   0.319892E-03    0.497476E-05
    1.27461        -0.426060      0.383128E-01
    2    3    2    1.68155
    6.04124        -5.93617       0.930340      -0.105061E-01
   0.122326         0.707036      0.193473       0.206644E-02
    9.21829        -10.3573        2.19789      -0.339653E-01
   0.398215        -0.771461E-02
    3    1    1    4.71099
    11.6962        -6.98520
    3.82101         0.889950
    11.6962        -6.98520
   0.621576E-05
    4    3    2    0.691656
    31.2398        -37.7555        6.83510       -0.314559E-01
   0.303452E-01     0.199088      0.580254E-01   0.505029E-03
    8.55491        -12.8833        4.65730       -0.409825E-01
   0.588904        -0.524332E-02
    5    0    1    1.47059
```

```
  1.47059
  1.47059
  1.47059
 0.000000

------------------------------------------
* File: CTFINPUT.DAT (CTF Input Data File)
------------------------------------------
  900.000
 6  44  45  36  20  46  47
 2  36  48
 3  43   8  43
 4   2  10   8  43
 3  49   8  49
```

(5) Creation of Weather Data File

```
----------------------
* Execution of RDTAPE
----------------------

  Enter Input File name up to 12 characters ---
WYEC67.DAT
  What is the type of weather tape?
  Enter 1 for (TRY), 2 (TMY), 3 (SOLMET), 4 (WYEC)
4
  Where is the weather station?
  Enter station ID number
93734
  Enter the year (4 digits)
1961
  Type the start date:  Month,Day
7,7
  Type the stop date:   Month,Day
7,9
  ---- The first day of the weather tape ----
  STTN=93734 WYR=1960 WMO=6 WDY=2
 ------- The start day -------
  STTN=93734 WYR=1961 WMO=7 WDY=7
  -------  The stop day -------
  STTN=93734 WYR=1961 WMO=7 WDY=9
         3 DAYS WRITTEN ON THE OUTPUT FILE

STOP --------- NORMAL END OF JOB ------

--------------------
* File: WYEC67.DAT
--------------------
(From July 7 to July 9)

9373406806606518000530030020230280007770200077702000777 9999          19610707009
93734068066065230003300100000303000077700000777000007779999          19610707019
93734067066065000000299900000201400077700000777000007779999          19610707029
93734067066065000000299800808302500077708000777080007779999          19610707039
93734067066065000000299700401201803303004008888040007779999          19610707049
93734067066065070004299811010303599999999999999999999990000          19610707050
93734067066065050004299810805303803888808000777080007770008          19610707060
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* File: WTPOUT.DAT

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| STTN | YR | MO | DAY | HR | DB (C) | DP (C) | P (kPa) | WS (m/s) | CC | IZER (W/m |
|---|---|---|---|---|---|---|---|---|---|---|
| 93734 | 1961 | 7 | 7 | 1 | 21.67 | 18.3 | 101.7 | 2.1 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 2 | 20.56 | 17.8 | 101.6 | 2.1 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 3 | 20.56 | 19.4 | 101.7 | 3.1 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 4 | 20.56 | 19.4 | 101.7 | 0.0 | 10 | -1000.0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 93734 | 1961 | 7 | 7 | 5 | 20.00 | 18.9 | 101.7 | 3.1 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 6 | 20.00 | 18.9 | 101.8 | 2.6 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 7 | 19.44 | 18.9 | 101.7 | 2.6 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 8 | 20.56 | 19.4 | 101.7 | 2.6 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 9 | 20.56 | 19.4 | 101.8 | 0.0 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 10 | 20.56 | 20.0 | 101.8 | 5.7 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 11 | 21.11 | 20.0 | 101.7 | 5.7 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 12 | 21.67 | 20.0 | 101.7 | 3.1 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 13 | 22.78 | 20.0 | 101.8 | 4.1 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 14 | 23.89 | 20.0 | 101.8 | 3.6 | 8 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 15 | 23.33 | 20.0 | 101.7 | 4.6 | 9 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 16 | 23.89 | 18.9 | 101.7 | 3.6 | 9 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 17 | 23.89 | 18.9 | 101.7 | 3.6 | 8 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 18 | 23.33 | 19.4 | 101.7 | 4.6 | 8 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 19 | 22.78 | 19.4 | 101.6 | 4.1 | 5 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 20 | 21.67 | 18.3 | 101.6 | 2.6 | 3 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 21 | 21.11 | 18.9 | 101.7 | 2.6 | 4 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 22 | 20.56 | 18.9 | 101.7 | 2.1 | 4 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 23 | 20.56 | 18.9 | 101.8 | 2.6 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 7 | 0 | 20.00 | 18.3 | 101.7 | 2.6 | 2 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 1 | 20.00 | 18.3 | 101.6 | 1.5 | 0 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 2 | 19.44 | 18.3 | 101.6 | 0.0 | 0 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 3 | 19.44 | 18.3 | 101.5 | 0.0 | 8 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 4 | 19.44 | 18.3 | 101.5 | 0.0 | 4 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 5 | 19.44 | 18.3 | 101.5 | 2.1 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 6 | 19.44 | 18.3 | 101.5 | 2.1 | 8 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 7 | 20.56 | 19.4 | 101.6 | 2.1 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 8 | 22.22 | 19.4 | 101.6 | 0.0 | 9 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 9 | 23.33 | 18.9 | 101.6 | 2.1 | 9 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 10 | 22.78 | 19.4 | 101.6 | 3.1 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 11 | 24.44 | 20.0 | 101.5 | 2.6 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 12 | 24.44 | 19.4 | 101.5 | 2.6 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 13 | 25.56 | 19.4 | 101.4 | 3.1 | 7 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 14 | 26.67 | 20.0 | 101.4 | 4.1 | 5 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 15 | 27.22 | 20.6 | 101.3 | 3.1 | 6 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 16 | 26.67 | 19.4 | 101.3 | 3.6 | 8 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 17 | 26.67 | 19.4 | 101.2 | 3.1 | 8 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 18 | 26.11 | 19.4 | 101.2 | 4.1 | 9 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 19 | 25.00 | 19.4 | 101.2 | 3.1 | 9 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 20 | 23.33 | 20.0 | 101.2 | 3.1 | 7 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 21 | 22.78 | 20.0 | 101.2 | 3.1 | 8 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 22 | 22.78 | 20.0 | 101.2 | 3.1 | 7 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 23 | 22.22 | 20.6 | 101.2 | 2.6 | 7 | -1000.0 |
| 93734 | 1961 | 7 | 8 | 0 | 21.67 | 20.6 | 101.1 | 2.6 | 6 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 1 | 21.11 | 20.0 | 101.1 | 2.1 | 8 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 2 | 20.56 | 19.4 | 101.0 | 2.6 | 5 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 3 | 20.00 | 18.9 | 101.0 | 2.1 | 3 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 4 | 19.44 | 18.9 | 101.0 | 2.1 | 4 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 5 | 19.44 | 18.3 | 101.0 | 2.1 | 4 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 6 | 18.89 | 18.3 | 101.1 | 2.6 | 10 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 7 | 20.00 | 18.9 | 101.1 | 2.6 | 4 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 8 | 21.67 | 19.4 | 101.2 | 2.6 | 6 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 9 | 22.78 | 20.0 | 101.2 | 3.1 | 3 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 10 | 24.44 | 20.0 | 101.2 | 2.6 | 3 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 11 | 25.56 | 20.0 | 101.1 | 0.0 | 3 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 12 | 27.22 | 16.7 | 101.1 | 4.1 | 2 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 13 | 27.22 | 11.7 | 101.1 | 5.7 | 2 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 14 | 27.22 | 12.8 | 101.1 | 5.1 | 2 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 15 | 26.67 | 15.0 | 101.1 | 5.1 | 5 | -1000.0 |
| 93734 | 1961 | 7 | 9 | 16 | 26.11 | 13.3 | 101.1 | 5.7 | 7 | -1000.0 |

