NISTIR 7514

HVACSIM$^+$ User's Guide Update

Cheol Park

National Institute of Standards and Technology
U.S. Department of Commerce

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Building Environment Division
Building and Fire Research Laboratory
Gaithersburg, MD 20899-8631

July 2008

U.S. Department of Commerce
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ABSTRACT

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The first version of HVACSIM$^+$, which stands for "HVAC SIMulation PLUS other systems", as introduced by National Institute of Standards and Technology (NIST) in 1985 as a computer simulation tool to simulate entire building systems [1]. Since then, the HVACSIM$^+$ computer program package and manuals have been distributed to researchers, students, and consultants in more than 40 countries around the world. Since the first distribution of the program to public, a number of modifications have been made.

Because some of statements in the Fortran 77 computer code of the HVACSIM$^+$ used more than 20 years have become obsolete in the context of today's Fortran 90/95 standards, an upgrade to Fortran 90/95 standards was deemed necessary. This conversion task was recently completed by NIST. During the conversion, the logic flows were maintained as close to the original as possible.

This update manual is a condensed guide to running the programs in the HVACSIM$^+$ package. Much of the substance of this manual is extracted directly from the previous manuals. This manual is intended to update and supplement the previous manuals, not to replace them. To confirm correct operation of the new code and illustrate its use, some of examples of system and building shell simulations were chosen from the previous documents. Simulation runs were made in the command line interface of a popular operating system in step-by-step manner. The input and output information of those runs is listed in this manual.

Key words: building simulation; building system modeling; computer simulation program; HVAC system simulations; HVACSIM$^+$

DISCLAIMER

This program is furnished by the government 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

The first version of HVACSIM$^+$, which stands for “HVAC SIMulation PLUS other systems”, was introduced by National Institute of Standards and Technology (NIST) in 1985 as a computer simulation tool to simulate entire building systems [1]. Since then, the HVACSIM$^+$ computer program package and manuals [2-4] have been distributed to researchers, students, and consultants in more than 40 countries around the world. Since the first distribution of the program to the public, a number of modifications have been made including the addition of the component models developed for the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 825 project by Norford and Haves [5]. Until now, however, no updates have been made to the user’s manual for HVACSIM$^+$.

Because some of statements in the Fortran 77 computer code of the HVACSIM$^+$ used more than 20 years have become obsolete in the context of today’s Fortran 90/95 standards, an upgrade to Fortran 90/95 standards was deemed necessary. This conversion task was recently completed by NIST by converting all the routines written in Fortran 77 code into Fortran 90. During the conversion, the logic flows were maintained as close to the original as possible. One of the front-end programs, HVAGEN, was converted using the program TO_F90 written by Alan Miller [6] and then further modifications were performed, while other programs were converted manually.

This update manual is a condensed guide to running the programs in the HVACSIM$^+$ Version 20.0 package. Much of the substance of this manual is extracted directly from the previous manuals. This manual is intended to update and supplement the previous manuals, not to replace them. Detailed information regarding HVACSIM$^+$ can be found in previous manuals. The names of specific programs or procedures are denoted in upper case characters, while the names of files and the terms specifically related to HVACSIM$^+$ have been italicized. There are some changes in output formats in this version, but the input formats are retained as closely as possible to the Fortran 77 version.

To confirm correct operation of the new code and illustrate its use, some of examples of system and building shell simulations were chosen from the previous documents. Simulation runs were made in the command line interface of a popular operating system in step-by-step manner for a user to follow. The input and output information of those runs is listed in this manual.

Note that programs in the HVACSIM$^+$ package are text-oriented. Any PC or equivalent computer systems may be utilized in performing simulations. The HVACSIM$^+$ package is distributed containing all the source code files as well as sample input data files. The HVACSIM$^+$ program may be expanded by adding user-developed component models. It is highly recommended that users develop their own component models for particular applications.

2. Overall Structure of HVACSIM$^+$

HVACSIM$^+$ is a collection of programs in three categories: preprocessing, simulation, and post-processing. **Figure 1** shows a flow diagram of programs and data files comprising HVACSIM$^+$. During the pre-processing stage, a simulation work file (*hvacsim.sim*) is created by the interactive front-end program, HVACGEN, employing a data file containing component model information. The simulation work file can be edited interactively by the HVACGEN. This simulation work file (*hvacsim.sim*) is then converted into the model definition file (*hvacsim.dfn*) by the SLIMCON program. The model definition file has the format required by the main simulation program, MODSIM.

The main simulation program, MODSIM, needs the model definition file (*hvacsim.dfn*), and the *boundary* data file (*hvacsim.bnd*). The *boundary* data file contains the time-dependent *state* variable data that is not computed but given externally. The *state* variables associated with the *boundary* data file are assigned when HVACGEN generates the simulation work file (*hvacsim.sim*).

During the execution of MODSIM, simulation control input data can be entered interactively or by redirecting the simulation control data file. After a successful simulation run, the summary data file (*hvacsim.sum*), the raw output data file (*hvacsim.out*), and the final *state* variable data file (*hvacsim.fin*) are generated. Post-processing is necessary if a graphical display of the raw output data is desired. The program SORTSB sorts the raw output data file (*hvacsim.out*) into a form suitable for graphical presentation.

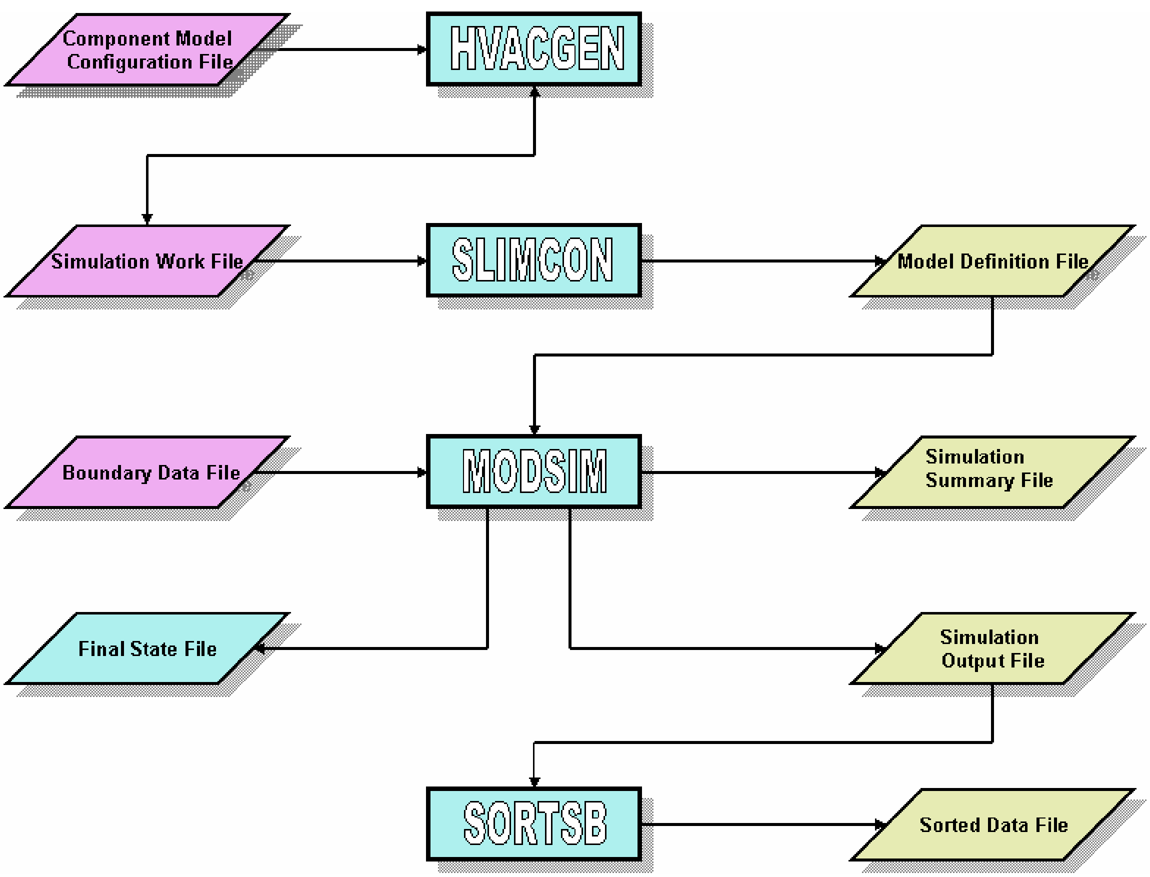

Figure 1. Flow diagram of programs and data files comprising HVACSIM+.

When a building shell is used in a simulation, two additional input data files are required: (1) the weather condition data file (*hvacsim.met*), and (2) the conduction transfer function data file (*hvacsim.ctf*) for multilayered constructs. As shown in **Figure 2,** the RDWDF program reads the selected portion of data from a designated whole year weather data file. The program CRWDTA transforms the selected weather data into the proper format compatible with the MODSIM program. If weather data is not available or information from a whole year weather data file is missing, the CRWDTA program produces a design day weather data file. The conduction transfer functions of multilayered constructs are generated by the program CTFGEN. This program requires a file of building material thermal property data.

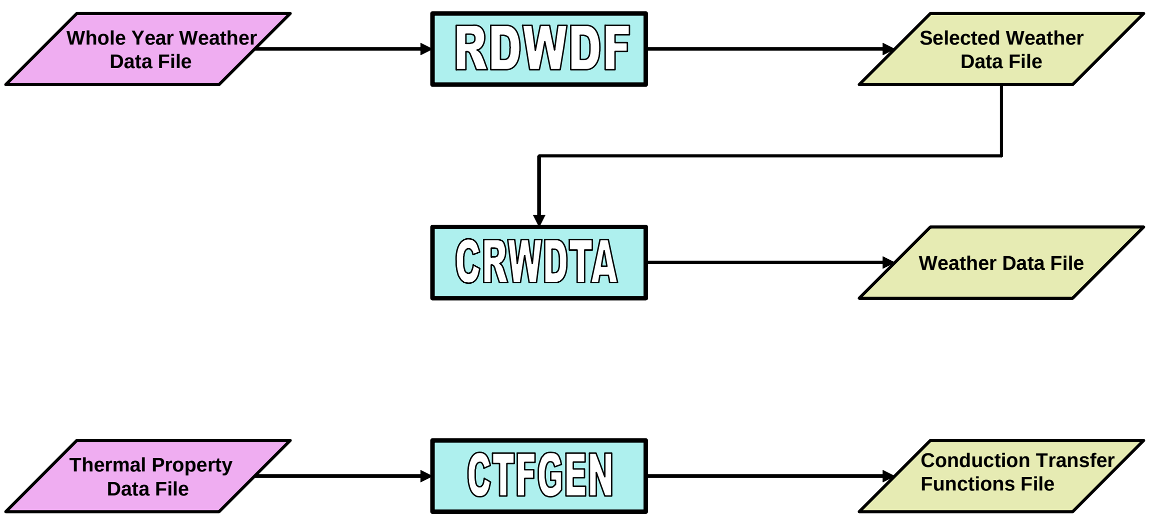

Figure 2. Flow diagram of front-end programs and data files for shell modeling.

2.1 <u>MODSIM</u>

The MODSIM program consists of a main drive program and many subprograms for input/output operation, *block* and *state* variable status control, integrating differential equations, solving a system of simultaneous non-linear algebraic equations, component models (HVAC, controls, building shell, etc.), and supporting utilities. See **Figure 3**.

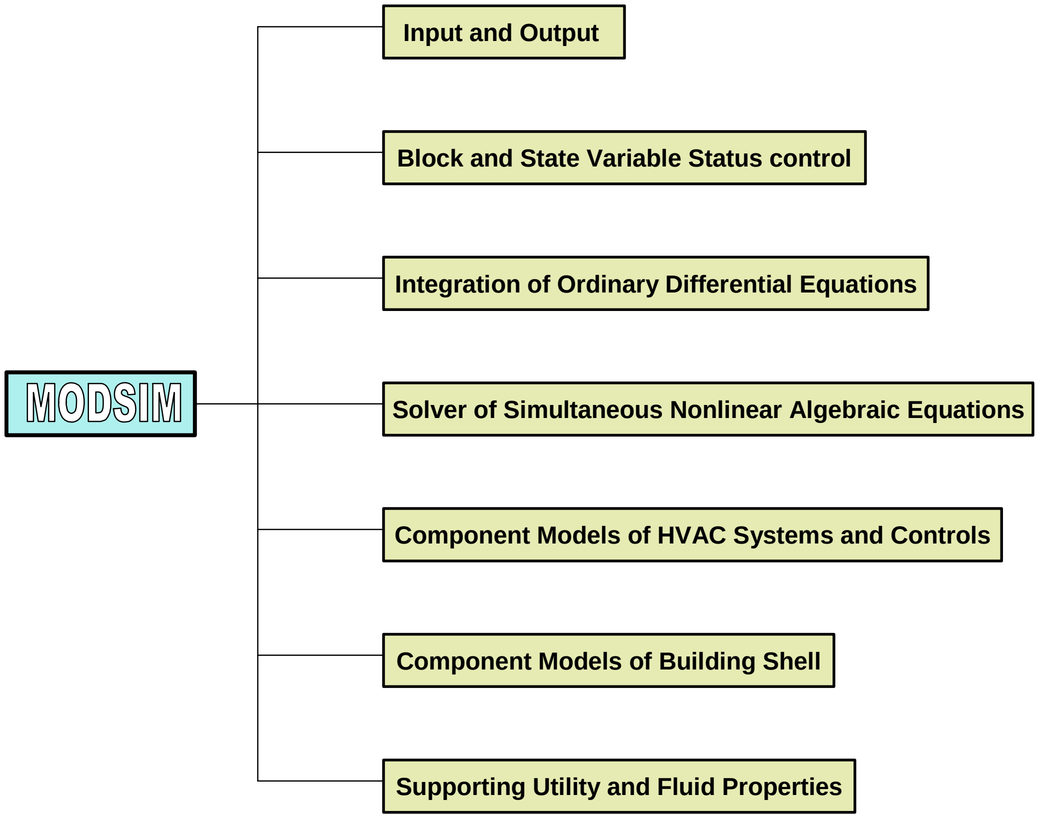

Figure 3. The structure of MODSIM.

A hierarchical approach is employed in simulation model setup. The simulation work file (*hvacsim.sim*) is constructed in the hierarchical structure, comprising *super blocks*, *blocks*, and *units*. As illustrated in **Figure 4**, a number of *units* (or a single *unit*) form a *block*, a number of *blocks* (or a single *block*) form a *superblock*, and a number of *superblocks* (or a single *superblock*) make up a simulation setup. The figure shows a setup with 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 *superblock* are solved simultaneously by using the non-linear equation solver routine, SNSQ (see pp. 14-17 of Reference 4). S*uperblocks* are weakly coupled through the *state* variables.

In the simulation setup a *unit* represents a component model of HVAC systems, controls, or building shells. Each component model is programmed as the subroutine TYPEn, where "n" represents the index number assigned to the specific component. More than one *unit* can call the same subroutine TYPEn as long as the *unit* numbers are different. The arguments of a TYPEn component subroutine are inputs, outputs, parameters, and a working vector for saving intermediate results. The component model configuration file (*typar.dat*), which is an input data file to the HVACGEN program, contains the numbers of elements in saved workspace vectors, differential equations, inputs, outputs, and parameters. **Listing 1** shows a sample in the *typar.dat* file.

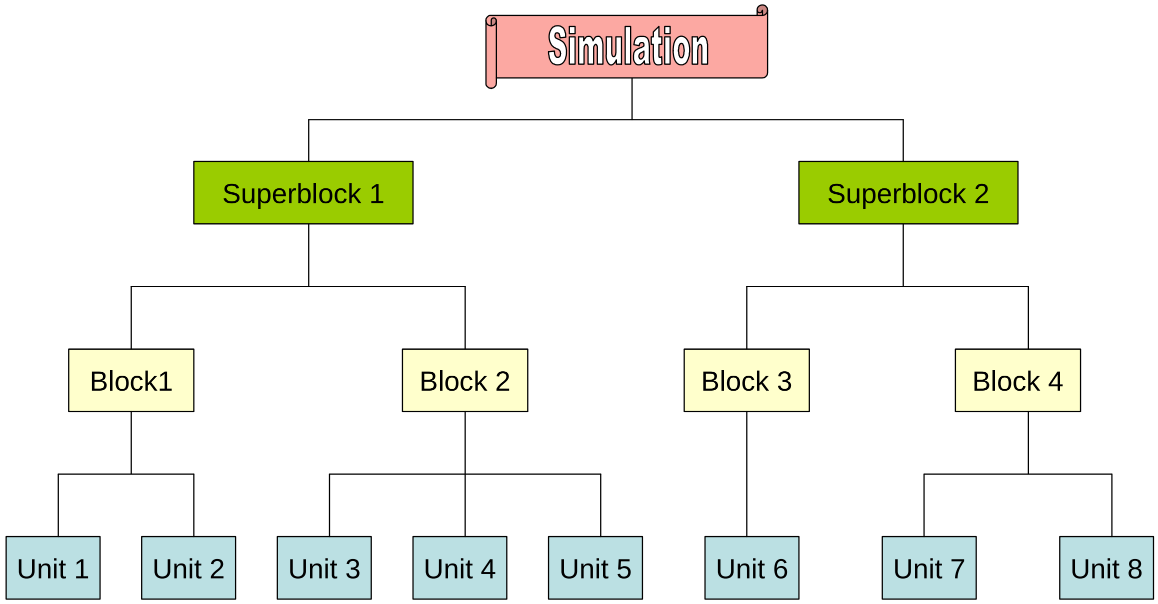

Figure 4. Hierarchical simulation setup.