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 93734 1961     7     9    17       25.56        12.8      101.1        5.7     7  -1000.0
 93734 1961     7     9    18       25.56        12.8      101.1        6.2     7  -1000.0
 93734 1961     7     9    19       23.33        12.8      101.2        6.2     7  -1000.0
 93734 1961     7     9    20       21.11        11.1      101.2        6.2     7  -1000.0
 93734 1961     7     9    21       20.00        11.1      101.3        3.6     8  -1000.0
 93734 1961     7     9    22       19.44        11.1      101.4        4.1     4  -1000.0
 93734 1961     7     9    23       18.89        11.7      101.4        4.6     3  -1000.0
 93734 1961     7     9     0       18.33        11.7      101.4        3.6     3  -1000.0

NOTE: Data in the columns greater than 80 are truncated.


----------------------
* Execution of CRWDTA
----------------------
    ************************************************
    *                                              *
    *         CREATING A WEATHER DATA FILE         *
    *                                              *
    ************************************************

  Enter LATITUDE, LONGITUDE, and TIME ZONE:
38.85
77.03
5
  Enter one of the following:
  1 - to process the weather data in file WTPOUT.DAT
    (previously read from weather tape by program RDTAPE)
  2 - to generate clear sky design data
  3 - to generate cloudy sky design data
1
  Enter output file name (up to 12 characters)
  or carriage return for default name: WEATHER.DAT

STOP ---- END OF CREATING WEATHER FILE ------


------------------
File: WEATHER.DAT
------------------
     7    7      38.85      77.03       5.00    1
     7    7  0.0   20.0000   -0.6220  101.7000    2.6000    0.0000    0.0000
     7    7  1.0   21.6700   -0.6220  101.7000    2.1000    0.0000    0.0000
     7    7  2.0   20.5600   -0.6220  101.6000    2.1000    0.0000    0.0000
     7    7  3.0   20.5600   -0.6220  101.7000    3.1000    0.0000    0.0000
     7    7  4.0   20.5600   -0.6220  101.7000    0.0000    0.0000    0.0000
     7    7  5.0   20.0000   -0.6220  101.7000    3.1000    0.0000    0.0000
     7    7  6.0   20.0000   -0.6220  101.8000    2.6000    0.1969    5.7888
     7    7  7.0   19.4400   -0.6220  101.7000    2.6000    0.7688   31.1430    3
     7    7  8.0   20.5600   -0.6220  101.7000    2.6000    0.1449   22.0106    2
     7    7  9.0   20.5600   -0.6220  101.8000    0.0000    0.1269   27.8079    2
     7    7 10.0   20.5600   -0.6220  101.8000    5.7000    0.4839   65.8495    6
     7    7 11.0   21.1100   -0.6220  101.7000    5.7000    2.3168  161.7803   16
     7    7 12.0   21.6700   -0.6220  101.7000    3.1000   22.0643  360.2322   38
     7    7 13.0   22.7800   -0.6220  101.8000    4.1000  107.1346  429.5686   53
     7    7 14.0   23.8900   -0.6220  101.8000    3.6000  147.1323  413.1729   54
     7    7 15.0   23.3300   -0.6220  101.7000    4.6000  378.0356  315.3931   63
     7    7 16.0   23.8900   -0.6220  101.7000    3.6000  769.6187  138.2964   68
     7    7 17.0   23.8900   -0.6220  101.7000    3.6000  181.6750  245.9064   34
     7    7 18.0   23.3300   -0.6220  101.7000    4.6000  115.4136  168.2981   21
```

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7 | 7 | 19.0 | 22.7800 | -0.6220 | 101.6000 | 4.1000 | 6.6053 | 55.7066 | 5 |
| 7 | 7 | 20.0 | 21.6700 | -0.6220 | 101.6000 | 2.6000 | 0.0000 | 0.0000 | |
| 7 | 7 | 21.0 | 21.1100 | -0.6220 | 101.7000 | 2.6000 | 0.0000 | 0.0000 | |
| 7 | 7 | 22.0 | 20.5600 | -0.6220 | 101.7000 | 2.1000 | 0.0000 | 0.0000 | |
| 7 | 7 | 23.0 | 20.5600 | -0.6220 | 101.8000 | 2.6000 | 0.0000 | 0.0000 | |
| 7 | 7 | 24.0 | 20.0000 | -0.6220 | 101.7000 | 2.6000 | 0.0000 | 0.0000 | |
| 7 | 8 | 1.0 | 20.0000 | -0.6220 | 101.6000 | 1.5000 | 0.0000 | 0.0000 | |
| 7 | 8 | 2.0 | 19.4400 | -0.6220 | 101.6000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 8 | 3.0 | 19.4400 | -0.6220 | 101.5000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 8 | 4.0 | 19.4400 | -0.6220 | 101.5000 | 0.0000 | 0.0000 | 0.0000 | |
| 7 | 8 | 5.0 | 19.4400 | -0.6220 | 101.5000 | 2.1000 | 0.0000 | 0.0000 | |
| 7 | 8 | 6.0 | 19.4400 | -0.6220 | 101.5000 | 2.1000 | 0.5209 | 9.2447 | |
| 7 | 8 | 7.0 | 20.5600 | -0.6220 | 101.6000 | 2.1000 | 4.9306 | 77.5720 | 7 |
| 7 | 8 | 8.0 | 22.2200 | -0.6220 | 101.6000 | 0.0000 | 28.4925 | 188.5826 | 20 |
| 7 | 8 | 9.0 | 23.3300 | -0.6220 | 101.6000 | 2.1000 | 197.4422 | 285.1067 | 41 |
| 7 | 8 | 10.0 | 22.7800 | -0.6220 | 101.6000 | 3.1000 | 191.8022 | 347.8713 | 49 |
| 7 | 8 | 11.0 | 24.4400 | -0.6220 | 101.5000 | 2.6000 | 262.0825 | 376.1016 | 60 |
| 7 | 8 | 12.0 | 24.4400 | -0.6220 | 101.5000 | 2.6000 | 237.6303 | 408.2700 | 63 |
| 7 | 8 | 13.0 | 25.5600 | -0.6220 | 101.4000 | 3.1000 | 741.7134 | 197.3627 | 90 |
| 7 | 8 | 14.0 | 26.6700 | -0.6220 | 101.4000 | 4.1000 | 15.9343 | 331.6353 | 34 |
| 7 | 8 | 15.0 | 27.2200 | -0.6220 | 101.3000 | 3.1000 | 300.4958 | 341.8843 | 59 |
| 7 | 8 | 16.0 | 26.6700 | -0.6220 | 101.3000 | 3.6000 | 394.5117 | 262.8533 | 54 |
| 7 | 8 | 17.0 | 26.6700 | -0.6220 | 101.2000 | 3.1000 | 415.3787 | 199.4689 | 42 |
| 7 | 8 | 18.0 | 26.1100 | -0.6220 | 101.2000 | 4.1000 | 211.0219 | 164.0207 | 24 |
| 7 | 8 | 19.0 | 25.0000 | -0.6220 | 101.2000 | 3.1000 | 4.9064 | 49.0572 | 4 |
| 7 | 8 | 20.0 | 23.3300 | -0.6220 | 101.2000 | 3.1000 | 0.0000 | 0.0000 | |
| 7 | 8 | 21.0 | 22.7800 | -0.6220 | 101.2000 | 3.1000 | 0.0000 | 0.0000 | |
| 7 | 8 | 22.0 | 22.7800 | -0.6220 | 101.2000 | 3.1000 | 0.0000 | 0.0000 | |
| 7 | 8 | 23.0 | 22.2200 | -0.6220 | 101.2000 | 2.6000 | 0.0000 | 0.0000 | |
| 7 | 8 | 24.0 | 21.6700 | -0.6220 | 101.1000 | 2.6000 | 0.0000 | 0.0000 | |
| 7 | 9 | 1.0 | 21.1100 | -0.6220 | 101.1000 | 2.1000 | 0.0000 | 0.0000 | |
| 7 | 9 | 2.0 | 20.5600 | -0.6220 | 101.0000 | 2.6000 | 0.0000 | 0.0000 | |
| 7 | 9 | 3.0 | 20.0000 | -0.6220 | 101.0000 | 2.1000 | 0.0000 | 0.0000 | |
| 7 | 9 | 4.0 | 19.4400 | -0.6220 | 101.0000 | 2.1000 | 0.0000 | 0.0000 | |
| 7 | 9 | 5.0 | 19.4400 | -0.6220 | 101.0000 | 2.1000 | 0.0000 | 0.0000 | |
| 7 | 9 | 6.0 | 18.8900 | -0.6220 | 101.1000 | 2.6000 | 18.3946 | 38.7504 | 4 |
| 7 | 9 | 7.0 | 20.0000 | -0.6220 | 101.1000 | 2.6000 | 235.8925 | 126.3230 | 19 |
| 7 | 9 | 8.0 | 21.6700 | -0.6220 | 101.2000 | 2.6000 | 549.5164 | 141.5620 | 40 |
| 7 | 9 | 9.0 | 22.7800 | -0.6220 | 101.2000 | 3.1000 | 664.4600 | 155.3863 | 58 |
| 7 | 9 | 10.0 | 24.4400 | -0.6220 | 101.2000 | 2.6000 | 721.2656 | 168.6929 | 73 |
| 7 | 9 | 11.0 | 25.5600 | -0.6220 | 101.1000 | 0.0000 | 759.7915 | 176.3566 | 85 |
| 7 | 9 | 12.0 | 27.2200 | -0.6220 | 101.1000 | 4.1000 | 766.8362 | 185.3893 | 91 |
| 7 | 9 | 13.0 | 27.2200 | -0.6220 | 101.1000 | 5.7000 | 742.5952 | 196.9268 | 90 |
| 7 | 9 | 14.0 | 27.2200 | -0.6220 | 101.1000 | 5.1000 | 638.1118 | 233.0332 | 81 |
| 7 | 9 | 15.0 | 26.6700 | -0.6220 | 101.1000 | 5.1000 | 504.5327 | 265.9695 | 68 |
| 7 | 9 | 16.0 | 26.1100 | -0.6220 | 101.1000 | 5.7000 | 89.4878 | 315.3828 | 37 |
| 7 | 9 | 17.0 | 25.5600 | -0.6220 | 101.1000 | 5.7000 | 504.6819 | 175.9864 | 45 |
| 7 | 9 | 18.0 | 25.5600 | -0.6220 | 101.1000 | 6.2000 | 401.5051 | 137.2548 | 28 |
| 7 | 9 | 19.0 | 23.3300 | -0.6220 | 101.2000 | 6.2000 | 41.8718 | 77.0723 | 8 |
| 7 | 9 | 20.0 | 21.1100 | -0.6220 | 101.2000 | 6.2000 | 0.0000 | 0.0000 | |
| 7 | 9 | 21.0 | 20.0000 | -0.6220 | 101.3000 | 3.6000 | 0.0000 | 0.0000 | |
| 7 | 9 | 22.0 | 19.4400 | -0.6220 | 101.4000 | 4.1000 | 0.0000 | 0.0000 | |
| 7 | 9 | 23.0 | 18.8900 | -0.6220 | 101.4000 | 4.6000 | 0.0000 | 0.0000 | |
| 7 | 9 | 24.0 | 18.3300 | -0.6220 | 101.4000 | 3.6000 | 0.0000 | 0.0000 | |

NOTE: Data in the columns greater than 80 are truncated.

B. Simulation

(1) Allocation of Output Files

Default names of the output files are MODSUM.DAT, MODOUT.DAT, and INITOUT.DAT.

(2) Execution of MODSIM for Initialization

Minimum time step, maximum time step, and simulation stopping time are 1, 1000, and 86400 seconds, respectively.

(3) Continuation of Simulation