Listing 1. A portion of Typar.dat file.

```
*************************************************************************
  4  'Flow merge                                                        '
  0  0  5  4  1              ! numbers of saved, diff. eq., xin, out, par
  2  'inlet mass flow rate 1                                            '
  2  'inlet mass flow rate 2                                            '
  1  'outlet pressure                                                   '
  3  'inlet temperature 1                                               '
  3  'inlet temperature 2                                               '
#
  2  'outlet mass flow rate                                             '
  1  'inlet pressure 1                                                  '
  1  'inlet pressure 2                                                  '
  3  'outlet temperature                                                '
#
  1  'flow resistance [1000/(kg m)]                                     '
*************************************************************************
  5  'Damper or valve                                                   '
  0  0  3  1  4              ! numbers of saved, diff. eq., xin, out, par
  2  'fluid mass flow rate                                              '
  1  'outlet pressure                                                   '
  4  'control: relative position of damper or valve                     '
#
  1  'inlet pressure                                                    '
#
  1  'flow resistance, damper or valve open [1000/(kg m)]               '
```

```
  2  'leakage parameter (dimensionless)                                  '
  3  'characteristic: 0=>exp., 1=>lin., intermediate=>intermed.         '
  4  'mode: 0=>closed when control=0; 1=>closed when control=1          '
```

The category numbers of inputs and outputs, and the descriptions of inputs, outputs, and parameters are also included in the file. In HVACSIM$^+$, eight categories of variables are used: pressure, flow rate, temperature, control, other, energy, power, and humidity. Assigned category numbers, abbreviations, variable names, and measurement units are given in **Table 1**. Each variable is identified in the simulation by the category and the index number of the variable (e.g., T1, p2, h5, etc.). The complete set of variables in the simulation is designated as "*state* vector". At any time during a simulation, the *state* vector completely describes the state of the system. The *state* vector has to be initialized at the beginning of each simulation run. The initial value vector can be generated by HVACGEN or by using the final *state* vector. The initial values should be as close as possible to the state at which the simulation should start. It is quite important to provide proper initial values to obtain a good simulation.

Table 1. Categories of variables in HVACSIM$^+$.

Categories of Variables				
Category #	**Name**	**Abbreviation**	**Short Abbreviation**	**Unit**
1	Pressure	pres	**p**	kPa
2	Mass flow rate	flow	**w** or **m**	kg
3	Temperature	temp	**T**	°C
4	Control	ctrl	**c**	dimensionless
5	Other	othr	**o**	as required
6	Energy	engr	**e**	kJ
7	Power	powr	**q**	kW
8	Humidity	ahum or humt	**h**	kg/kg

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. A schematic drawing of the system to be simulated is a convenient way to visualize what parts make up the entire system (see pp.2-9 of Reference 2).

A *state* variable that is external to the system is designated as a "*boundary* variable" when the simulation work file (*hvacsim.sim*) is generated by HVACGEN. The *boundary* variable is an input to at least one *unit* in the simulation but not an output of any *unit*. *Boundary* variables can be constant or time-dependent. Whether used or not, the *boundary* data file (*hvacsim.bnd*) must be present as an input file for a simulation run. The time intervals in the *boundary* data file do not have to be equal. For cases when a step change occurs, two different values should be given at the same time.

There are two methods available in MODSIM for integrating ordinary differential equations. One of the methods employs Gear's algorithm to solve a stiff ordinary differential equation (see pp. 17-23 of Reference 4). The other employs the exact method using the subroutine DIFF.

2.2 HVACGEN

The HVACGEN program has three types of operations: the creation, viewing, and editing of the simulation work file (*hvacsim.sim*) interactively on a computer terminal. The component model configuration file (*typar.dat*) must be present in the same folder/directory where the executable code of HVACGEN resides.

Using the *create* command (see Reference 3), title, error tolerances, type numbers, indices of inputs and outputs of *units*, parameter values of *units*, initial values of *state* variables, categories and indices of *boundary* and *reported* variables are entered to make a simulation work file. **Table 2** shows a skeleton of the simulation work file in which relative error tolerance, absolute error tolerance, error tolerance used by the equation solver, SNSQ, and the time interval for integrating differential equations are denoted as "rtolx", "atolx", "xtolx", and "ttime," respectively. The numbers of *superblocks*, *blocks*, *units*, *boundary* variables, *reported* variables, variables in each category, as well as the *state* variables in the whole simulation are created automatically.

The work file can be viewed by using the *view* command. The structure of the *unit*, the *block*, or the simulation setup can be displayed. The resulting *view all* of the whole simulation setup can be stored in a user specified file or in the default file (*viewsave.txt*).

The simulation work file can be edited using the *edit* command. The title, structure, initial values, *boundary* values, *reported* variables, error tolerances, input *scan* option, and *freeze* option can be changed. A *unit* or *block* can be inserted or deleted. A *unit* can also be replaced. However, deleting or inserting a *superblock* is not possible using HVACGEN.

In entering a command, the first two characters are sufficient. Aborting operation in *create*, *view*, or *edit* can be done by using the *abort* command. Be aware that the currently updated information is usually not saved after aborting. The *continue* command brings the operation to the previous level. See **Figure 5** for the summary of commands used in HVACGEN. Detail information concerning the commands can be found in Reference 3.

Instead of using this text oriented HVACGEN, a visual front-end program developed by the Oklahoma University [7], which is not included in the HVACSIM$^+$ package, may be used to create a simulation work file (*hvacsim.sim*).

Table 2. Structure of the simulation work file.

```
 Structure of Simulation Work File

Title
Number of Superblocks
rtox, atolx, xtol, ttime

--------------- Superblock level -----------------------------|
                                                              |
Number of Blocks                                              |
--------------- Block level -------------------------|        |
Number of Units                                      |        |
--------------- Unit level ---------------|          |        |
   of Unit, ID of Type                    |          |        |
Indices of Input Variables                |          |        |
Indices of Output Variables               |          |        |
Parameter Values                          |          |        |
     -------------------------------------|          |        |
-----------------------------------------------------|        |
--------------------------------------------------------------|

Initial Values of State Variables

Number of Boundary Variables
Locations of Boundary Variables

Number of Reported Variables and Time interval in the 1st Superblock
Location of Reported Variables
Indices of Category of Reported Variables
Indices of Reported Variables

Number of Reported Variables and Time interval in the 2nd Superblock
Location of Reported Variables
Indices of Category of Reported Variables
Indices of Reported Variables

Freezing options in Superblocks
Input Scan options in Superblocks

**************** SUMMARY OF WORK FILE ****************
Number of Superblocks, No. of Blocks, No. of Units in the simulation
Number of Blocks in Superblocks
Number of Variables in PRES, FLOW, TEMP, CTRL, OTHR, ENRG, POWR, HUMT
Number of State Variables in the simulation
Number of Reported Variables in Superblocks
```

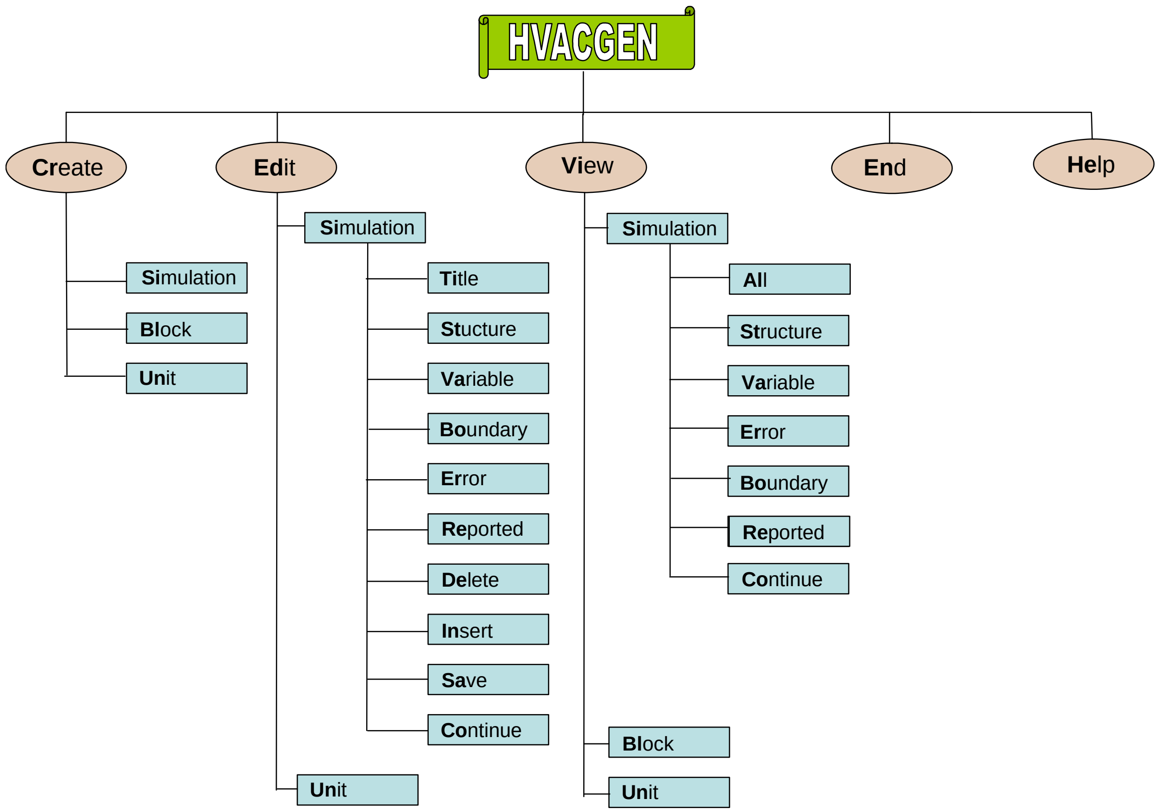

Figure 5. Summary of commands used in HVACGEN.

2.3 SLIMCON

The simulation work file, which is the output of HVACGEN, must be analyzed and transformed into a file that has the format required by MODSIM. This process is achieved by the SLIMCON program. The SLIMCON program not only creates the model definition file (*hvacsim.dfn*) but also checks any errors in configuration of the simulation setup. A table is displayed to show the information on actual array sizes of variables along with maximum allowable sizes. For each *unit*, the program also displays the *unit* number, the *type* number, the number of *saved* variables, the number of differential equations which use Gear's algorithm, the number of inputs, the number of outputs, and the number of parameters. An option is provided to allow algebraic variables to be inputs and outputs of the same units.

2.4 <u>UPD_INFO</u>

In general, when the command *view all* is used, the output file (*viewsave.txt*) of HVACGEN sufficiently enables the user see the simulation setup, if a small number of component models are involved. Sometimes supplemental information is needed to distinguish the roles of components when the same *type* component is called by a number of different *units*. The program UPD_INFO calls *viewsave.txt* and adds the supplemental information from the supplemental unit information file (*hvacsim.inf*) on it to make an updated model information file (*hvacsim.model*). The file, *hvacsim.inf*, contains the unit numbers and supplemental information for the corresponding, particular *units*. Note that this program has never been documented previously.

2.5 <u>RDWDF</u>

When a simulation involves building thermal loads, weather data are required. From a whole year weather data file, the program RDWDF reads the type of weather data format, the weather station identification number, and the beginning and ending dates of the period of interest. The selected weather data is then written on the output file (*wtpout.dat*). The output file comprises the time of day, dry-bulb outside air temperature, humidity ratio, barometric pressure, wind speed, direct normal solar beam radiation, sky diffuse radiation, and total horizontal solar radiation.

RDWDF is capable of reading five data formats: ‘NOAA SOLMET,’ ‘NOAA Typical Meteorological Year (TMY),’ ‘NOAA Test Reference Year (TRY),’ ‘Weather Year for Energy Calculation (WYEC),’ and ‘Weather Year for Energy Calculation2 (WYEC2).’ [8].

2.6 <u>CRWDTA</u>

The CRWDTA program reads the output of RDWDF (*wtpout.dat*), and rewrites the data into the format requested by MODSIM. If weather data is not available, a weather data file can be generated by CRWDTA. CRWDTA generates smooth design day solar radiation and temperature data for a clear or cloudy sky design day for given latitude, longitude, and time zone. For details, see pp. 65-72 of Reference 4.

2.7 <u>CTFGEN</u>

Using the program CTFGEN, the thermal property data file (*therm2.dat*) from Reference 9 can be displayed and more data can be added. Thermal properties of building materials (thickness, thermal conductivity, density, specific heat, and thermal resistance) are listed in that data file. The main function of CTFGEN is to compute conduction transfer functions of multilayered constructs such as walls, floors, ceilings, and windows of a building shell. Heat fluxes are also computed. For details, see pp. 53-63 of Reference 4.

2.8 <u>SORTSB</u>

When more than one *superblock* are involved, it is necessary to sort the output file of MODSIM (*hvacsim.out*) *superblock* by *superblock* for plotting. The SORTSB handles up to 10 *superblocks*.

3. Getting Started

3.1 System Requirements

- PC system computer or compatible computer
- 254 megabytes of memory
- 100 megabytes of hard disk space
- Fortran 90/95 compiler for development of source code
- PDF file reader for reading manuals

All executable programs in this distribution were created by using a Fortran 90/95 compiler. HVACSIM$^+$ has not been tested with a Linux operating system.

3.2 Installing HVACSIM$^+$

1. Create a folder/directory (e.g., HVACSIM20) on a hard drive.
2. Copy all files on the CD into the folder.
3. Make a working subfolder (e.g., WORK) in the folder.
4. Copy the files in the folders, BIN and DATA, into the working folder for an initial run.
5. The folder DOC contains manuals in PDF format, and the folder SAMPLE contains the inputs for sample runs.

4. Case 1: Running Programs for System Simulation

Example 1 in the folder SAMPLE is selected for the purpose of illustration. Note that default file names are not used in most cases of this example run. See pp. 52-89 of Reference 3.

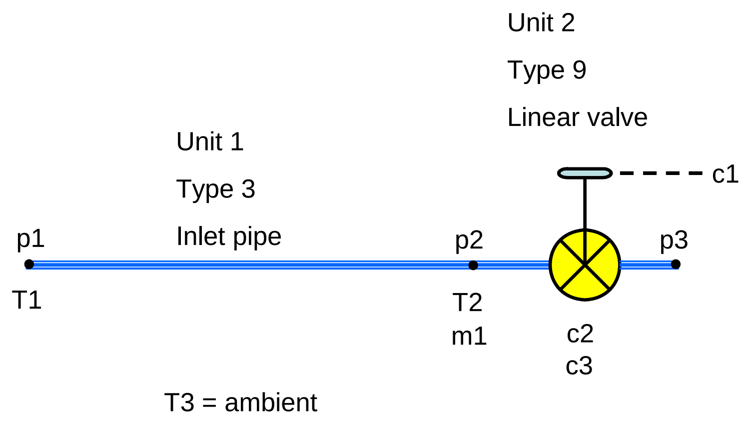

Figure 6. System schematic diagram of Example 1.

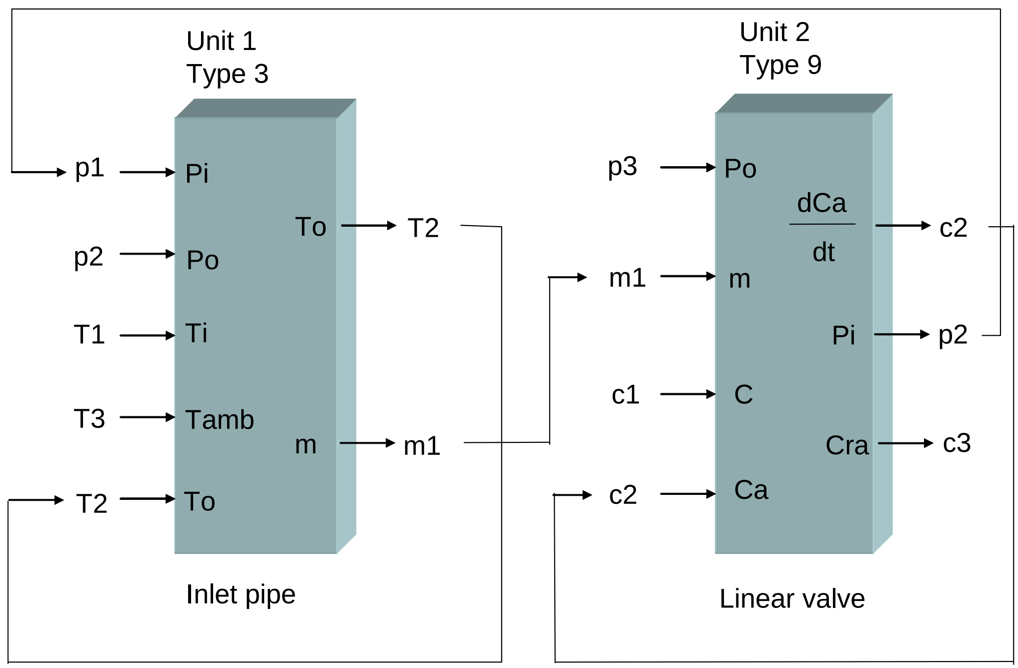

Figure 7. Information flow diagram of Example 1.