```
-----------------------------------------------------------------
* Execution of MODSIM for Simulation using the Initialization File
-----------------------------------------------------------------

    *********************************************
    *                                           *
    *          MODSIM      Version 5.0          *
    *                                           *
    *********************************************

  Enter MINIMUM TIME STEP, MAXIMUM TIME STEP, and SIMULATION STOPPING TIME:
1,1000,259200
   Is the Building Shell Model used? <N>
Y
   Will the Initialization File be called? <N>
Y

   What is the INDEX NUMBER of the SUPERBLOCK for the Building Shell?
1
   ISSHEL =1

  Enter the time of day (in hours after midnight)
  at which the simulation is to begin
0
  Use default file names for all files? (Y/N) <Y>

   Do you want Diagnostic Information to be written <N>?

  Would you like to monitor the Simulation on Screen? <N>

    ------- SIMULATION BEGINS ---------
 --  FIRST WEATHER DATA SET HAS BEEN READ
  -----  INITIALIZATION FILE HAS BEEN WRITTEN -----
STOP    ------------END OF SIMULATION ---------

----------------------------------------
* File: MODOUT.DAT (for the second run)
----------------------------------------
SUPERBLOCK 1       1.00
    20.3338        18.7336        20.2245        20.2587        20.2350
    20.2348        20.3646        20.3782        20.3393        20.0000
   2.392979E-02   2.222411E-02   2.281072E-02   0.000000       0.000000
   0.000000
```

```
SUPERBLOCK 2       1.00
    20.0006         20.0006         20.0190         22.1665         20.0000
   7.400326E-04    7.400326E-04    7.400324E-04
SUPERBLOCK 2       3.00
    20.0012         20.0012         20.0379         22.1665         20.0000
   7.400652E-04    7.400652E-04    7.400645E-04
SUPERBLOCK 2     361.00
    20.1085         20.1074         21.3665         22.1665         20.0000
   7.458397E-04    7.458394E-04    7.428809E-04
SUPERBLOCK 1     900.00
    20.2759         19.0246         20.2807         20.2373         20.2915
    20.2914         20.3087         20.2832         20.5286         20.7815
   2.963960E-03   -1.935803E-03   -0.251706        0.000000        0.000000
   0.000000
SUPERBLOCK 2    1030.00
    20.2914         20.2848         21.9241         22.1665         20.0000
   7.564859E-04    7.564828E-04    7.447517E-04
SUPERBLOCK 1    1800.00
    20.3788         19.1844         20.4744         20.3599         20.4871
    20.4858         20.3460         20.3776         20.8428         21.3204
   8.122213E-04   -5.813498E-03   -0.318652        0.000000        0.000000
   0.000000
SUPERBLOCK 2    2030.00
    20.5684         20.5509         22.0615         22.1665         20.0000
   7.722455E-04    7.722310E-04    7.456099E-04
SUPERBLOCK 1    2700.00
    20.5417         19.3457         20.7105         20.5468         20.7238
    20.7221         20.4563         20.5410         21.0963         21.6165
  -1.365668E-02   -1.414384E-02   -0.274801        0.000000        0.000000
   0.000000
SUPERBLOCK 2    3030.00
    20.8199         20.8021         22.1027         22.1665         20.0000
   7.880400E-04    7.880139E-04    7.459365E-04
SUPERBLOCK 1    3600.00
    20.7171         19.5224         20.9170         20.7383         20.9268
    20.9277         20.6030         20.7128         21.2837         21.6700
  -3.207046E-02   -1.868834E-02   -0.226565        0.000000        0.000000
   0.000000
SUPERBLOCK 2    4030.00
    21.0320         21.0371         22.1258         22.1665         20.0000
   8.040539E-04    8.040317E-04    7.460907E-04
SUPERBLOCK 1    4500.00
    20.8678         19.6788         21.0512         20.8912         21.0556
    21.0583         20.7467         20.8577         21.4103         21.4980
  -4.560097E-02   -1.715894E-02   -0.196922        0.000000        0.000000
   0.000000
SUPERBLOCK 2    5030.00
    21.2083         21.2612         22.1383         22.1665         20.0000
   8.203641E-04    8.203788E-04    7.461554E-04
SUPERBLOCK 1    5400.00
    20.9771         19.8039         21.1038         21.0048         21.1012
    21.1027         20.8734         20.9925         21.4787         21.1868
  -6.460547E-02   -6.795895E-02   -0.185209        0.000000        0.000000
   0.000000
SUPERBLOCK 2    6030.00
    21.3388         21.3847         22.1425         22.1665         20.0000
   8.363114E-04    8.363035E-04    7.461291E-04
SUPERBLOCK 1    6300.00
    21.0412         19.8925         21.0877         21.0771         21.0774
    21.0786         20.9682         21.0801         21.4985         20.8396
```

```
  -8.624774E-02  -8.800596E-02  -0.187045       0.000000       0.000000
   0.000000
SUPERBLOCK 2   7030.00
    21.4201        21.4618        22.1407        22.1665        20.0000
   8.513825E-04   8.513539E-04   7.459873E-04
SUPERBLOCK 1   7200.00
    21.0646        19.9451        21.0291        21.1050        21.0119
    21.0139        21.0245        21.1266        21.4826        20.5600
  -0.106536      -0.104631      -0.197710       0.000000       0.000000
   0.000000
SUPERBLOCK 2   8030.00
    21.4587        21.5024        22.1354        22.1665        20.0000
   8.651502E-04   8.651000E-04   7.457146E-04
SUPERBLOCK 1   8100.00
    21.0615        19.9696        20.9622        21.1058        20.9397
    20.9433        21.0477        21.1442        21.4495        20.4258
  -0.121632      -0.116654      -0.210883       0.000000       0.000000
   0.000000
SUPERBLOCK 1   9000.00
    21.0460        19.9751        20.9115        21.0928        20.8857
    20.8906        21.0481        21.1434        21.4171        20.4137
  -0.127826      -0.120037      -0.223062       0.000000       0.000000
   0.000000
SUPERBLOCK 2   9030.00
    21.4581        21.5134        22.1255        22.1665        20.0000
   8.775999E-04   8.775219E-04   7.454029E-04

----------(OUTPUTS FROM TIME=9900 TO  251796 ARE DELETED)--------------

SUPERBLOCK 1 252000.00
    21.9522        20.9661        21.2759        21.9833        21.2252
    21.2573        22.1396        22.0591        21.3677        19.4400
  -0.263559      -0.238100      -0.265956       0.000000       0.000000
   0.000000
SUPERBLOCK 2 252796.00
    22.3498        22.3719        22.0977        22.1665        20.0000
   1.271887E-03   1.306680E-03   7.443607E-04
SUPERBLOCK 1 252900.00
    21.6665        20.7074        21.0275        21.7072        20.9788
    21.0090        21.8346        21.8050        21.2637        19.3084
  -0.247862      -0.225442      -0.291922       0.000000       0.000000
   0.000000
SUPERBLOCK 2 253796.00
    22.0627        22.1211        22.0852        22.1665        20.0000
   1.270476E-03   1.304380E-03   7.441964E-04
SUPERBLOCK 1 253800.00
    21.4073        20.4740        20.7989        21.4561        20.7517
    20.7804        21.5584        21.5725        21.1705        19.1715
  -0.234484      -0.214536      -0.316101       0.000000       0.000000
   0.000000
SUPERBLOCK 1 254700.00
    21.2307        20.3158        20.6300        21.3117        20.5824
    20.6115        21.3537        21.4194        21.0885        19.0314
  -0.285258      -0.255413      -0.341664       0.000000       0.000000
   0.000000
SUPERBLOCK 2 254796.00
    21.7180        21.8235        22.0655        22.1665        20.0000
   1.268979E-03   1.301975E-03   7.440925E-04
SUPERBLOCK 1 255600.00
    21.0173        20.1295        20.4385        21.0954        20.3922
```