4.1 Configuration of Simulation Scope

Make a block diagram of the building system to be simulated, and then assign index numbers to each node and draw lines, if possible, to make connections based on the information on inputs/outputs of component models provided in the component model configuration file (*typar.dat*). See **Figures 6** and **7.**

4.2 Creating Input Data Files

4.2.1 Simulation work file (*hvacsim.sim*)

Open a command line interface of an operating system, and then execute HVACGEN interactively.

Listing 2 shows the interactive HVACGEN session in which the simulation work file was generated. During an interactive session, simply hitting the return key on a terminal key board selects the default response, which in most case is “yes” in response to a “yes or no” question. Making errors in entering data is quite common. In that situation, it is better to keep going into the next entry rather than aborting. After creating a simulation work file, those errors can be corrected by rerunning HVACGEN and using the *edit* command.

Listing 3 shows the simulation work file, which comprises the title, *superblock* number, error tolerances, time interval, *block* number, number of *units*, *unit* number, *type* number, input indices, output indices, parameter values, initial values, number of *boundary* variables, indices of *boundary* variables, number of *reported* variables, reporting time interval, indices of *reported* variables, *state* variables, locations of reported variables, categories of reported variables, variable *freezing* option, variable input *scan* option, and summary information.

The summary information has the total number of *superblocks* in the simulation, the total number of *blocks*, the total number of *units*, the numbers of *blocks* in each *superblock*, the numbers of variables in each category, the total number of *state* variables in the simulation, and the numbers of *reported* variables in each *superblock*. See Table 2.

Listing 2. Interactive session to create the simulation work file.

```
C:\HVACSIM20\WORK>hvacgen


HVACGEN - Simulation GENeration Program

Version 5.0      March 9, 2007


Choose from the list below:


CReate (SImulation, BLock, UNit)

EDit (SImulation, UNit)

VIew (SImulation, BLock, UNit)

HElp

ENd

-----------------------------------------------------------------------
Selection ?
=> cr


Create a:

SImulation
BLock
UNit
-----------------------------------------------------------------------

=> si
 Superblock number=  1
BLock number=  1
-----------------------------------------------------------------------
Enter the type number (or TYPES for list of types)
=> 3
 INITIALIZING TYPES INFORMATION...

Inlet conduit (duct or pipe)


INPUTS
```

```
========================================================================
index for inlet fluid pressure
------------------------------------------------------------------------
PRESSURE
=> 1

========================================================================
index for outlet fluid pressure
------------------------------------------------------------------------
PRESSURE
=> 2

========================================================================
index for inlet fluid temperature
------------------------------------------------------------------------
TEMPERATURE
=> 1

========================================================================
index for ambient air temperature
------------------------------------------------------------------------
TEMPERATURE
=> 3

========================================================================
index for outlet fluid temperature (same as first output)
------------------------------------------------------------------------
TEMPERATURE
=> 2

OUTPUTS


========================================================================
index for outlet fluid temperature (same as fifth input)
------------------------------------------------------------------------
TEMPERATURE
=> 2

========================================================================
index for fluid mass flow rate
------------------------------------------------------------------------
FLOW
=> 1

========================================================================
PARAMETER  1 inside heat transfer coefficient x area (kW/C)
------------------------------------------------------------------------
ENTER THE VALUE
=> 16.4

========================================================================
PARAMETER  2 outside heat transfer coefficient x area (kW/C)
------------------------------------------------------------------------
ENTER THE VALUE
=> 0.17

========================================================================
PARAMETER  3 thermal capacitance of conduit material (kJ/C)
------------------------------------------------------------------------
ENTER THE VALUE
=> 25.2
```

```
========================================================================
PARAMETER  4 volume (m3)
------------------------------------------------------------------------
ENTER THE VALUE
=> 0.015

========================================================================
PARAMETER  5 flow resistance [1000/(kg m)]
------------------------------------------------------------------------
ENTER THE VALUE
=> 13.5

========================================================================
PARAMETER  6 height of outlet above inlet (m)
------------------------------------------------------------------------
ENTER THE VALUE
=> 0.0

========================================================================
PARAMETER  7 mode: 2=water, 1=air, neg.=detailed, pos.=simple dynamics
------------------------------------------------------------------------
ENTER THE VALUE
=> 2
 Maximum number of UNits per BLock= 40
Number of available UNits= 39
------------------------------------------------------------------------
Do you wish to continue entering UNits, Y/N
=> y
-------------------------------------------------------------------------
Enter the type number (or TYPES for list of types)
=> 9

Linear valve with pneumatic actuator


INPUTS


========================================================================
index for outlet water pressure
------------------------------------------------------------------------
PRESSURE
=> 3

========================================================================
index for water mass flow rate
------------------------------------------------------------------------
FLOW
=> 1

========================================================================
index for control variable from controller
------------------------------------------------------------------------
CONTROL
=> 1

========================================================================
index for actuator relative position (same as first output)
------------------------------------------------------------------------
CONTROL
=> 2
```

```
OUTPUTS


========================================================================
index for actuator relative position
------------------------------------------------------------------------
CONTROL
=> 2

========================================================================
index for inlet water pressure
------------------------------------------------------------------------
PRESSURE
=> 2

========================================================================
index for valve stem relative position
------------------------------------------------------------------------
CONTROL
=> 3

========================================================================
PARAMETER  1 flow resistance [1000/(kg m)]
------------------------------------------------------------------------
ENTER THE VALUE
=> 1.5

========================================================================
PARAMETER  2 actuator time constant (sec)
------------------------------------------------------------------------
ENTER THE VALUE
=> 5.0

========================================================================
PARAMETER  3 leakage parameter (dimensionless)
------------------------------------------------------------------------
ENTER THE VALUE
=> 0.316e-2

========================================================================
PARAMETER  4 hysteresis parameter (dimensionless)
------------------------------------------------------------------------
ENTER THE VALUE
=> 0.2
 Maximum number of UNits per BLock= 40
Number of available UNits= 38
------------------------------------------------------------------------
Do you wish to continue entering UNits, Y/N
=> n
 Maximum number of BLocks per SUperblock= 20
Number of available BLocks=19
------------------------------------------------------------------------
Do you wish to continue entering BLocks, Y/N
=> n
 Maximum number of SUperblocks per SImulation= 40
Number of available SUperblocks= 39
------------------------------------------------------------------------
Do you wish to continue entering SUperblocks, Y/N
=> n
-------------------------------------------------------------------------
Enter the title for this SImulation
=> Example1: Inlet pipe and (nominally) linear valve
 The default values for the error tolerances are as follows:
```

```
RTOLX=   0.100000E-03  ATOLX=   0.100000E-04
XTOL=    0.200000E-03  TTIME=   0.100000E+01

-----------------------------------------------------------------------
Use these default values, Y/N
=> n
------------------------------------------------------------------------
Enter RTOLX
=> 0.005
------------------------------------------------------------------------
Enter ATOLX
=> 0.1e-4
------------------------------------------------------------------------
Enter XTOL
=> 0.001
------------------------------------------------------------------------
Enter TTIME
=> 10.0
 PRES=  3 FLOW=  1 TEMP=  3 CNTR=  3 OTHR=  0 ENRG=  0 POWR=  0 AHUM=  0



Entering Variable Initial values:


ENTER PRESSURE  1             (kPa)
-----------------------------------------------------------------------

=> 33.75

ENTER PRESSURE  2             (kPa)
-----------------------------------------------------------------------

=> 3.0

ENTER PRESSURE  3             (kPa)
-----------------------------------------------------------------------

=> 0.0

ENTER FLOWRATE  1             (kg/s)
-----------------------------------------------------------------------

=> 2.0

ENTER TEMPERATURE  1             (C)
-----------------------------------------------------------------------

=> 80.0

ENTER TEMPERATURE  2             (C)
-----------------------------------------------------------------------

=> 80.0

ENTER TEMPERATURE  3             (C)
-----------------------------------------------------------------------

=> 20.0

ENTER CONTROL  1             (-)
-----------------------------------------------------------------------
```

```
=> 1.0

ENTER CONTROL  2              (-)
----------------------------------------------------------------------

=> 1.0

ENTER CONTROL  3              (-)
----------------------------------------------------------------------

=> 1.0



Entering Boundary Variables:

----------------------------------------------------------------------
Enter a PRESSURE boundary variable or CR to move on
=>
-----------------------------------------------------------------------
Enter a FLOW boundary variable or CR to move on
=>
-----------------------------------------------------------------------
Enter a TEMPERATURE boundary variable or CR to move on
=> 1
-----------------------------------------------------------------------
Enter a TEMPERATURE boundary variable or CR to move on
=>
-----------------------------------------------------------------------
Enter a CONTROL boundary variable or CR to move on
=> 1
-----------------------------------------------------------------------
Enter a CONTROL boundary variable or CR to move on
=>



Entering Reported Variables for Superblock  1


----------------------------------------------------------------------
Enter the reporting interval for this SUperblock in seconds
=> 10.0
-----------------------------------------------------------------------
Enter a PRESSURE reported variable or CR to move on
=> 2
-----------------------------------------------------------------------
Enter a PRESSURE reported variable or CR to move on
=>
-----------------------------------------------------------------------
Enter a FLOW reported variable or CR to move on
=> 1
-----------------------------------------------------------------------
Enter a TEMPERATURE reported variable or CR to move on
=> 1
-----------------------------------------------------------------------
Enter a TEMPERATURE reported variable or CR to move on
=> 2
-----------------------------------------------------------------------
Enter a TEMPERATURE reported variable or CR to move on
=>
-----------------------------------------------------------------------
```

```
Enter a CONTROL reported variable or CR to move on
=> 1
----------------------------------------------------------------------
Enter a CONTROL reported variable or CR to move on
=> 2
----------------------------------------------------------------------
Enter a CONTROL reported variable or CR to move on
=> 3
----------------------------------------------------------------------
Enter the variable freezing option for this SUperblock:  0,1,or 2.
=> 0
----------------------------------------------------------------------
Enter the variable input scan option for this SUperblock:  0 or 1.
=> 0
----------------------------------------------------------------------
Enter the filename (Maximum of 46 characters)
=> Example1
 Saving to work file....





HVACGEN - Simulation GENeration Program

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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 46 characters)
=> example1
 Reading from work file....
 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

 Save the model setup? (y/n)
y
use the default file name (viewsave.txt) (y/n)?
y

Example1: Inlet pipe and (nominally) linear valve

SUPERBLOCK 1
     BLOCK 1
         UNIT  1     TYPE  3 - Inlet conduit (duct or pipe)
         UNIT  2     TYPE  9 - Linear valve with pneumatic actuator
--------------------------------------------------

UNIT   1      TYPE   3
Inlet conduit (duct or pipe)

1     INPUTS:
       PRESSURE         1 - inlet fluid pressure
       PRESSURE         2 - outlet fluid pressure
       TEMPERATURE      1 - inlet fluid temperature
       TEMPERATURE      3 - ambient air temperature
       TEMPERATURE      2 - outlet fluid temperature (same as first output)

2     OUTPUTS:
       TEMPERATURE      2 - outlet fluid temperature (same as fifth input)
       FLOW             1 - fluid mass flow rate

3     PARAMETERS:
          16.4000     inside heat transfer coefficient x area (kW/C)
         0.170000     outside heat transfer coefficient x area (kW/C)
          25.2000     thermal capacitance of conduit material (kJ/C)
         0.150000E-01 volume (m3)
          13.5000     flow resistance [1000/(kg m)]
          0.00000     height of outlet above inlet (m)
          2.00000     mode: 2=water, 1=air, neg.=detailed, pos.=simple dynami
--------------------------------------------------

UNIT   2      TYPE   9
Linear valve with pneumatic actuator

1     INPUTS:
       PRESSURE         3 - outlet water pressure
       FLOW             1 - water mass flow rate
       CONTROL          1 - control variable from controller
       CONTROL          2 - actuator relative position (same as first output)

2     OUTPUTS:
       CONTROL          2 - actuator relative position
       PRESSURE         2 - inlet water pressure
       CONTROL          3 - valve stem relative position
```

```
3     PARAMETERS:
          1.50000     flow resistance [1000/(kg m)]
          5.00000     actuator time constant (sec)
         0.316000E-02 leakage parameter (dimensionless)
         0.200000     hysteresis parameter (dimensionless)
----------------------------------------------------
Initial Variable Values:

PRESSURE         1 ->     33.7500                (kPa)
PRESSURE         2 ->     3.00000                (kPa)
PRESSURE         3 ->     0.00000                (kPa)
FLOW             1 ->     2.00000                (kg/s)
TEMPERATURE      1 ->     80.0000                (C)
TEMPERATURE      2 ->     80.0000                (C)
TEMPERATURE      3 ->     20.0000                (C)
CONTROL          1 ->     1.00000                (-)
CONTROL          2 ->     1.00000                (-)
CONTROL          3 ->     1.00000                (-)
----------------------------------------------------
Simulation Error Tolerances:

1      RTOLX=   0.500000E-02      ATOLX=   0.100000E-04
       XTOL=    0.100000E-02      TTIME=    10.0000

SUPERBLOCK 1
2      FREEZE OPTION 0      SCAN OPTION 0
----------------------------------------------------
The following are Boundary Variables in the simulation:

TEMPERATURE     1
CONTROL         1
----------------------------------------------------
The following are the Reported Variables:


SUPERBLOCK 1      REPORTING INTERVAL    10.0000
PRESSURE         2
FLOW             1
TEMPERATURE      1
TEMPERATURE      2
CONTROL          1
CONTROL          2
CONTROL          3
-----------------------------------------------------------------------
Push the Carriage Return to continue
=>


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Version 5.0      March 9, 2007


Choose from the list below:


CReate (SImulation, BLock, UNit)

EDit (SImulation, UNit)

VIew (SImulation, BLock, UNit)

HElp
```

```
ENd

------------------------------------------------------------------------
Selection ?
=> en

Program Completed
```

Listing 3. The simulation work file of Example 1 (*example1.sim*).

```
Example1: Inlet pipe and (nominally) linear valve
   1                                               (Superblocks in simulation)
   0.500000E-02   0.100000E-04   0.100000E-02   0.100000E+02    (Error Tol.)
   1                                               (Blocks in SB# 1)
   2                                               (Units in BLK# 1)
   1   3 ----------------------------------------(Unit #,Type #)----------
    1    2    1    3    2
    2    1
   0.164000E+02   0.170000E+00   0.252000E+02   0.150000E-01   0.135000E+02
   0.000000E+00   0.200000E+01
   2   9 ----------------------------------------(Unit #,Type #)----------
    3    1    1    2
    2    2    3
   0.150000E+01   0.500000E+01   0.316000E-02   0.200000E+00
   0.337500E+02   0.300000E+01   0.000000E+00   0.200000E+01   0.800000E+02
   0.800000E+02   0.200000E+02   0.100000E+01   0.100000E+01   0.100000E+01
   2                           (Boundary Variables in simulation)
    5    8
   7   0.100000E+02     (Reported Var. & Interval in SB# 1)
    2    4    5    6    8    9   10
    1    2    3    3    4    4    4
    2    1    1    2    1    2    3
   0
   0
**************** SUMMARY OF WORK FILE ***************
   1   1   2                                       (Superblocks, Blocks, Units)
   1
   3   1   3   3   0   0   0   0                   (Variables per category)
  10                                               (State Variables)
   7
```

4.2.2 Model definition file (*hvacsim.dfn*)

Execute SLIMCON to create the model definition file with the simulation work file (*hvacsim.sim*) and *typar.dat*. In this example run, select the default option (“no”) in response to the question of whether to allow algebraic variables as inputs and outputs of the same units. **Listing 4** is the display on the monitor screen of the SLIMCON run. The model definition file of Example 1 is shown in **Listing 5**.