```
     20.4205        21.1365        21.2273        21.0109        18.8900
   -0.241197      -0.220511      -0.359827       0.000000       0.000000
    0.000000
SUPERBLOCK 2 255796.00
     21.4541        21.5897        22.0548        22.1665        20.0000
  1.267662E-03   1.299750E-03   7.440553E-04
SUPERBLOCK 1 256500.00
     20.8110        19.9485        20.2499        20.8892        20.2050
     20.2323        20.9246        21.0394        20.9373        18.7490
   -0.220682      -0.203429      -0.380644       0.000000       0.000000
    0.000000
SUPERBLOCK 2 256796.00
     21.2297        21.3887        22.0451        22.1665        20.0000
  1.266833E-03   1.298028E-03   7.440895E-04
SUPERBLOCK 1 257400.00
     20.6175        19.7789        20.0705        20.6980        20.0268
     20.0533        20.7238        20.8625        20.8683        18.6086
   -0.208762      -0.193080      -0.400627       0.000000       0.000000
    0.000000
SUPERBLOCK 2 257796.00
     21.0301        21.2090        22.0363        22.1665        20.0000
  1.266805E-03   1.297132E-03   7.441971E-04
SUPERBLOCK 1 258300.00
     20.4375        19.6212        19.9016        20.5214        19.8589
     19.8849        20.5357        20.6978        20.8033        18.4689
   -0.200604      -0.185770      -0.419944       0.000000       0.000000
    0.000000
SUPERBLOCK 2 258796.00
     20.8491        21.0461        22.0282        22.1665        20.0000
  1.267894E-03   1.297383E-03   7.443784E-04
SUPERBLOCK 1 259200.00
     20.2705        19.4752        19.7435        20.3584        19.7015
     19.7271        20.3605        20.5448        20.7424        18.3300
   -0.194380      -0.180170      -0.438363       0.000000       0.000000