Listing 4. SLIMCON run to create the model definition file.

```
C:\HVACSIM20\WORK>slimcon
 ---------------------------------------------------------
 *                                                       *
 *                    SLIMCON                            *
 *                                                       *
 * Converts simulation work file to model definition file *
 *             Version 6.0 ( April 10, 2007)             *
 *                                                       *
 ---------------------------------------------------------
 Enter the simulation file name (up to 46 characters)
 without any extension, or carriage return to end.
=> example1
 Do you want to allow algebraic variables to be inputs
  and outputs of the same unit? (y/n) (default= no)
=>
----------------------------------------
 iu  itype nsaved iude nnin nnout nnpar
----------------------------------------
   1    3     11    1    5    2    7
   2    9      5    1    4    3    4

                   ========= SLIMCON SUMMARY ==========

             1 Superblocks in the simulation .......... maxsbk =  40 (  2.5%)
             1 Blocks in the simulation ............... maxblk =  50 (  2.0%)
             1 Differential equations in the simulation maxdeq =  90 (  1.1%)
            16 Saved variables in the simulation ...... maxsav =9000 (  0.2%)
             2 Units in the simulation ................ maxunt = 400 (  0.5%)
             2 Units in a single block ................ muntib =  40 (  5.0%)
             1 Differential equations in one unit ..... mdeqiu =  10 ( 10.0%)
             5 Inputs or outputs in a single unit ..... minoiu =  50 ( 10.0%)
             7 Parameters in a single unit ............ mpariu =  30 ( 23.3%)
             1 Blocks in the largest superblock ....... mblkis =  20 (  5.0%)
             1 Differential equations in one superblock mdeqis =  50 (  2.0%)
            10 State variables in the simulation ...... maxstv =3000 (  0.3%)
             9 Inputs or outputs in a single block .... minoib = 200 (  4.5%)
            11 Unit parameters in the simulation ...... maxpar =5000 (  0.2%)
             3 Simultaneous equations in a single block mseqib =  75 (  4.0%)
             0 Simultaneous equations in one superblock mseqis =  20 (  0.0%)
             2 Time dependent boundary variables ...... maxbnd =  50 (  4.0%)
             2 Boundary conditions in one superblock .. mbndis =  50 (  4.0%)
             7 Reported variables in one superblock ... mrptis =  60 ( 11.7%)

Model definition file completed
Program Completed
```

Listing 5. The model definition file of Example 1 (*example1.dfn*).

```
title: simulation title
 Example1: Inlet pipe and (nominally) linear valve
 nstate,nsblok: # of state variables, # of SBS
   10    1
 nsuper(s): # of blocks in each SB
    1
 state(i): vector of state variable initial values
   0.337500E+02   0.300000E+01   0.000000E+00   0.200000E+01   0.800000E+02
   0.800000E+02   0.200000E+02   0.100000E+01   0.100000E+01   0.100000E+01
 ndent(i): state variable identification vector
    0    3    4    7   -1   -1   -1   -1
 nunits(b): # of units in each block B
    2
 njsslv(s): # of simultaneous eqs in each SB
    0
 njsolv(b): # of simultaneqou eqs in each block
    3
 isuper(s,i): array of block numbers in each SB
    1
 iblock(b,i): array of unit numbers in each block
    1    2
 iunits(u): array of type #s for each unit
    3    9
 nin(u): number of inputs to unit u
    5    4
 in(u,i): array of input connections for unit U
    1    2    5    7    6
    3    4    8    9
 nout(u): number of outputs from unit U
    2    3
 iout(u,i): array of output connections for unit U
    6    4
    9    2   10
 jssolv(s,i): array of variables solved
  simultaneously within each sb (between blocks)
    0
 jsolve(b,i): array of variables solved
  simultaneously within each block
    9    2    4
 nde(u): # of differential eqs in unit U
    0    1
 inde(u,i): de index for the ith de in unit U
    0
    1
 idevar(d): variable index for de #d
    9
 isaved(u): index of first saved var. for unit U
    1   12
 jpar(u): index of first parameter for unit U
    1    8
 npar,nsaved: # of parameters & saved variables
   11   16
 par(i): array of parameters for all units
   0.164000E+02   0.170000E+00   0.252000E+02   0.150000E-01   0.135000E+02
```

```
   0.000000E+00   0.200000E+01   0.150000E+01   0.500000E+01   0.316000E-02
   0.200000E+00
 nbound: # of time-dependent boundary variables
    2
 ibound(i) state variable indices of boundary variables.
    5    8
 nreprt(s): # of reported variables in each SB
    7
 treprt(s): reporting interval for each SB
   0.100000E+02
 ireprt(i): indices of reported variables
 ident1: category # of reported variables
 ident2: position in category of reported variables
    2    4    5    6    8    9   10
    1    2    3    3    4    4    4
    2    1    1    2    1    2    3
 rtolx,atolx, xtol,ttime: error tolerances
   0.500000E-02   0.100000E-04   0.100000E-02   0.100000E+02
 ifzopt(s): sb variable unfreezing option vector
    0
 insopt(s): sb input scan option vector
    0
```

4.2.3 Boundary data file (*hvacsim.bnd*)

A text editor can be used to create the *boundary* data file. The first column must be time in seconds, and the other columns are the values of *boundary* variables. These were previously defined as boundary variables in the simulation work file by HVACGEN. Since a third order Lagrangian interpolation method is used, the time intervals need not be equal. To produce a step change in *boundary* variables, two different values must be provided at the same time. This signals resetting the simulation time step to a minimum value. At least three regular records have to be given between reset record pairs. Because a simulation begins at time zero, the time of the first record of the *boundary* data file must be zero. Even if no boundary data is required in a simulation, the data file with null values must be provided. Whether used or not, a *boundary* data file must be available to MODSIM. **Listing 6** shows the *boundary* data file of Example 1. The first, the second, and the third columns are time, T1, and c1, respectively.

Listing 6. The boundary data file of Example 1 (*example1.bnd*).

```
  0., 80., 1.00
 20., 80., 1.00
 27., 80., 1.00
 30., 80., 1.00
 30., 80.  0.85
 35., 80., 0.85
 40., 80., 0.70
 45., 80., 0.55
 50., 80., 0.40
 55., 80., 0.25
 55., 80.  0.1
```

```
 60., 80., 0.10
 80., 80., 0.10
100., 80., 0.10
120., 80., 0.10
150., 80., 0.10
150., 80., 0.25
155., 80., 0.25
160., 80., 0.40
165., 80., 0.55
170., 80., 0.70
175., 80., 0.85
180., 80., 0.85
180., 80., 1.00
190., 80., 1.0
200., 80., 1.0
210., 80., 1.0
210., 75., 1.0
220., 75., 1.0
230., 75., 1.0
255., 75., 1.0
255., 80., 1.0
270., 80., 1.0
300., 80., 1.0
450., 80., 1.0
600., 80., 1.0
```

4.3 Creating a Model Information File

Although it is not required to create a model information file (*hvacsim.model*) in a simulation run, the model information file is a quite helpful document file, when a large number of component models are involved, especially if different *units* use the same *type* of component model. The UPD_INFO program uses two input data files to produce the model information file. One of them is the HVACGEN output file (*viewsave.txt*) that is created when the *view all* command is used. The other is the supplemental unit information file (*hvacsim.inf*) which is generated by the user using a text editor entering *unit* numbers and supplemental information of the *units*. **Listings 7** and **8** show *viewsave.txt* and *hvacsim.inf*. **Listings 9** and **10** show the interactive session of running UPD_INFO and the model information file, respectively.

Listing 7. The HVACGEN output file (*viewsave.txt*) created by using the command, view all

```
Example1: Inlet pipe and (nominally) linear valve

 SUPERBLOCK 1
      BLOCK 1
          UNIT  1     TYPE  3 - Inlet conduit (duct or pipe)
          UNIT  2     TYPE  9 - Linear valve with pneumatic actuator

 UNIT   1      TYPE   3
 Inlet conduit (duct or pipe)

 1     INPUTS:
        PRESSURE         1 - inlet fluid pressure
        PRESSURE         2 - outlet fluid pressure
        TEMPERATURE      1 - inlet fluid temperature
        TEMPERATURE      3 - ambient air temperature
```

```
       TEMPERATURE      2 - outlet fluid temperature (same as first output)

2     OUTPUTS:
       TEMPERATURE      2 - outlet fluid temperature (same as fifth input)
       FLOW             1 - fluid mass flow rate

3     PARAMETERS:
          16.4000     inside heat transfer coefficient x area (kW/C)
         0.170000     outside heat transfer coefficient x area (kW/C)
          25.2000     thermal capacitance of conduit material (kJ/C)
         0.150000E-01 volume (m3)
          13.5000     flow resistance [1000/(kg m)]
          0.00000     height of outlet above inlet (m)
          2.00000     mode: 2=water, 1=air, neg.=detailed, pos.=simple dynami

UNIT   2      TYPE   9
Linear valve with pneumatic actuator

1     INPUTS:
       PRESSURE         3 - outlet water pressure
       FLOW             1 - water mass flow rate
       CONTROL          1 - control variable from controller
       CONTROL          2 - actuator relative position (same as first output)

2     OUTPUTS:
       CONTROL          2 - actuator relative position
       PRESSURE         2 - inlet water pressure
       CONTROL          3 - valve stem relative position

3     PARAMETERS:
          1.50000     flow resistance [1000/(kg m)]
          5.00000     actuator time constant (sec)
         0.316000E-02 leakage parameter (dimensionless)
         0.200000     hysteresis parameter (dimensionless)
Initial Variable Values:

PRESSURE         1 ->     33.7500                (kPa)
PRESSURE         2 ->     3.00000                (kPa)
PRESSURE         3 ->     0.00000                (kPa)
FLOW             1 ->     2.00000                (kg/s)
TEMPERATURE      1 ->     80.0000                (C)
TEMPERATURE      2 ->     80.0000                (C)
TEMPERATURE      3 ->     20.0000                (C)
CONTROL          1 ->     1.00000                (-)
CONTROL          2 ->     1.00000                (-)
CONTROL          3 ->     1.00000                (-)
Simulation Error Tolerances:

1      RTOLX=   0.500000E-02      ATOLX=   0.100000E-04
       XTOL=    0.100000E-02      TTIME=    10.0000

SUPERBLOCK 1
2      FREEZE OPTION 0      SCAN OPTION 0
The following are Boundary Variables in the simulation:

TEMPERATURE     1
CONTROL         1

SUPERBLOCK 1      REPORTING INTERVAL    10.0000
PRESSURE         2
FLOW             1
TEMPERATURE      1
TEMPERATURE      2
CONTROL          1
CONTROL          2
CONTROL          3
```

Listing 8. Supplemental unit information file (*example1.inf*)

```
1 Water inlet pipe
2 Water valve
```

Listing 9. Interactive session of running UPD_INFO

```
C:\HVACSIM20\WORK>upd_info
 Enter the name of view output file of HVACGEN (viewsave.txt)
=> viewsave.txt
  Enter the supplemental unit information file (hvacsim.inf)
=> example1.inf
  Enter the name of model information file (hvacsim.model)
=> example1.model
 Line No.  9
----- matched data ----
Line No.  32
----- matched data ----
End of file
```

Listing 10. The model information file (*example1.model*)

```
Example1: Inlet pipe and (nominally) linear valve

 SUPERBLOCK 1
      BLOCK 1
          UNIT  1     TYPE  3 - Inlet conduit (duct or pipe)
          UNIT  2     TYPE  9 - Linear valve with pneumatic actuator

 UNIT   1      TYPE   3 ----- Water inlet pipe
 Inlet conduit (duct or pipe)

 1     INPUTS:
        PRESSURE         1 - inlet fluid pressure
        PRESSURE         2 - outlet fluid pressure
        TEMPERATURE      1 - inlet fluid temperature
        TEMPERATURE      3 - ambient air temperature
        TEMPERATURE      2 - outlet fluid temperature (same as first output)

 2     OUTPUTS:
        TEMPERATURE      2 - outlet fluid temperature (same as fifth input)
        FLOW             1 - fluid mass flow rate

 3     PARAMETERS:
           16.4000     inside heat transfer coefficient x area (kW/C)
          0.170000     outside heat transfer coefficient x area (kW/C)
           25.2000     thermal capacitance of conduit material (kJ/C)
          0.150000E-01 volume (m3)
           13.5000     flow resistance [1000/(kg m)]
           0.00000     height of outlet above inlet (m)
           2.00000     mode: 2=water, 1=air, neg.=detailed, pos.=simple dynami

 UNIT   2      TYPE   9 ----- Water valve
 Linear valve with pneumatic actuator

 1     INPUTS:
```

```
       PRESSURE          3 - outlet water pressure
       FLOW              1 - water mass flow rate
       CONTROL           1 - control variable from controller
       CONTROL           2 - actuator relative position (same as first output)

2     OUTPUTS:
       CONTROL           2 - actuator relative position
       PRESSURE          2 - inlet water pressure
       CONTROL           3 - valve stem relative position

3     PARAMETERS:
          1.50000     flow resistance [1000/(kg m)]
          5.00000     actuator time constant (sec)
         0.316000E-02 leakage parameter (dimensionless)
         0.200000     hysteresis parameter (dimensionless)
Initial Variable Values:

PRESSURE         1 ->     33.7500                (kPa)
PRESSURE         2 ->     3.00000                (kPa)
PRESSURE         3 ->     0.00000                (kPa)
FLOW             1 ->     2.00000                (kg/s)
TEMPERATURE      1 ->     80.0000                (C)
TEMPERATURE      2 ->     80.0000                (C)
TEMPERATURE      3 ->     20.0000                (C)
CONTROL          1 ->     1.00000                (-)
CONTROL          2 ->     1.00000                (-)
CONTROL          3 ->     1.00000                (-)
Simulation Error Tolerances:

1      RTOLX=   0.500000E-02      ATOLX=   0.100000E-04
       XTOL=    0.100000E-02      TTIME=    10.0000

SUPERBLOCK 1
2      FREEZE OPTION 0      SCAN OPTION 0
The following are Boundary Variables in the simulation:

TEMPERATURE     1
CONTROL         1

SUPERBLOCK 1      REPORTING INTERVAL    10.0000
PRESSURE         2
FLOW             1
TEMPERATURE      1
TEMPERATURE      2
CONTROL          1
CONTROL          2
CONTROL          3
```

4.4 System Simulation using MODSIM

Execution of MODSIM can be done using either the interactive approach or a batch job using a redirecting method. A minimum time step, a maximum time step, and a stopping time for the simulation must be entered. In running Example 1, the default can be chosen for most of the questions. Viewing diagnostic information or monitoring the progress of simulation on a computer terminal screen may not be practical due to fast scrolling rates of recent high speed computers. **Listings 11, 12, 13,** and **14** show the interactive session of MODSIM, the final *state* variable file (*hvacsim.fin*), the simulation summary file (*hvacsim.sum*), and the simulation output file (*hvacsim.out*), respectively. Note that 'example1' is used in place of '*hvacsim*' for the body of file name in listings.

Batch processing can be done by redirecting the simulation control input data file (*example1.inp*), which is shown in **Listing 15.**

modsim < example1.inp

When a simulation stops after reaching the stopping time, the simulation can be continued by using the final *state* variable file (*hvacsim.fin*), which stores the *state* variable vector at the end of simulation time. Before proceeding with such a continuation, the file *hvacsim.fin* should be renamed as *hvacsim.ini*, which becomes the initialization file.

One shortcoming of using the initialization file is that the starting time of simulation is zero. Thus the beginning time of a *boundary* variable file should be zero. If possible, refrain from using the continuation method, as accuracy may suffer.

Listing 11. Interactive session of MODSIM

```
C:\HVACSIM20\WORK>modsim

       *************************************************
       *                                               *
       *   MODSIM   : A MODular SIMulation program     *
       *      Main program of HVACSIM+ package         *
       *                                               *
       *                 version 20.0                  *
       *                                               *
       * National Institute of Standards & Technology  *
       *   Gaithersburg, Maryland 20899-8631  U.S.A.   *
       *                                               *
       *************************************************


 Enter minimum time step, maximum time step, and simulation stopping time:
=> 0.1 60.0 300.0
  Is the building shell model used? <n>
=> n
  Will the initialization file be called? <n>
=> n
 Use same file names for all files? (y/n) <y>
=> y
 Enter the name for all files to open or
hit carriage return for default filename <hvacsim>
=> example1

      File name : example1.dfn

      File name : example1.bnd

      File name : example1.fin

      File name : example1.out

      File name : example1.sum
  -- The outputs can be written to the output file
```

```
  -- based on either simulation time or reported time.

 Do you want to use reported time for outputs <n>?
=> n

 Do you wish to disable freezing variable feature <n>?
=> n

 Do you want diagnostic information to be written <n>?
=> n
 Would you like to monitor simulation on screen? <n>
=> n
   ------- simulation begins ---------
time=     10.00
time=     20.00
time=     30.00
time=     40.00
time=     50.00
time=     60.00
time=     70.00
time=     80.00
time=     90.00
time=    100.00
time=    110.00
time=    120.00
time=    130.00
time=    140.00
time=    150.00
time=    160.00
time=    170.00
time=    180.00
time=    190.00
time=    200.00
time=    210.00
time=    220.00
time=    230.00
time=    240.00
time=    250.00
time=    260.00
time=    270.00
time=    280.00
time=    290.00
time=    300.00
 --Final state file has been written -----
   ------------End of simulation ---------
Program Completed
```

Listing 12. The final state file (*example1.fin*).

```
      0.10      60.00     300.00     300.00    10    16
    33.7500         3.38531         0.00000         1.49917         80.0000
    78.4110         20.0000         1.00000        0.997666        0.997915
  1 -1  1  1  1  1  1  1 -1  1
    78.4030         0.00000         0.00000         0.00000         0.00000
    0.00000         78.4110         1.94967         300.000         78.4030
    78.4110        0.798332        0.798332         300.000        0.997666
    0.00000
```