    0.000000
SUPERBLOCK 2 259200.00
     20.7811        20.9849        22.0223        22.1665        20.0000
  1.268553E-03   1.297710E-03   7.444688E-04
```

C. Postprocessing - Output Data Analysis

Execution of SORTSB program and plotting using the output of SORTSB.

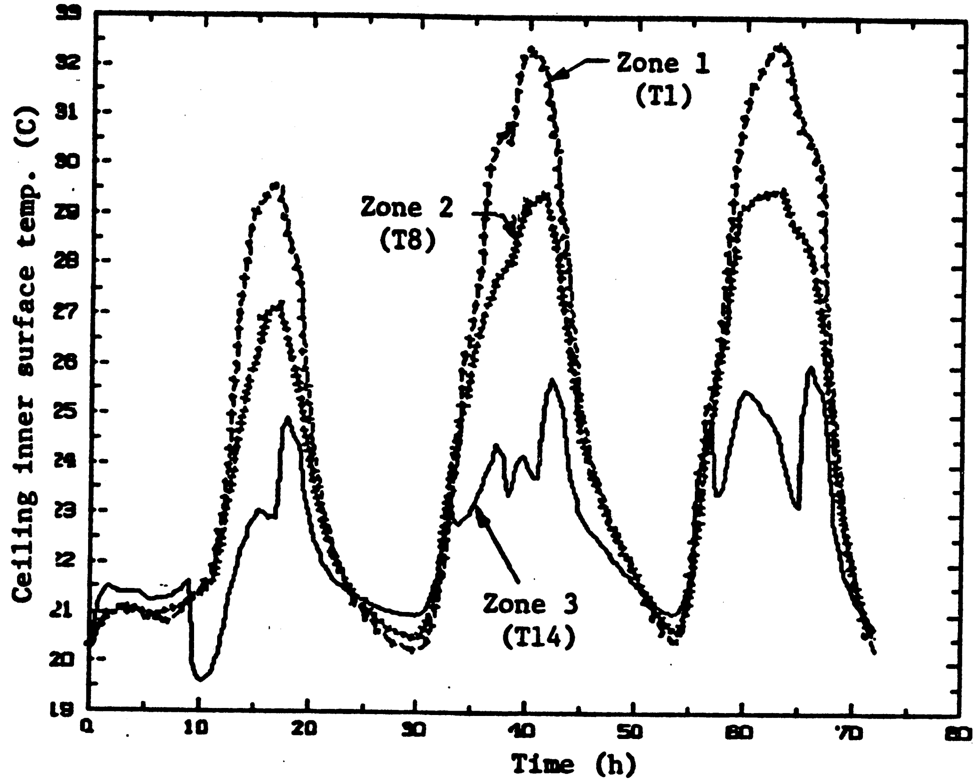


Figure D-3. Ceiling inner surface temperatures of the three-zone model

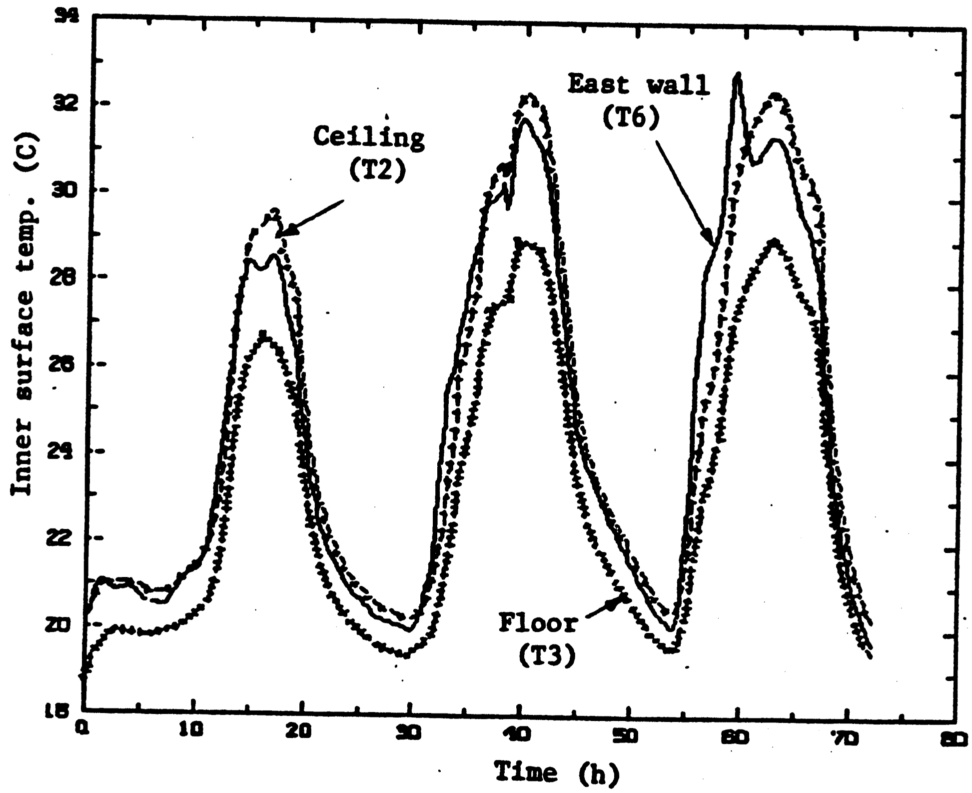


Figure D-4. Inner surface temperatures of the selected building surfaces in Zone 1.

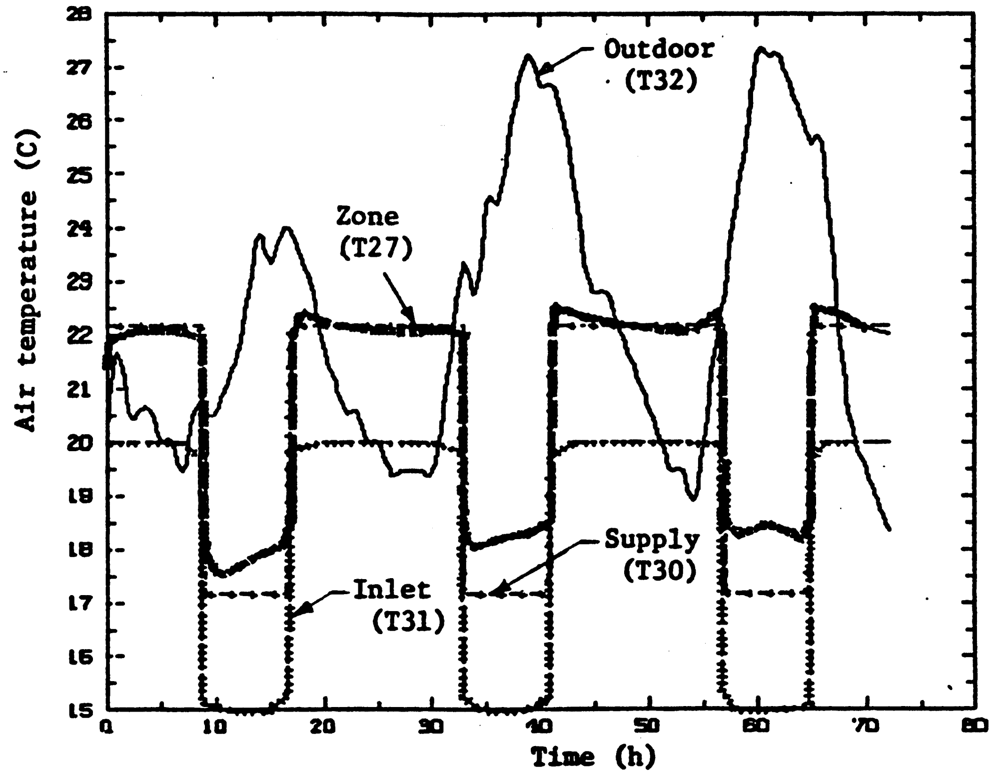


Figure D-5. Outdoor, zone, supply, and inlet air temperatures in Zone 3

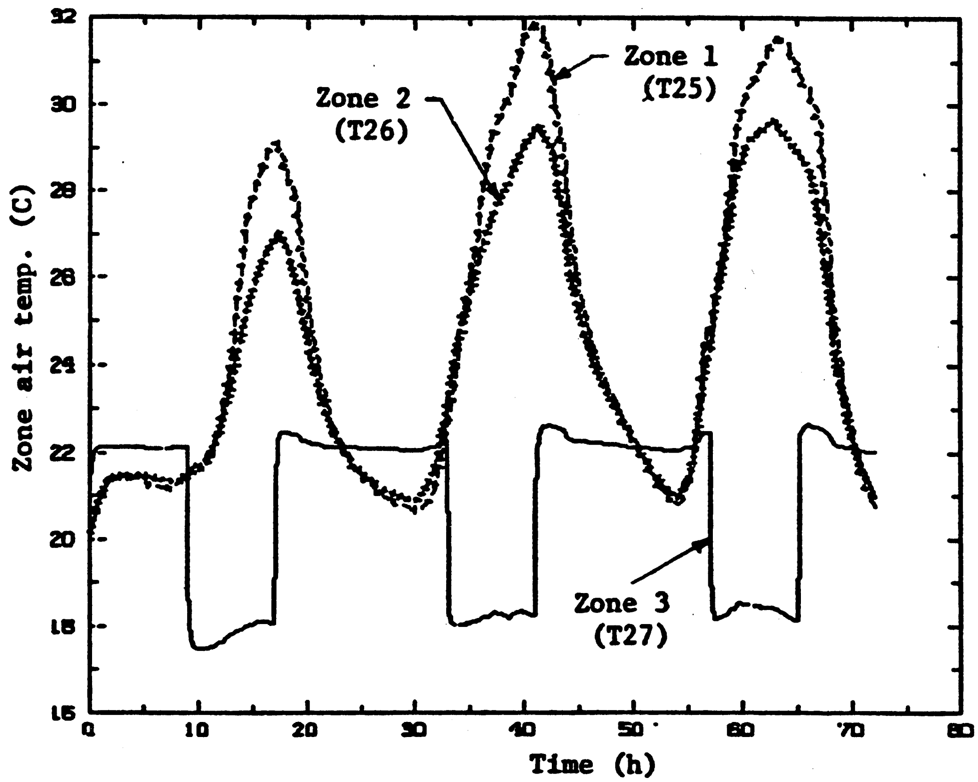


Figure D-6. Zone air temperatures in the three-zone model

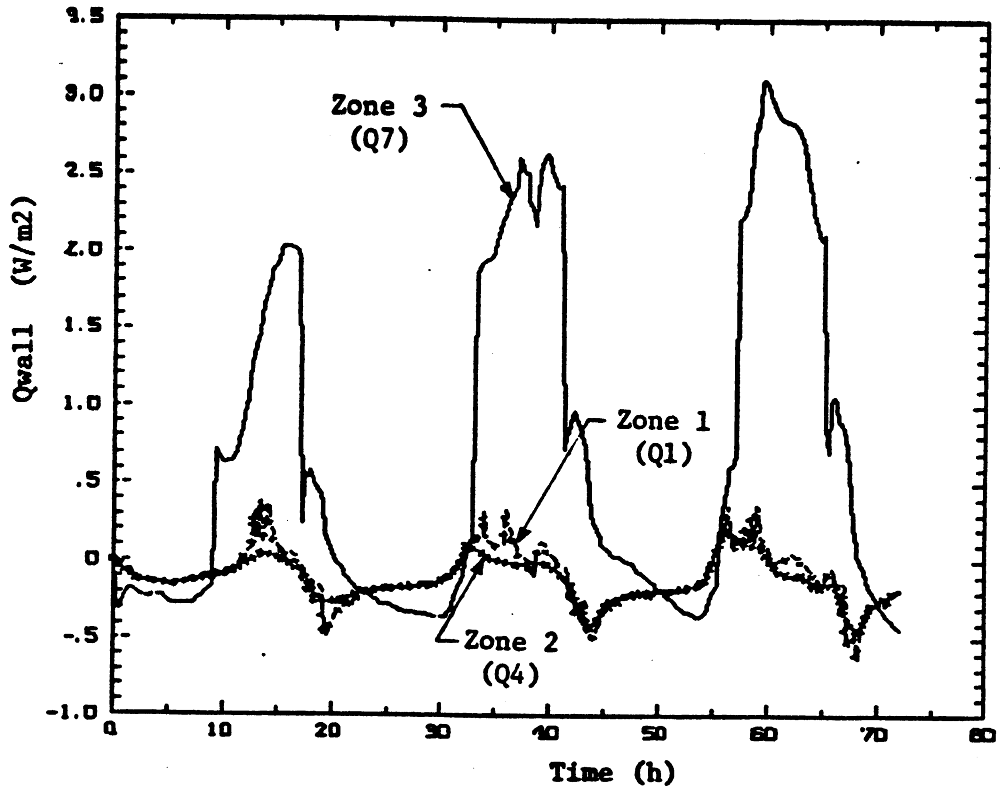


Figure D-7. Convective heat flow rates from the building inner surfaces

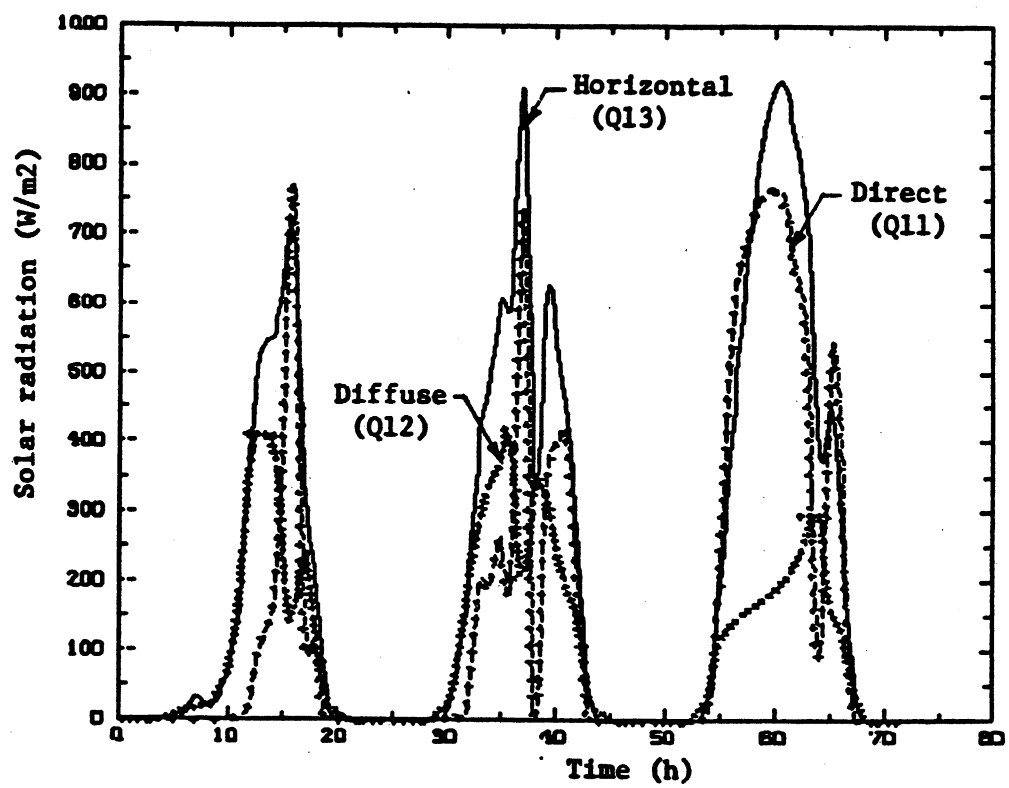


Figure D-8. Solar radiation influxes from a weather tape

NBS-114A (REV. 2-80)

| U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions) | 1. PUBLICATION OR REPORT NO. NBSIR-86/3331 | 2. Performing Organ. Report No. | 3. Publication Date MARCH 1986 |
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4. TITLE AND SUBTITLE

HVACSIM$^+$ Building Systems and Equipment Simulation Program: Building Loads Calculation

5. AUTHOR(S)

Cheol Park, Daniel R. Clark, George E. Kelly

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

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Washington, DC 20585

U.S. Navy Civil Engineering Laboratory
U.S. Department of Defense
Port Hueneme, CA 93043

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

A non-proprietary building system simulation program called HVACSIM$^+$, which stands for HVAC SIMulation PLUS other systems, has been developed at the National Bureau of Standards (NBS) in an effort to understand the dynamic interactions between a building shell, an HVAC system, and building controls. HVACSIM$^+$ consists of a main simulation program, a library of HVAC system component models, a building shell model, and interactive front end input data generation programs.

The main simulation program employs a hierarchical, modular approach and advanced equation solving techniques to perform dynamic simulations of building/HVAC/control systems. In the building shell model, a fixed time step selected by the user is employed, while a variable time step approach is used in the HVAC and control systems portion of a simulation and the zone model.

This report presents the overall architecture of the HVACSIM$^+$ program, algorithms used in the main simulation program, a brief discussion of the numerical methods used in solving a system of non-linear simultaneous equations, integrating stiff ordinary differential equations and interpolating data and descriptions of the building shell and zone models. Conduction transfer functions, weather data, and simulation procedure are also described. This report is the third document, which describes the building model, supplied with HVACSIM$^+$.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

building dynamics; building simulation; building system modeling; computer simulation programs; control dynamics; dynamic modeling of building systems; dynamic performance of building systems; dynamic simulations; HVAC system simulations; HVACSIM$^+$

13. AVAILABILITY

[X] Unlimited
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