Listing 13. The simulation summary file (*example1.sum*).

```
         ***** Program MODSIM *****
       A MODular SIMulation program

Example1: Inlet pipe and (nominally) linear valve

 1 superblocks       1 blocks        2 units

  10 state variables:
   3 pres    1 flow    3 temp    3 ctrl

initial state vector:

 pres:
     33.7500        3.00000        0.00000

 flow:
     2.00000

 temp:
     80.0000        80.0000        20.0000

 ctrl:
     1.00000        1.00000        1.00000

 2 time dependent boundary variables:
temp  1   ctrl  1

error tolerances:  rtolx, atolx, xtol, ttime:
    5.00000E-03    1.00000E-05    1.00000E-03     10.000

***** superblock  1 *****

 superblock simultaneous equation unfreezing option, ifzopt =  0
 superblock input scan option, insopt =  0

 7 reported variables:
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3

 0 simultaneous equations; variables:

***** block  1 *****

 3 simultaneous equations; variables:
ctrl  2   pres  2   flow  1

unit   1     type  3

  5 inputs:
pres  1   pres  2   temp  1   temp  3   temp  2

  2 outputs:
temp  2   flow  1

parameters:
     16.400        0.17000         25.200        1.50000E-02     13.500
     0.0000         2.0000

unit   2     type  9

  4 inputs:
pres  3   flow  1   ctrl  1   ctrl  2

  3 outputs:
ctrl  2   pres  2   ctrl  3

parameters:
```

```
     1.5000         5.0000        3.16000E-03    0.20000

-----------------------------------------------------------
tmin =       0.100  tmax =      60.000  tstop =     300.000
-----------------------------------------------------------


********** SUPERBLOCK  1 **********
time=     10.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.38      1.50      80.0      79.5      1.00      1.00      1.00

********** SUPERBLOCK  1 **********
time=     20.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.38      1.50      80.0      78.8      1.00      1.00      1.00

********** SUPERBLOCK  1 **********
time=     30.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.38      1.50      80.0      78.4      1.00      1.00      1.00

********** SUPERBLOCK  1 **********
time=     40.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.38      1.50      80.0      78.4     0.700     0.825      1.00

********** SUPERBLOCK  1 **********
time=     50.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  6.64      1.42      80.0      78.4     0.400     0.547     0.683

********** SUPERBLOCK  1 **********
time=     60.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  20.6     0.985      80.0      78.4     0.100     0.211     0.264

********** SUPERBLOCK  1 **********
time=     70.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  28.3     0.636      80.0      78.3     0.100     0.115     0.144

********** SUPERBLOCK  1 **********
time=     80.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  29.3     0.575      80.0      78.1     0.100     0.102     0.127

********** SUPERBLOCK  1 **********
time=     90.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  29.4     0.569      80.0      77.6     0.100     0.101     0.126

********** SUPERBLOCK  1 **********
time=    100.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  29.4     0.567      80.0      76.8     0.100     0.100     0.125

********** SUPERBLOCK  1 **********
time=    110.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  29.4     0.567      80.0      76.3     0.100     0.100     0.125

********** SUPERBLOCK  1 **********
time=    120.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  29.4     0.567      80.0      76.1     0.100     0.100     0.125

********** SUPERBLOCK  1 **********
time=    130.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  29.4     0.567      80.0      76.0     0.100     0.100     0.125
```

```
********** SUPERBLOCK  1 **********
time=    140.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  29.4     0.567      80.0      75.9     0.100     0.100     0.125

********** SUPERBLOCK  1 **********
time=    150.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  29.4     0.567      80.0      75.9     0.100     0.100     0.125

********** SUPERBLOCK  1 **********
time=    160.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  29.1     0.582      80.0      75.9     0.399     0.277     0.130

********** SUPERBLOCK  1 **********
time=    170.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  12.3      1.26      80.0      75.9     0.703     0.555     0.444

********** SUPERBLOCK  1 **********
time=    180.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  5.48      1.45      80.0      77.4     0.850     0.805     0.756

********** SUPERBLOCK  1 **********
time=    190.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.58      1.49      80.0      78.3      1.00     0.974     0.967

********** SUPERBLOCK  1 **********
time=    200.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.41      1.50      80.0      78.4      1.00     0.995     0.994

********** SUPERBLOCK  1 **********
time=    210.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.39      1.50      80.0      78.4      1.00     0.998     0.998

********** SUPERBLOCK  1 **********
time=    220.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.39      1.50      75.0      77.1      1.00     0.998     0.998

********** SUPERBLOCK  1 **********
time=    230.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.39      1.50      75.0      74.6      1.00     0.998     0.998

********** SUPERBLOCK  1 **********
time=    240.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.39      1.50      75.0      73.5      1.00     0.998     0.998

********** SUPERBLOCK  1 **********
time=    250.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.39      1.50      75.0      73.5      1.00     0.998     0.998

********** SUPERBLOCK  1 **********
time=    260.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.39      1.50      80.0      73.5      1.00     0.998     0.998

********** SUPERBLOCK  1 **********
time=    270.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.39      1.50      80.0      76.4      1.00     0.998     0.998
```

```
********** SUPERBLOCK  1 **********
time=    280.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.39      1.50      80.0      78.3      1.00     0.998     0.998

********** SUPERBLOCK  1 **********
time=    290.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.39      1.50      80.0      78.4      1.00     0.998     0.998

********** SUPERBLOCK  1 **********
time=    300.00
pres  2   flow  1   temp  1   temp  2   ctrl  1   ctrl  2   ctrl  3
  3.39      1.50      80.0      78.4      1.00      0.998     0.998
```

Listing 14. The simulation output file (*example1.out*).

```
SUPERBLOCK 1      0.10
    3.37500       1.50000       80.0000       79.9606        1.00000
    1.00000       1.00000
SUPERBLOCK 1      0.30
    3.37500       1.50000       80.0000       79.9606        1.00000
    1.00000       1.00000
SUPERBLOCK 1      0.70
    3.37500       1.50000       80.0000       79.9366        1.00000
    1.00000       1.00000
SUPERBLOCK 1      1.50
    3.37500       1.50000       80.0000       79.9524        1.00000
    1.00000       1.00000
SUPERBLOCK 1      3.10
    3.37500       1.50000       80.0000       79.9768        1.00000
    1.00000       1.00000
SUPERBLOCK 1      6.30
    3.37500       1.50000       80.0000       79.9692        1.00000
    1.00000       1.00000
SUPERBLOCK 1     12.70
    3.37500       1.50000       80.0000       79.2213        1.00000
    1.00000       1.00000
SUPERBLOCK 1     25.50
    3.37500       1.50000       80.0000       78.4139        1.00000
    1.00000       1.00000
SUPERBLOCK 1     30.00
    3.37500       1.50000       80.0000       78.4139        1.00000
    1.00000       1.00000
SUPERBLOCK 1     30.10
    3.37500       1.50000       80.0000       78.4139       0.852440
   0.997107       1.00000
SUPERBLOCK 1     30.20
    3.37500       1.50000       80.0000       78.4139       0.854762
   0.996802       1.00000
SUPERBLOCK 1     30.30
    3.37500       1.50000       80.0000       78.4139       0.856965
   0.994060       1.00000
SUPERBLOCK 1     30.40
    3.37500       1.50000       80.0000       78.4139       0.859053
   0.991413       1.00000
SUPERBLOCK 1     30.50
    3.37500       1.50000       80.0000       78.4139       0.861025
   0.988857       1.00000
SUPERBLOCK 1     31.10
    3.37500       1.50000       80.0000       78.4139       0.870506
   0.975023       1.00000
SUPERBLOCK 1     31.60
    3.37500       1.50000       80.0000       78.4139       0.875459
   0.965248       1.00000
SUPERBLOCK 1     32.40
    3.37500       1.50000       80.0000       78.4139       0.878205
```

```
   0.951982       1.00000
SUPERBLOCK 1     33.10
    3.37500       1.50000       80.0000       78.4139       0.875798
   0.941972       1.00000
SUPERBLOCK 1     34.30
    3.37500       1.50000       80.0000       78.4139       0.862461
   0.926426       1.00000
SUPERBLOCK 1     36.00
    3.37500       1.50000       80.0000       78.4139       0.827200
   0.903328       1.00000
SUPERBLOCK 1     38.30
    3.37500       1.50000       80.0000       78.4139       0.758517
   0.863247       1.00000
SUPERBLOCK 1     40.00
    3.37500       1.50000       80.0000       78.4139       0.700000
   0.825018       1.00000
SUPERBLOCK 1     41.50
    3.48732       1.50000       80.0000       78.4119       0.655000
   0.786971      0.983713
SUPERBLOCK 1     43.60
    3.97193       1.48519       80.0000       78.4116       0.592000
   0.729936      0.912420
SUPERBLOCK 1     45.50
    4.53352       1.47112       80.0000       78.4116       0.535000
   0.676573      0.845716
SUPERBLOCK 1     47.80
    5.39437       1.44928       80.0000       78.4116       0.466000
   0.610792      0.763490
SUPERBLOCK 1     52.30
    7.94552       1.38255       80.0000       78.4099       0.331000
   0.479555      0.599444
SUPERBLOCK 1     55.00
    10.3591       1.31630       80.0000       78.4022       0.250000
   0.399444      0.499305
SUPERBLOCK 1     55.10
    10.5716       1.31031       80.0000       78.4019       0.100000
   0.393572      0.491965
SUPERBLOCK 1     55.20
    10.7853       1.30426       80.0000       78.4016       0.100000
   0.387816      0.484770
SUPERBLOCK 1     55.30
    11.0002       1.29814       80.0000       78.4012       0.100000
   0.382173      0.477716
SUPERBLOCK 1     55.80
    12.0949       1.26653       80.0000       78.3991       0.100000
   0.355415      0.444269
SUPERBLOCK 1     56.10
    12.7612       1.24689       80.0000       78.3972       0.100000
   0.340540      0.425675
SUPERBLOCK 1     56.70
    14.0993       1.20650       80.0000       78.3938       0.100000
   0.313284      0.391605
SUPERBLOCK 1     57.40
    15.6423       1.15818       80.0000       78.3899       0.100000
   0.285292      0.356616
SUPERBLOCK 1     58.40
    17.7391       1.08903       80.0000       78.3850       0.100000
   0.251611      0.314514
SUPERBLOCK 1     59.40
    19.6454       1.02214       80.0000       78.3797       0.100000
   0.224133      0.280167
SUPERBLOCK 1     60.90
    22.0698      0.930142       80.0000       78.3706       0.100000
   0.192075      0.240094
SUPERBLOCK 1     62.30
    23.8568      0.856041       80.0000       78.3593       0.100000
   0.169732      0.212165
SUPERBLOCK 1     63.50
    25.0635      0.802146       80.0000       78.3501       0.100000
   0.154951      0.193689
SUPERBLOCK 1     65.20
```

```
    26.3568       0.740024        80.0000        78.3355       0.100000
   0.139146       0.173933
SUPERBLOCK 1     67.30
    27.4476       0.683256        80.0000        78.3165       0.100000
   0.125652       0.157065
SUPERBLOCK 1     69.70
    28.2296       0.639470        80.0000        78.2981       0.100000
   0.115763       0.144704
SUPERBLOCK 1     71.80
    28.6536       0.614458        80.0000        78.2802       0.100000
   0.110289       0.137861
SUPERBLOCK 1     73.90
    28.9249       0.597853        80.0000        78.2557       0.100000
   0.106725       0.133406
SUPERBLOCK 1     76.40
    29.1259       0.585263        80.0000        78.2130       0.100000
   0.104055       0.130069
SUPERBLOCK 1     79.60
    29.2717       0.575958        80.0000        78.1315       0.100000
   0.102099       0.127624
SUPERBLOCK 1     83.40
    29.3595       0.570281        80.0000        77.9810       0.100000
   0.100913       0.126141
SUPERBLOCK 1     87.40
    29.3595       0.570281        80.0000        77.7481       0.100000
   0.100967       0.126141
SUPERBLOCK 1     88.50
    29.3595       0.570281        80.0000        77.6728       0.100000
   0.100793       0.126141
SUPERBLOCK 1     89.10
    29.3746       0.569299        80.0000        77.6294       0.100000
   0.100708       0.126141
SUPERBLOCK 1     90.30
    29.3847       0.568641        80.0000        77.5385       0.100000
   0.100571       0.125714
SUPERBLOCK 1     92.10
    29.3971       0.567835        80.0000        77.3956       0.100000
   0.100403       0.125714
SUPERBLOCK 1     95.70
    29.4130       0.566800        80.0000        77.1037       0.100000
   0.100188       0.125235
SUPERBLOCK 1    102.90
    29.4130       0.566800        80.0000        76.5920       0.100000
   0.100188       0.125235
SUPERBLOCK 1    117.30
    29.4130       0.566800        80.0000        76.0812       0.100000
   0.100188       0.125235
SUPERBLOCK 1    146.10
    29.4130       0.566800        80.0000        75.8878       0.100000
   0.100188       0.125235
SUPERBLOCK 1    150.00
    29.4130       0.566800        80.0000        75.8878       0.100000
   0.100188       0.125235
SUPERBLOCK 1    150.10
    29.4130       0.566800        80.0000        75.8878       0.247560
   0.101935       0.125235
SUPERBLOCK 1    150.20
    29.4130       0.566800        80.0000        75.8878       0.245238
   0.102242       0.125235
SUPERBLOCK 1    150.30
    29.4130       0.566800        80.0000        75.8878       0.243035
   0.105002       0.125235
SUPERBLOCK 1    150.40
    29.4130       0.566800        80.0000        75.8878       0.240947
   0.107668       0.125235
SUPERBLOCK 1    150.50
    29.4130       0.566800        80.0000        75.8878       0.238975
   0.110243       0.125235
SUPERBLOCK 1    150.60
    29.4130       0.566800        80.0000        75.8878       0.237117
   0.112730       0.125235
```

```
SUPERBLOCK 1    150.70
    29.4130       0.566800        80.0000        75.8878       0.235371
   0.115135       0.125235
SUPERBLOCK 1    150.80
    29.4130       0.566800        80.0000        75.8878       0.233738
   0.117461       0.125235
SUPERBLOCK 1    150.90
    29.4130       0.566800        80.0000        75.8878       0.232214
   0.119711       0.125235
SUPERBLOCK 1    151.00
    29.4130       0.566800        80.0000        75.8878       0.230800
   0.121889       0.125235
SUPERBLOCK 1    151.10
    29.4130       0.566800        80.0000        75.8878       0.229494
   0.123999       0.125235
SUPERBLOCK 1    151.20
    29.4130       0.566800        80.0000        75.8878       0.228294
   0.126044       0.125235
SUPERBLOCK 1    151.30
    29.4130       0.566800        80.0000        75.8878       0.227201
   0.128027       0.125235
SUPERBLOCK 1    151.40
    29.4130       0.566800        80.0000        75.8878       0.226211
   0.129952       0.125235
SUPERBLOCK 1    151.50
    29.4130       0.566800        80.0000        75.8878       0.225325
   0.131822       0.125235
SUPERBLOCK 1    151.60
    29.4130       0.566800        80.0000        75.8878       0.224541
   0.133640       0.125235
SUPERBLOCK 1    151.70
    29.4130       0.566800        80.0000        75.8878       0.223857
   0.135409       0.125235
SUPERBLOCK 1    151.80
    29.4130       0.566800        80.0000        75.8878       0.223274
   0.137132       0.125235
SUPERBLOCK 1    151.90
    29.4130       0.566800        80.0000        75.8878       0.222788
   0.138812       0.125235
SUPERBLOCK 1    152.00
    29.4130       0.566800        80.0000        75.8878       0.222400
   0.140451       0.125235
SUPERBLOCK 1    152.20
    29.4130       0.566800        80.0000        75.8878       0.221910
   0.143640       0.125235
SUPERBLOCK 1    152.30
    29.4130       0.566800        80.0000        75.8878       0.221807
   0.145188       0.125235
SUPERBLOCK 1    152.60
    29.4130       0.566800        80.0000        75.8878       0.222045
   0.149660       0.125235
SUPERBLOCK 1    153.10
    29.4130       0.566800        80.0000        75.8878       0.224202
   0.156682       0.125235
SUPERBLOCK 1    153.60
    29.4130       0.566800        80.0000        75.8878       0.228429
   0.163323       0.125235
SUPERBLOCK 1    154.10
    29.4130       0.566800        80.0000        75.8878       0.234576
   0.169805       0.125235
SUPERBLOCK 1    154.80
    29.4130       0.566800        80.0000        75.8878       0.246122
   0.178987       0.125235
SUPERBLOCK 1    155.90
    29.4130       0.566800        80.0000        75.8878       0.270284
   0.194543       0.125235
SUPERBLOCK 1    156.90
    29.4130       0.566800        80.0000        75.8878       0.297458
   0.210672       0.125235
SUPERBLOCK 1    158.10
    29.4130       0.566800        80.0000        75.8878       0.334872
```

```
   0.233219      0.125235
SUPERBLOCK 1    159.80
    29.4130      0.566800        80.0000        75.8878       0.393002
   0.271329      0.125235
SUPERBLOCK 1    163.20
    24.5194      0.826888        80.0000        75.8878       0.496000
   0.361601      0.202001
SUPERBLOCK 1    163.60
    23.6369      0.865517        80.0000        75.8970       0.508000
   0.372445      0.215556
SUPERBLOCK 1    163.80
    23.1975      0.884113        80.0000        75.8900       0.514000
   0.377889      0.222362
SUPERBLOCK 1    164.80
    21.0255      0.970845        80.0000        75.8729       0.544000
   0.405575      0.256968
SUPERBLOCK 1    165.90
    18.7768       1.05314        80.0000        75.8809       0.577000
   0.436349      0.295437
SUPERBLOCK 1    166.30
    18.0042       1.07997        80.0000        75.8849       0.589000
   0.447634      0.309542
SUPERBLOCK 1    167.10
    16.5391       1.12911        80.0000        75.8916       0.613000
   0.470355      0.337944
SUPERBLOCK 1    168.70
    13.9426       1.21128        80.0000        75.8926       0.661000
   0.516312      0.395391
SUPERBLOCK 1    171.90
    9.92581       1.32844        80.0000        75.9006       0.765128
   0.611913      0.514891
SUPERBLOCK 1    175.10
    7.31415       1.39936        80.0000        76.2934       0.851970
   0.706042      0.632553
SUPERBLOCK 1    177.20
    6.24037       1.42750        80.0000        76.7936       0.877350
   0.759133      0.698917
SUPERBLOCK 1    178.50
    5.79402       1.43903        80.0000        77.0921       0.874675
   0.785076      0.731345
SUPERBLOCK 1    180.00
    5.48100       1.44707        80.0000        77.4197       0.850000
   0.804995      0.756244
SUPERBLOCK 1    180.10
    5.42364       1.44853        80.0000        77.4377        1.00000
   0.808819      0.761023
SUPERBLOCK 1    180.20
    5.35774       1.44853        80.0000        77.4552        1.00000
   0.812567      0.765709
SUPERBLOCK 1    180.30
    5.29428       1.44853        80.0000        77.4724        1.00000
   0.816242      0.770303
SUPERBLOCK 1    181.20
    4.90151       1.46182        80.0000        77.6115        1.00000
   0.846456      0.808071
SUPERBLOCK 1    182.10
    4.58799       1.46974        80.0000        77.7280        1.00000
   0.871900      0.839875
SUPERBLOCK 1    183.40
    4.25661       1.47807        80.0000        77.8679        1.00000
   0.901627      0.877034
SUPERBLOCK 1    184.70
    4.02341       1.48390        80.0000        77.9840        1.00000
   0.924605      0.905756
SUPERBLOCK 1    187.10
    3.75471       1.49059        80.0000        78.1438        1.00000
   0.953568      0.941960
SUPERBLOCK 1    190.00
    3.58432       1.49482        80.0000        78.2528        1.00000
   0.973526      0.966908
SUPERBLOCK 1    193.90
```

```
    3.46619        1.49482        80.0000        78.3333        1.00000
   0.986639       0.983299
SUPERBLOCK 1    197.30
    3.43432        1.49853        80.0000        78.3710        1.00000
   0.992261       0.990327
SUPERBLOCK 1    200.80
    3.40871        1.49917        80.0000        78.3914        1.00000
   0.995579       0.994473
SUPERBLOCK 1    205.60
    3.38531        1.49917        80.0000        78.4041        1.00000
   0.998332       0.997915
SUPERBLOCK 1    210.00
    3.38531        1.49917        80.0000        78.4081        1.00000
   0.997666       0.997915
SUPERBLOCK 1    210.10
    3.38531        1.49917        75.0000        78.4083        1.00000
   0.997666       0.997915
SUPERBLOCK 1    210.30
    3.38531        1.49917        75.0000        78.3602        1.00000
   0.997666       0.997915
SUPERBLOCK 1    210.70
    3.38531        1.49917        75.0000        78.3370        1.00000
   0.997666       0.997915
SUPERBLOCK 1    211.50
    3.38531        1.49917        75.0000        78.4111        1.00000
   0.997666       0.997915
SUPERBLOCK 1    213.10
    3.38531        1.49917        75.0000        78.4509        1.00000
   0.997666       0.997915
SUPERBLOCK 1    216.30
    3.38531        1.49917        75.0000        78.4639        1.00000
   0.997666       0.997915
SUPERBLOCK 1    222.70
    3.38531        1.49917        75.0000        76.0268        1.00000
   0.997666       0.997915
SUPERBLOCK 1    235.50
    3.38531        1.49917        75.0000        73.5515        1.00000
   0.997666       0.997915
SUPERBLOCK 1    255.00
    3.38531        1.49917        75.0000        73.5435        1.00000
   0.997666       0.997915
SUPERBLOCK 1    255.10
    3.38531        1.49917        80.0000        73.5435        1.00000
   0.997666       0.997915
SUPERBLOCK 1    255.30
    3.38531        1.49917        80.0000        73.5919        1.00000
   0.997666       0.997915
SUPERBLOCK 1    255.70
    3.38531        1.49917        80.0000        73.6156        1.00000
   0.997666       0.997915
SUPERBLOCK 1    256.50
    3.38531        1.49917        80.0000        73.5418        1.00000
   0.997666       0.997915
SUPERBLOCK 1    258.10
    3.38531        1.49917        80.0000        73.5019        1.00000
   0.997666       0.997915
SUPERBLOCK 1    261.30
    3.38531        1.49917        80.0000        73.4904        1.00000
   0.997666       0.997915
SUPERBLOCK 1    267.70
    3.38531        1.49917        80.0000        75.9276        1.00000
   0.997666       0.997915
SUPERBLOCK 1    280.50
    3.38531        1.49917        80.0000        78.4030        1.00000
   0.997666       0.997915
SUPERBLOCK 1    300.00
    3.38531        1.49917        80.0000        78.4110        1.00000
   0.997666       0.997915
```

Listing 15. The simulation control input data file (*example1.inp*).

```
0.1, 60.0, 300.       (tmin, tmax, tstop)
n                     (building shell use)
n                     (initialization file use)
n                     (default file use)
example1.dfn                                      (hvacsim.dfn)
example1.bnd                                      (hvacsim.bnd)
example1.fin                                      (hvacsim.fin)
example1.out                                      (hvacsim.out)
example1.sum                                      (hvacsim.sum)
n                     (reporting time for output)
n                     (disabling freezing variable feature)
n                     (diagnostic information)
n                     (monitoring on screen)
```

4.5 Sorting the Simulation Output Data File

The format of the simulation output data file (*hvacsim.out*) is not suitable for plotting. SORTSB sorts the file *superblock* by *superblock*. According to the preference of the user, the time unit that is second can be scaled to minute, hour, or day. The output data of SORTSB can also be recorded in a fixed interval by skipping a number of records. **Listing 16** shows the interactive session of running SORTSB and **Listing 17** shows the output of SORTSB. **Figure 8** is the plot of the water mass flow rate with respect to actuator and valve stem positions. The inlet and outlet temperatures of the water pipe are plotted in terms of time in **Figure 9**.

Listing 16. Interactive session of running SORTSB.

```
C:\HVACSIM20\WORK>sortsb
 Enter input file name
=> example1.out
  Enter output file name
=> example1.sb1
  Superblock # ?
=> 1
  Number of output lines to be skipped =
=> 0
 SUPERBLOCK 1      0.10
    3.37500        1.50000        80.0000        79.9606        1.00000
    1.00000        1.00000
SUPERBLOCK 1      0.30
    3.37500        1.50000        80.0000        79.9606        1.00000
    1.00000        1.00000
SUPERBLOCK 1      0.70
    3.37500        1.50000        80.0000        79.9366        1.00000
 Number of seconds per unit time?
=> 1
  Extract another superblock? <n>
=> n
---- End of sortsb -----
```

Listing 17. <u>The output of SORTSB.</u>

```
       134          8
  0.100000       3.37500       1.50000       80.0000       79.9606       1.00000       1.00000
1.00000
  0.300000       3.37500       1.50000       80.0000       79.9606       1.00000       1.00000
1.00000
  0.700000       3.37500       1.50000       80.0000       79.9366       1.00000       1.00000
1.00000
   1.50000       3.37500       1.50000       80.0000       79.9524       1.00000       1.00000
1.00000
   3.10000       3.37500       1.50000       80.0000       79.9768       1.00000       1.00000
1.00000
   6.30000       3.37500       1.50000       80.0000       79.9692       1.00000       1.00000
1.00000
   12.7000       3.37500       1.50000       80.0000       79.2213       1.00000       1.00000
1.00000
   25.5000       3.37500       1.50000       80.0000       78.4139       1.00000       1.00000
1.00000
   30.0000       3.37500       1.50000       80.0000       78.4139       1.00000       1.00000
1.00000
   30.1000       3.37500       1.50000       80.0000       78.4139      0.852440      0.997107
1.00000
   30.2000       3.37500       1.50000       80.0000       78.4139      0.854762      0.996802
1.00000
   30.3000       3.37500       1.50000       80.0000       78.4139      0.856965      0.994060
1.00000
   30.4000       3.37500       1.50000       80.0000       78.4139      0.859053      0.991413
1.00000
   30.5000       3.37500       1.50000       80.0000       78.4139      0.861025      0.988857
1.00000
   31.1000       3.37500       1.50000       80.0000       78.4139      0.870506      0.975023
1.00000
   31.6000       3.37500       1.50000       80.0000       78.4139      0.875459      0.965248
1.00000
   32.4000       3.37500       1.50000       80.0000       78.4139      0.878205      0.951982
1.00000
   33.1000       3.37500       1.50000       80.0000       78.4139      0.875798      0.941972
1.00000
   34.3000       3.37500       1.50000       80.0000       78.4139      0.862461      0.926426
1.00000
   36.0000       3.37500       1.50000       80.0000       78.4139      0.827200      0.903328
1.00000
   38.3000       3.37500       1.50000       80.0000       78.4139      0.758517      0.863247
1.00000
   40.0000       3.37500       1.50000       80.0000       78.4139      0.700000      0.825018
1.00000
   41.5000       3.48732       1.50000       80.0000       78.4119      0.655000      0.786971
0.983713
   43.6000       3.97193       1.48519       80.0000       78.4116      0.592000      0.729936
0.912420
   45.5000       4.53352       1.47112       80.0000       78.4116      0.535000      0.676573
0.845716
   47.8000       5.39437       1.44928       80.0000       78.4116      0.466000      0.610792
0.763490
   52.3000       7.94552       1.38255       80.0000       78.4099      0.331000      0.479555
0.599444
   55.0000       10.3591       1.31630       80.0000       78.4022      0.250000      0.399444
0.499305
   55.1000       10.5716       1.31031       80.0000       78.4019      0.100000      0.393572
0.491965
   55.2000       10.7853       1.30426       80.0000       78.4016      0.100000      0.387816
0.484770
   55.3000       11.0002       1.29814       80.0000       78.4012      0.100000      0.382173
0.477716
   55.8000       12.0949       1.26653       80.0000       78.3991      0.100000      0.355415
0.444269
   56.1000       12.7612       1.24689       80.0000       78.3972      0.100000      0.340540
0.425675
```

56.7000	14.0993	1.20650	80.0000	78.3938	0.100000	0.313284	0.391605
57.4000	15.6423	1.15818	80.0000	78.3899	0.100000	0.285292	0.356616
58.4000	17.7391	1.08903	80.0000	78.3850	0.100000	0.251611	0.314514
59.4000	19.6454	1.02214	80.0000	78.3797	0.100000	0.224133	0.280167
60.9000	22.0698	0.930142	80.0000	78.3706	0.100000	0.192075	0.240094
62.3000	23.8568	0.856041	80.0000	78.3593	0.100000	0.169732	0.212165
63.5000	25.0635	0.802146	80.0000	78.3501	0.100000	0.154951	0.193689
65.2000	26.3568	0.740024	80.0000	78.3355	0.100000	0.139146	0.173933
67.3000	27.4476	0.683256	80.0000	78.3165	0.100000	0.125652	0.157065
69.7000	28.2296	0.639470	80.0000	78.2981	0.100000	0.115763	0.144704
71.8000	28.6536	0.614458	80.0000	78.2802	0.100000	0.110289	0.137861
73.9000	28.9249	0.597853	80.0000	78.2557	0.100000	0.106725	0.133406
76.4000	29.1259	0.585263	80.0000	78.2130	0.100000	0.104055	0.130069
79.6000	29.2717	0.575958	80.0000	78.1315	0.100000	0.102099	0.127624
83.4000	29.3595	0.570281	80.0000	77.9810	0.100000	0.100913	0.126141
87.4000	29.3595	0.570281	80.0000	77.7481	0.100000	0.100967	0.126141
88.5000	29.3595	0.570281	80.0000	77.6728	0.100000	0.100793	0.126141
89.1000	29.3746	0.569299	80.0000	77.6294	0.100000	0.100708	0.126141
90.3000	29.3847	0.568641	80.0000	77.5385	0.100000	0.100571	0.125714
92.1000	29.3971	0.567835	80.0000	77.3956	0.100000	0.100403	0.125714
95.7000	29.4130	0.566800	80.0000	77.1037	0.100000	0.100188	0.125235
102.900	29.4130	0.566800	80.0000	76.5920	0.100000	0.100188	0.125235
117.300	29.4130	0.566800	80.0000	76.0812	0.100000	0.100188	0.125235
146.100	29.4130	0.566800	80.0000	75.8878	0.100000	0.100188	0.125235
150.000	29.4130	0.566800	80.0000	75.8878	0.100000	0.100188	0.125235
150.100	29.4130	0.566800	80.0000	75.8878	0.247560	0.101935	0.125235
150.200	29.4130	0.566800	80.0000	75.8878	0.245238	0.102242	0.125235
150.300	29.4130	0.566800	80.0000	75.8878	0.243035	0.105002	0.125235
150.400	29.4130	0.566800	80.0000	75.8878	0.240947	0.107668	0.125235
150.500	29.4130	0.566800	80.0000	75.8878	0.238975	0.110243	0.125235
150.600	29.4130	0.566800	80.0000	75.8878	0.237117	0.112730	0.125235
150.700	29.4130	0.566800	80.0000	75.8878	0.235371	0.115135	0.125235
150.800	29.4130	0.566800	80.0000	75.8878	0.233738	0.117461	0.125235
150.900	29.4130	0.566800	80.0000	75.8878	0.232214	0.119711	0.125235
151.000	29.4130	0.566800	80.0000	75.8878	0.230800	0.121889	0.125235

151.100	29.4130	0.566800	80.0000	75.8878	0.229494	0.123999	0.125235
151.200	29.4130	0.566800	80.0000	75.8878	0.228294	0.126044	0.125235
151.300	29.4130	0.566800	80.0000	75.8878	0.227201	0.128027	0.125235
151.400	29.4130	0.566800	80.0000	75.8878	0.226211	0.129952	0.125235
151.500	29.4130	0.566800	80.0000	75.8878	0.225325	0.131822	0.125235
151.600	29.4130	0.566800	80.0000	75.8878	0.224541	0.133640	0.125235
151.700	29.4130	0.566800	80.0000	75.8878	0.223857	0.135409	0.125235
151.800	29.4130	0.566800	80.0000	75.8878	0.223274	0.137132	0.125235
151.900	29.4130	0.566800	80.0000	75.8878	0.222788	0.138812	0.125235
152.000	29.4130	0.566800	80.0000	75.8878	0.222400	0.140451	0.125235
152.200	29.4130	0.566800	80.0000	75.8878	0.221910	0.143640	0.125235
152.300	29.4130	0.566800	80.0000	75.8878	0.221807	0.145188	0.125235
152.600	29.4130	0.566800	80.0000	75.8878	0.222045	0.149660	0.125235
153.100	29.4130	0.566800	80.0000	75.8878	0.224202	0.156682	0.125235
153.600	29.4130	0.566800	80.0000	75.8878	0.228429	0.163323	0.125235
154.100	29.4130	0.566800	80.0000	75.8878	0.234576	0.169805	0.125235
154.800	29.4130	0.566800	80.0000	75.8878	0.246122	0.178987	0.125235
155.900	29.4130	0.566800	80.0000	75.8878	0.270284	0.194543	0.125235
156.900	29.4130	0.566800	80.0000	75.8878	0.297458	0.210672	0.125235
158.100	29.4130	0.566800	80.0000	75.8878	0.334872	0.233219	0.125235
159.800	29.4130	0.566800	80.0000	75.8878	0.393002	0.271329	0.125235
163.200	24.5194	0.826888	80.0000	75.8878	0.496000	0.361601	0.202001
163.600	23.6369	0.865517	80.0000	75.8970	0.508000	0.372445	0.215556
163.800	23.1975	0.884113	80.0000	75.8900	0.514000	0.377889	0.222362
164.800	21.0255	0.970845	80.0000	75.8729	0.544000	0.405575	0.256968
165.900	18.7768	1.05314	80.0000	75.8809	0.577000	0.436349	0.295437
166.300	18.0042	1.07997	80.0000	75.8849	0.589000	0.447634	0.309542
167.100	16.5391	1.12911	80.0000	75.8916	0.613000	0.470355	0.337944
168.700	13.9426	1.21128	80.0000	75.8926	0.661000	0.516312	0.395391
171.900	9.92581	1.32844	80.0000	75.9006	0.765128	0.611913	0.514891
175.100	7.31415	1.39936	80.0000	76.2934	0.851970	0.706042	0.632553
177.200	6.24037	1.42750	80.0000	76.7936	0.877350	0.759133	0.698917
178.500	5.79402	1.43903	80.0000	77.0921	0.874675	0.785076	0.731345
180.000	5.48100	1.44707	80.0000	77.4197	0.850000	0.804995	0.756244
180.100	5.42364	1.44853	80.0000	77.4377	1.00000	0.808819	0.761023

180.200	5.35774	1.44853	80.0000	77.4552	1.00000	0.812567	0.765709
180.300	5.29428	1.44853	80.0000	77.4724	1.00000	0.816242	0.770303
181.200	4.90151	1.46182	80.0000	77.6115	1.00000	0.846456	0.808071
182.100	4.58799	1.46974	80.0000	77.7280	1.00000	0.871900	0.839875
183.400	4.25661	1.47807	80.0000	77.8679	1.00000	0.901627	0.877034
184.700	4.02341	1.48390	80.0000	77.9840	1.00000	0.924605	0.905756
187.100	3.75471	1.49059	80.0000	78.1438	1.00000	0.953568	0.941960
190.000	3.58432	1.49482	80.0000	78.2528	1.00000	0.973526	0.966908
193.900	3.46619	1.49482	80.0000	78.3333	1.00000	0.986639	0.983299
197.300	3.43432	1.49853	80.0000	78.3710	1.00000	0.992261	0.990327
200.800	3.40871	1.49917	80.0000	78.3914	1.00000	0.995579	0.994473
205.600	3.38531	1.49917	80.0000	78.4041	1.00000	0.998332	0.997915
210.000	3.38531	1.49917	80.0000	78.4081	1.00000	0.997666	0.997915
210.100	3.38531	1.49917	75.0000	78.4083	1.00000	0.997666	0.997915
210.300	3.38531	1.49917	75.0000	78.3602	1.00000	0.997666	0.997915
210.700	3.38531	1.49917	75.0000	78.3370	1.00000	0.997666	0.997915
211.500	3.38531	1.49917	75.0000	78.4111	1.00000	0.997666	0.997915
213.100	3.38531	1.49917	75.0000	78.4509	1.00000	0.997666	0.997915
216.300	3.38531	1.49917	75.0000	78.4639	1.00000	0.997666	0.997915
222.700	3.38531	1.49917	75.0000	76.0268	1.00000	0.997666	0.997915
235.500	3.38531	1.49917	75.0000	73.5515	1.00000	0.997666	0.997915
255.000	3.38531	1.49917	75.0000	73.5435	1.00000	0.997666	0.997915
255.100	3.38531	1.49917	80.0000	73.5435	1.00000	0.997666	0.997915
255.300	3.38531	1.49917	80.0000	73.5919	1.00000	0.997666	0.997915
255.700	3.38531	1.49917	80.0000	73.6156	1.00000	0.997666	0.997915
256.500	3.38531	1.49917	80.0000	73.5418	1.00000	0.997666	0.997915
258.100	3.38531	1.49917	80.0000	73.5019	1.00000	0.997666	0.997915
261.300	3.38531	1.49917	80.0000	73.4904	1.00000	0.997666	0.997915
267.700	3.38531	1.49917	80.0000	75.9276	1.00000	0.997666	0.997915
280.500	3.38531	1.49917	80.0000	78.4030	1.00000	0.997666	0.997915
300.000	3.38531	1.49917	80.0000	78.4110	1.00000	0.997666	0.997915

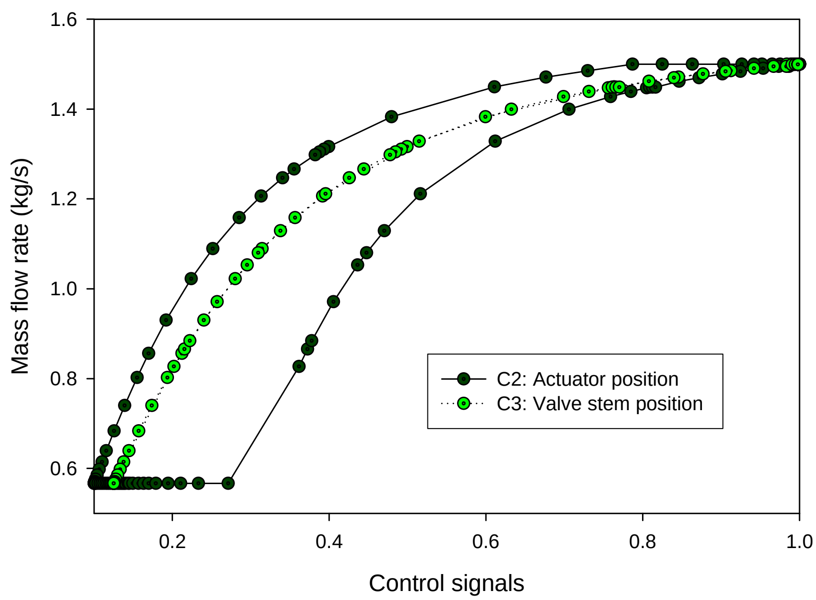

Figure 8. The water mass flow rate with respect to actuator and valve stem positions of Example 1.

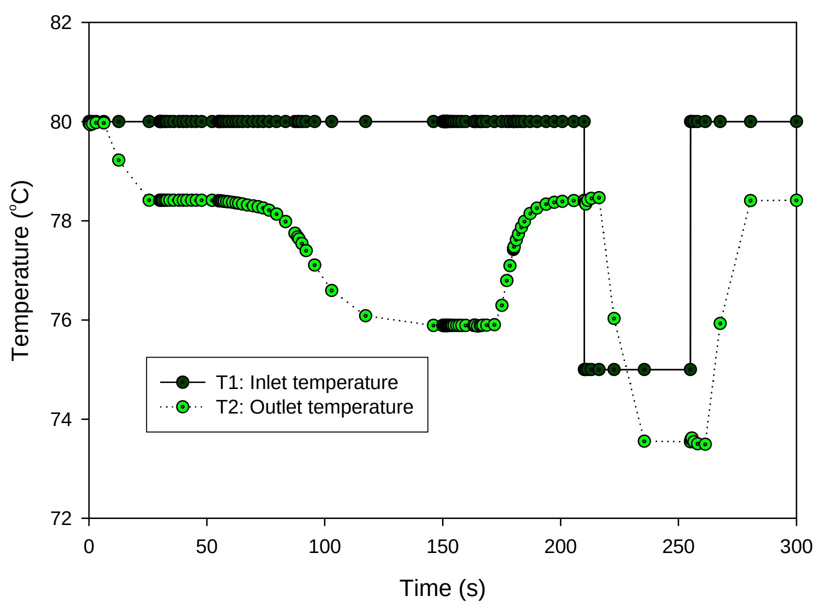

Figure 9. The inlet and outlet temperatures of water pipe of Example 1.

5. Case 2: Running Programs for a Building Shell Simulation

To illustrate a building shell simulation, a single zone model is selected as shown in **Figures 10** and **11**. See pp. 99-149 of Reference 4. In this case, '*onezone*' is used in place of '*hvacsim*'.

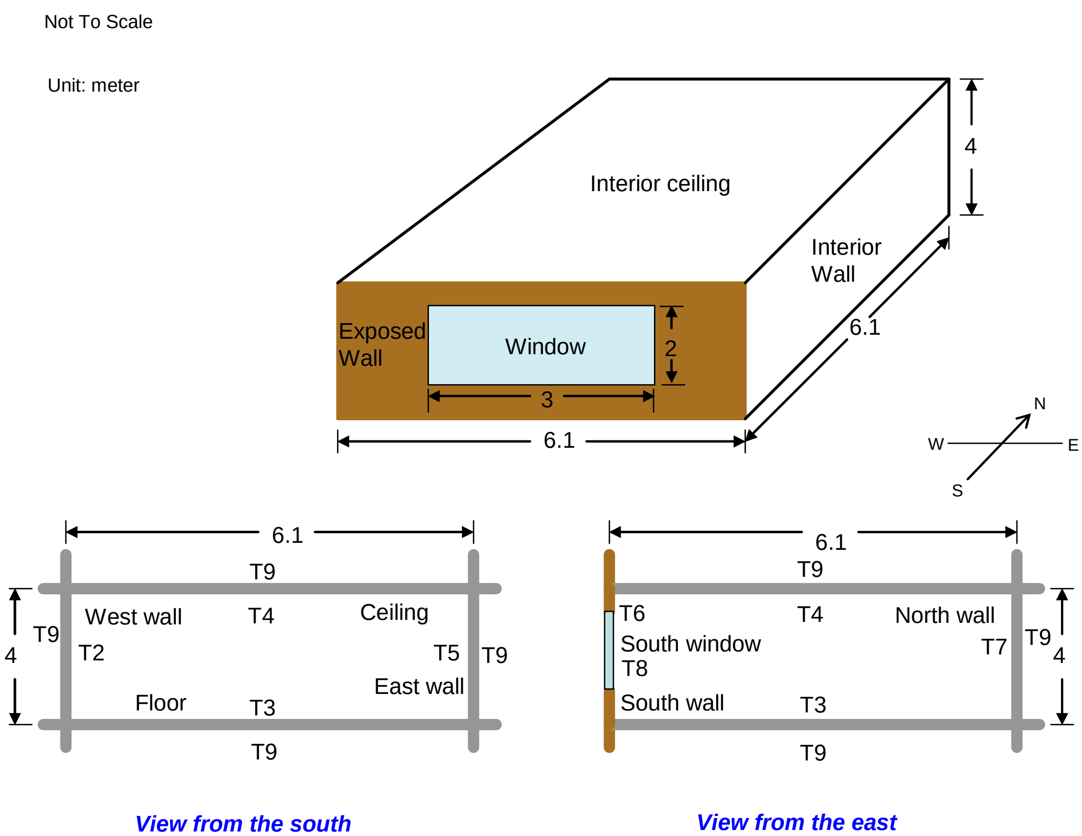

Figure 10. The single-zone model.

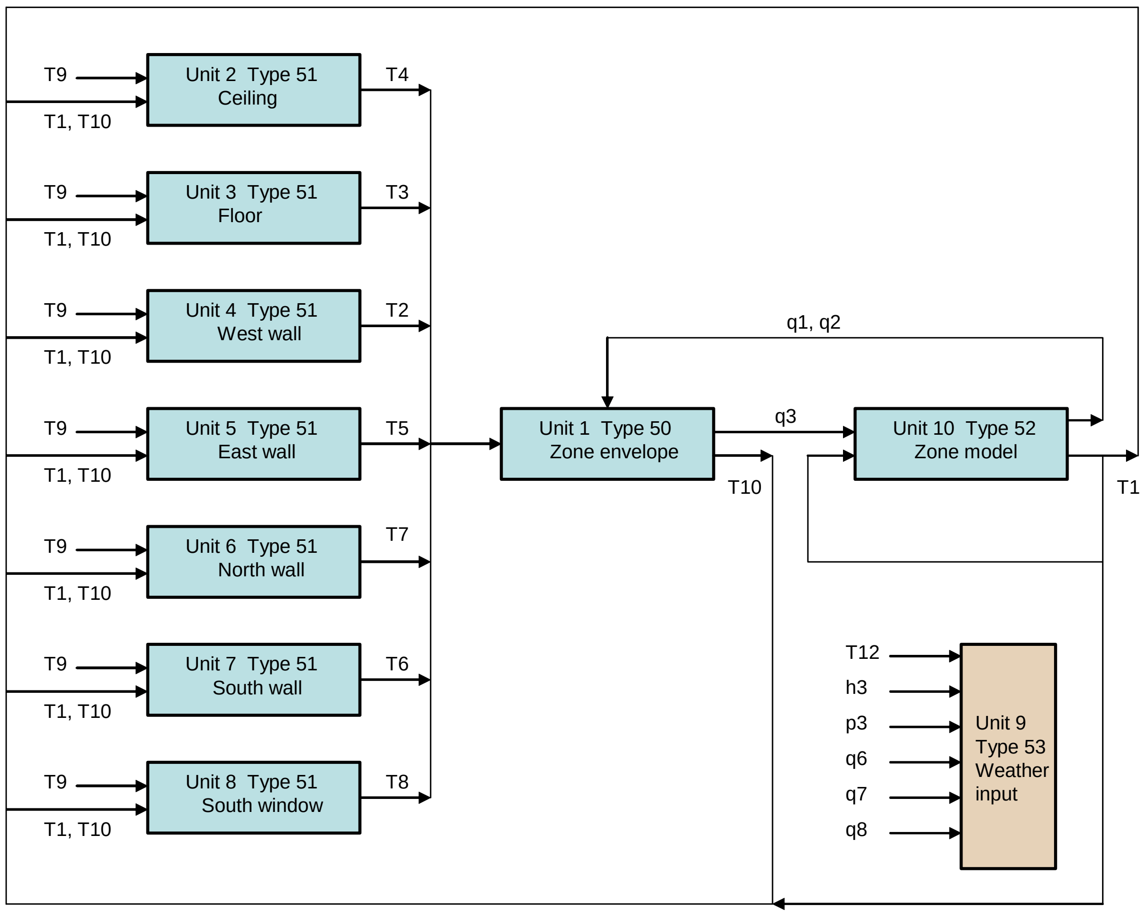

Figure 11. Information flow diagram of the single-zone model.

5.1 Creating Input Data Files for the Building Shell Simulation

5.1.1 Conduction transfer function file (*hvacsim.ctf*)

Execute the CTFGEN program to view the contents of the thermal property data file (*therm2.dat*). If required thermal property data of interest are missing, add them to the file. The following information must be provided interactively as inputs: the time step for building shell computation, the numbers of layers of multilayer construct, and the identification numbers of material in the thermal property data file. As for the order of the identification numbers, the outside layer comes first, then the next layer, and so on. The innermost layer should be last. When a construct has very low thermal capacitance, specify thermal resistance. **Listing 18** shows the interactive session for creating the conduction transfer function file. **Listing 19** is the resulting conduction transfer function file (*hvacsim.ctf*).

Listing 18. Interactive session to create conduction transfer functions.

```
C:\HVACSIM20\WORK>ctfgen
 Enter the name of the thermal property data file,
 or carriage return for default name: therm2.dat
=>
 ***************************************************
                select your choice:
***************************************************
Enter A, C, D, or E

A : Add thermal property data to the construction
     materials database
C : Create a ctf data file
D : Display the contents of the database 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: hvacsim.ctf
=>
 What kind units are used for material properties?

Enter  1 for metric units
       2 for standard(English)units
=> 1
 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 53
 istr:  1
nctf:  6   nord:  4
uval:  0.968215525
ctfx:  5.77757454 -13.3066082 10.6433306 -3.46747708 0.402874321 -1.01672607E-02 -
2.20753591E-05
ctfy:  1.29634060E-07 5.59825916E-04 9.70261917E-03 1.98281351E-02 8.42879154E-03
9.43974766E-04 4.09526147E-05
ctfz:  14.5398598 -34.2151947 27.8764000 -9.31735039 1.20246959 -4.65699472E-02 -
1.10163681E-04
ctfq:  1.68333852 -0.867561460 0.150875375 -7.45377177E-03
Do you want to continue? <y/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
=> 53 36 46 47
 istr:  2
nctf:  6   nord:  4
uval:  0.968215525
```

```
ctfx:  14.5398598 -34.2151947 27.8764000 -9.31735039 1.20246959 -4.65699472E-02 -
1.10163681E-04
ctfy:  1.29634060E-07 5.59825916E-04 9.70261917E-03 1.98281351E-02 8.42879154E-03
9.43974766E-04 4.09526147E-05
ctfz:  5.77757454 -13.3066082 10.6433306 -3.46747708 0.402874321 -1.01672607E-02 -
2.20753591E-05
ctfq:  1.68333852 -0.867561460 0.150875375 -7.45377177E-03
Do you want to continue? <y/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:  3   nord:  1
uval:  4.71099043
ctfx:  29.3481579 -25.1638699 0.354720056 2.57876702E-03
ctfy:  1.78437543 2.59330821 0.161323264 2.57876702E-03
ctfz:  29.3481579 -25.1638699 0.354720056 2.57876702E-03
ctfq:  3.59595045E-02
Do you want to continue? <y/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:  5   nord:  4
uval:  0.691656530
ctfx:  59.4346199 -106.359474 54.9494362 -8.31945229 0.364596575 -4.13608598E-03
ctfy:  1.20150007E-05 5.33784321E-03 3.22867334E-02 2.44872365E-02 3.36399884E-03
1.03239363E-04
ctfz:  28.0523319 -60.2245445 39.8903046 -7.92132902 0.270762205 -1.93616585E-03
ctfq:  1.20370615 -0.316528589 1.82767957E-02 -2.86226335E-04
Do you want to continue? <y/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
=> 52 8 52
 istr:  5
nctf:  1   nord:  1
uval:  5.17124224
ctfx:  12.8699331 -7.69869089
ctfy:  4.48962641 0.681615591
ctfz:  12.8699331 -7.69869089
ctfq:  2.17744880E-08
Do you want to continue? <y/n>
=> n
 ***************************************************
                select your choice:
***************************************************
Enter A, C, D, or E

A : Add thermal property data to the construction
     materials database
C : Create a ctf data file
D : Display the contents of the database file
E : End
=> d
```

```
================================================================================

 Therm2.dat    Thermal Properties of Building Wall and Roof

 Revised:    9/8/1999

 Ref: ASHRAE Handbook 1997 Fundamentals p.28.19

===============================================================================
ID                  Description               Thickness   k    Density  Sp.Ht
                                                 (m)  (W/m-K) (kg/m3) (kJ/kg-K)
===============================================================================
 1  Stucco 25.4 mm(1")                           0.0254  0.692 1858.    0.840  0.036
47.2    A1
 2  Face brick 101.6 mm(4")                      0.1016  1.298 2082.    0.924  0.078
211.4    A2
 3  Steel siding                                 0.0015 44.990 7689.    0.420  0.000
11.7    A3
 4  Slag membrane   12.7 mm(0.5")                0.0127  1.143  881.    1.680  0.011
11.2    A4
 5  Felt 9.5 mm(0.375")                          0.0095  0.190 1121.    1.680  0.050
10.6    A5
 6  Finish                                       0.0127  0.415 1249.    1.092  0.031
15.9    A6
 7  Face brick 101.6 mm(4")                      0.1016  1.332 2002.    0.924  0.076
203.1    A7
 8  Air space resistance                         0.0000  0.000    0.    0.000  0.160
0.0    B1
 9  Insulation 25.4 mm(1")                       0.0254  0.043   32.    0.840  0.585
0.8    B2
10  Insulation 50.8 mm(2")                       0.0508  0.043   32.    0.840  1.176
1.6    B3
11  Insulation 76.2 mm(3")                       0.0762  0.043   32.    0.840  1.766
2.4    B4
12  Insulation 25.4 mm(1")                       0.0254  0.043   91.    0.840  0.586
2.3    B5
13  Insulation 50.8 mm(2")                       0.0508  0.043   91.    0.840  1.176
4.6    B6
14  Wood 25.4 mm(1")                             0.0254  0.116  592.    2.520  0.209
15.0    B7
15  Wood 63.5 mm(2.5")                           0.0635  0.116  592.    2.520  0.525
37.6    B8
16  Wood 101.6 mm(4")                            0.1016  0.116  592.    2.520  0.838
60.0    B9
17  Wood 50.8 mm(2")                             0.0508  0.116  592.    2.520  0.421
30.2    B10
18  Wood 76.2 mm(3")                             0.0762  0.116  592.    2.520  0.631
45.2    B11
19  Insulation  76.2 mm(3")                      0.0762  0.043   91.    0.840  1.761
6.9    B12
20  Insulation 101.6 mm(4")                      0.1016  0.043   91.    0.840  2.346
9.3    B13
21  Insulation 127.0 mm(5")                      0.1270  0.043   91.    0.840  2.934
11.6    B14
22  Insulation 152.4 mm(6")                      0.1524  0.043   91.    0.840  3.520
13.9    B15
23  Clay tile 101.6 mm(4")                       0.1016  0.571 1121.    0.840  0.178
113.7    C1
24  Concrete block l.w. 101.6 mm(4")             0.1016  0.381  608.    0.840  0.266
62.0    C2
25  Concrete block h.w. 101.6 mm(4")             0.1016  0.813  977.    0.840  0.125
99.1    C3
```

26	Common brick 101.6 mm(4")	0.1016	0.727	1922.	0.840	0.139	195.3	C4
27	Concrete l.w. 101.6 mm(4")	0.1016	1.730	2242.	0.840	0.059	227.5	C5
28	Clay tile 203.2 mm(8")	0.2032	0.571	1121.	0.840	0.356	227.9	C6
29	Concrete block l.w. 203.2 mm(8")	0.2032	0.571	608.	0.840	0.356	124.0	C7
30	Concrete block h.w. 203.2 mm(8")	0.2032	1.038	977.	0.840	0.195	198.7	C8
31	Common brick 203.2 mm(8")	0.2032	0.727	1922.	0.840	0.280	390.6	C9
32	Concrete h.w. 203.2 mm(8")	0.2032	1.730	2242.	0.840	0.117	455.9	C10
33	Concrete h.w. 304.8 mm(12")	0.3048	1.730	2242.	0.840	0.176	683.5	C11
34	Concrete h.w. 50.8 mm(2")	0.0508	1.730	2242.	0.840	0.029	114.2	C12
35	Concrete h.w. 152.4 mm(6")	0.1524	1.730	2242.	0.840	0.088	341.7	C13
36	Concrete l.w. 101.6 mm(4")	0.1016	0.173	640.	0.840	0.586	64.9	C14
37	Concrete l.w. 152.4 mm(6")	0.1524	0.173	640.	0.840	0.088	97.6	C15
38	Concrete l.w. 203.2 mm(8")	0.2032	0.173	640.	0.840	1.174	130.3	C16
39	Concrete block(filled) l.w. 203.2 mm(8")	0.2032	0.138	288.	0.840	1.584	58.6	C17
40	Concrete block(filled) l.w. 203.2 mm(8")	0.2032	0.588	849.	0.840	0.348	172.8	C18
41	Concrete block(filled) l.w. 304.8 mm(12")	0.3048	0.138	304.	0.840	2.376	92.8	C19
42	Concrete block (filled)l.w. 304.8 mm(12")	0.3048	0.675	897.	0.840	0.456	273.4	C20
43	Plaster/gypsum 19.0 mm(0.75")	0.0190	0.727	1601.	0.840	0.026	30.5	E1
44	Slag or stone 12.7 mm(0.5")	0.0127	1.436	881.	1.680	0.009	11.2	E2
45	Felt & membrane 9.5 mm(0.375")	0.0095	0.190	1121.	1.680	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.	0.840	0.315	9.2	E5
48	Face brick wall 10-1/2"	0.2667	1.332	2002.	0.924	0.000	533.9	XXX
49	Insulation 1-5/8"	0.0413	0.043	32.	0.840	0.000	1.3	XXX
50	Concrete h.w. 8-1/2"	0.2159	1.730	2242.	0.840	0.000	484.0	XXX
51	Insulation 1/2"	0.0127	0.043	32.	0.840	0.000	0.4	XXX
52	Glass window 1/2"	0.0127	0.761	707.	0.840	0.000	9.0	XXX
53	Vinyl tile 3/32"	0.0024	0.270	1552.	1.004	0.000	3.7	XXX
54	Concrete h.w. 10"	0.2540	1.730	2242.	0.840	0.000	569.5	XXX
55	Insulation 2-1/2"	0.0635	0.043	32.	0.840	0.000	2.0	XXX
56	Plywood 6.4 mm (0.25")	0.0064	0.120	540.	1.210	0.053	3.5	

```
57  Glass window   3.2 mm (0.125")            0.0032  0.761  707.    0.840  0.000
2.3
***************************************************
                select your choice:
***************************************************
Enter A, C, D, or E

A : Add thermal property data to the construction
     materials database
C : Create a ctf data file
D : Display the contents of the database file
E : End
=> e
 ********** End of ctf run **********
```

Listing 19. The conduction transfer function file (*hvacsim.ctf*).

```
    900.000
     1   6   4   0.968216
    5.77757       -13.3066        10.6433       -3.46748       0.402874
  -0.101673E-01  -0.220754E-04
   0.129634E-06   0.559826E-03   0.970262E-02   0.198281E-01   0.842879E-02
   0.943975E-03   0.409526E-04
    14.5399       -34.2152        27.8764       -9.31735        1.20247
  -0.465699E-01  -0.110164E-03
    1.68334      -0.867561       0.150875      -0.745377E-02
     2   6   4   0.968216
    14.5399       -34.2152        27.8764       -9.31735        1.20247
  -0.465699E-01  -0.110164E-03
   0.129634E-06   0.559826E-03   0.970262E-02   0.198281E-01   0.842879E-02
   0.943975E-03   0.409526E-04
    5.77757       -13.3066        10.6433       -3.46748       0.402874
  -0.101673E-01  -0.220754E-04
    1.68334      -0.867561       0.150875      -0.745377E-02
     3   3   1    4.71099
    29.3482       -25.1639       0.354720       0.257877E-02
    1.78438        2.59331       0.161323       0.257877E-02
    29.3482       -25.1639       0.354720       0.257877E-02
   0.359595E-01
     4   5   4   0.691657
    59.4346       -106.359        54.9494       -8.31945       0.364597
  -0.413609E-02
   0.120150E-04   0.533784E-02   0.322867E-01   0.244872E-01   0.336400E-02
   0.103239E-03
    28.0523       -60.2245        39.8903       -7.92133       0.270762
  -0.193617E-02
    1.20371      -0.316529       0.182768E-01  -0.286226E-03
     5   1   1    5.17124
    12.8699       -7.69869
    4.48963        0.681616
    12.8699       -7.69869
   0.217745E-07
```

5.1.2 Weather data file (*hvacsim.met*)

Execute the RDWDF program interactively to read weather data from a whole year weather data file and create the data file (*wtpout.dat*). Taking this file as input file, the program CRWDTA then creates the needed weather data file (*hvacsim.met*).

Listing 20 shows the interactive session to generate the weather data file. **Listings 21** and **22** show the output file of RDWDF and the resulting weather data file, respectively.

If no weather data is available, the CRWDTA program can be used to make a weather data file artificially. For a given period of time, barometric pressure, wind speed, relative humidity, maximum dry-bulb outside air temperature, minimum dry-bulb air temperature, visibility, and geographic correction factor are to be provided. **Listings 23** and **24** show the interactive session and the artificially generated weather data file.

Listing 20. Interactive session to generate weather data file.

```
C:\HVACSIM20\WORK>rdwdf
 Enter input file name up to 12 characters ---
=> vasterlw.wy2
  What is the type of weather data format?
 Enter 1 for (TRY), 2 (TMY), 3 (SOLMET), 4 (WYEC),
       5 (WYEC2)
=> 5
  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 data ----
 sttn= 93734  wyr= 59  wmo= 1  wdy= 1
------- The start day -------
 sttn= 93734  wyr= 61  wmo= 7  wdy= 7
 -------  The stop day -------
 sttn= 93734  wyr= 61  wmo= 7  wdy= 9
        3 Days written on the output file

--------- Normal end of job ------

C:\HVACSIM20\WORK>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 file by program rdwdf)
 2 - to generate clear sky design data
 3 - to generate cloudy sky design data
```

```
=> 1
  Enter output file name (up to 40 characters)
 or carriage return for default name: hvacsim.met
=>
  End of input data file
---- End of creating weather file ------
```

Listing 21. The output file of RDWDF (*wtpout.dat*).

```
sttn    yr    mo  day   hr      db        dp         p         ws      cc     izero      ibeam
isky     ithorz
                                 (c)       (c)       (kpa)      (m/s)          (w/m**2)  (w/m**2)
(w/m**2) (w/m**2)
 93734   61    7    7    1      20.00      18.3      101.3      15.0    0       0.00       0.00
0.00      0.00
 93734   61    7    7    2      19.40      18.3      101.3       0.0    0       0.00       0.00
0.00      0.00
 93734   61    7    7    3      19.40      18.3      101.2       0.0    8       0.00       0.00
0.00      0.00
 93734   61    7    7    4      19.40      18.3      101.2       0.0    4       0.00       0.00
0.00      0.00
 93734   61    7    7    5      19.40      18.3      101.2      20.0   10       1.39       0.00
0.00      0.00
 93734   61    7    7    6      19.40      18.3      101.2      20.0    8     138.89       0.00
4.44      4.44
 93734   61    7    7    7      20.60      19.4      101.3      20.0   10     383.89       0.00
54.44     54.44
 93734   61    7    7    8      22.20      19.4      101.3       0.0    9     626.11      13.61
160.00    166.39
 93734   61    7    7    9      23.30      18.9      101.3      20.0    9     847.78     105.56
286.94    354.72
 93734   61    7    7   10      22.80      19.4      101.3      30.0   10    1033.61     111.11
392.78    479.72
 93734   61    7    7   11      24.40      20.0      101.2      25.0   10    1170.56     116.67
480.28    583.61
 93734   61    7    7   12      24.40      19.4      101.2      25.0   10    1249.72     179.44
461.11    630.83
 93734   61    7    7   13      25.60      19.4      101.1      30.0    7    1265.56     436.39
426.11    844.17
 93734   61    7    7   14      26.70      20.0      101.1      41.0    5    1216.67      99.17
392.22    483.61
 93734   61    7    7   15      27.20      20.6      101.0      30.0    6    1106.94     184.44
386.94    541.39
 93734   61    7    7   16      26.70      19.4      101.0      36.0    8     943.33     376.94
291.67    560.83
 93734   61    7    7   17      26.70      19.4      100.9      30.0    8     737.22     618.61
116.94    461.94
 93734   61    7    7   18      26.10      19.4      100.9      41.0    9     502.78     474.44
107.78    288.33
 93734   61    7    7   19      25.00      19.4      100.9      30.0    9     256.39      72.78
69.72     83.89
 93734   61    7    7   20      23.30      20.0      100.9      30.0    7      40.00       0.00
1.94      1.94
 93734   61    7    7   21      22.80      20.0      100.9      30.0    8       0.00       0.00
0.00      0.00
 93734   61    7    7   22      22.80      20.0      100.9      30.0    7       0.00       0.00
0.00      0.00
 93734   61    7    7   23      22.20      20.6      100.9      25.0    7       0.00       0.00
0.00      0.00
 93734   61    7    7   24      21.70      20.6      100.8      25.0    6       0.00       0.00
0.00      0.00
 93734   61    7    8    1      21.10      20.0      100.8      20.0    8       0.00       0.00
0.00      0.00
 93734   61    7    8    2      20.60      19.4      100.8      25.0    5       0.00       0.00
0.00      0.00
```

93734	61	7	8	3	20.00	18.9	100.7	20.0	3	0.00	0.00	0.00	0.00
93734	61	7	8	4	19.40	18.9	100.7	20.0	4	0.00	0.00	0.00	0.00
93734	61	7	8	5	19.40	18.3	100.8	20.0	4	1.39	0.00	0.00	0.00
93734	61	7	8	6	18.90	18.3	100.8	25.0	10	136.67	0.00	18.89	18.89
93734	61	7	8	7	20.00	18.9	100.8	25.0	4	381.94	128.06	108.33	145.28
93734	61	7	8	8	21.70	19.4	100.9	25.0	6	624.44	383.06	165.28	346.11
93734	61	7	8	9	22.80	20.0	100.9	30.0	3	846.11	570.00	174.17	539.17
93734	61	7	8	10	24.40	20.0	100.9	25.0	3	1032.22	634.72	203.89	699.72
93734	61	7	8	11	25.60	20.0	100.8	0.0	3	1169.72	685.28	219.17	825.83
93734	61	7	8	12	27.20	16.7	100.8	41.0	2	1248.89	682.78	255.83	901.11
93734	61	7	8	13	27.20	11.7	100.8	56.0	2	1264.72	655.28	286.94	914.17
93734	61	7	8	14	27.20	12.8	100.8	51.0	2	1216.11	559.72	330.83	846.11
93734	61	7	8	15	26.70	15.0	100.8	51.0	5	1106.39	480.56	320.83	723.33
93734	61	7	8	16	26.10	13.3	100.8	56.0	7	942.78	142.78	348.89	450.56
93734	61	7	8	17	25.60	12.8	100.8	56.0	7	736.67	447.78	200.56	450.28
93734	61	7	8	18	25.60	12.8	100.8	61.0	7	501.94	591.67	106.94	331.67
93734	61	7	8	19	23.30	12.8	100.9	61.0	7	255.56	321.11	64.44	126.67
93734	61	7	8	20	21.10	11.1	100.9	61.0	7	39.44	0.00	3.33	3.33
93734	61	7	8	21	20.00	11.1	101.0	36.0	8	0.00	0.00	0.00	0.00
93734	61	7	8	22	19.40	11.1	101.1	41.0	4	0.00	0.00	0.00	0.00
93734	61	7	8	23	18.90	11.7	101.1	46.0	3	0.00	0.00	0.00	0.00
93734	61	7	8	24	18.30	11.7	101.1	36.0	3	0.00	0.00	0.00	0.00
93734	61	7	9	1	17.80	11.7	101.1	25.0	2	0.00	0.00	0.00	0.00
93734	61	7	9	2	17.20	11.7	101.0	30.0	0	0.00	0.00	0.00	0.00
93734	61	7	9	3	15.00	12.2	101.0	41.0	0	0.00	0.00	0.00	0.00
93734	61	7	9	4	15.00	12.2	101.1	36.0	0	0.00	0.00	0.00	0.00
93734	61	7	9	5	15.00	12.2	101.1	30.0	0	0.83	0.00	0.00	0.00
93734	61	7	9	6	16.10	12.8	101.2	30.0	0	134.44	1.67	32.22	32.50
93734	61	7	9	7	18.90	13.3	101.2	46.0	0	379.72	327.22	98.06	192.22
93734	61	7	9	8	19.40	13.9	101.2	41.0	0	622.50	546.39	124.17	381.67
93734	61	7	9	9	21.10	13.9	101.2	41.0	0	844.72	626.67	160.00	560.56
93734	61	7	9	10	22.20	14.4	101.3	36.0	1	1030.83	703.33	184.17	732.78
93734	61	7	9	11	23.90	15.0	101.3	30.0	3	1168.61	779.17	175.56	864.72
93734	61	7	9	12	25.00	14.4	101.2	41.0	6	1248.06	796.94	191.39	944.17
93734	61	7	9	13	25.00	13.9	101.2	61.0	8	1264.17	751.67	251.39	970.56

```
 93734   61    7     9   14     25.60      13.3     101.2       46.0    6   1215.56    496.39
365.56    822.22
 93734   61    7     9   15     26.70      13.9     101.1       36.0    7   1105.83    393.89
350.28    680.00
 93734   61    7     9   16     25.00      13.3     101.1       46.0    7    942.22    346.39
309.72    556.67
 93734   61    7     9   17     25.60      12.8     101.1       46.0    5    736.11     30.83
229.72    246.94
 93734   61    7     9   18     25.00      10.0     101.2       41.0    4    501.39    177.78
156.94    224.44
 93734   61    7     9   19     23.90      11.7     101.2       41.0    6    254.44    183.33
69.44    104.72
 93734   61    7     9   20     21.70      11.1     101.3       36.0    8     38.61      0.00
2.78      2.78
 93734   61    7     9   21     20.60      11.1     101.3       20.0    6      0.00      0.00
0.00      0.00
 93734   61    7     9   22     21.10      12.2     101.4       61.0    3      0.00      0.00
0.00      0.00
 93734   61    7     9   23     18.90      10.6     101.4       51.0    3      0.00      0.00
0.00      0.00
 93734   61    7     9   24     19.40      10.6     101.4        0.0    7      0.00      0.00
0.00      0.00
```

Listing 22. The weather data file (*hvacsim.met*).

```
     7    7     38.85     77.03      5.00    1
     7    7  0.0   20.0000    0.0131  101.3000   15.0000    0.0000    0.0000    0.0000
     7    7  1.0   20.0000    0.0131  101.3000   15.0000    0.0000    0.0000    0.0000
     7    7  2.0   19.4000    0.0131  101.3000    0.0000    0.0000    0.0000    0.0000
     7    7  3.0   19.4000    0.0131  101.2000    0.0000    0.0000    0.0000    0.0000
     7    7  4.0   19.4000    0.0131  101.2000    0.0000    0.0000    0.0000    0.0000
     7    7  5.0   19.4000    0.0131  101.2000   20.0000    0.0000    0.0000    0.0000
     7    7  6.0   19.4000    0.0131  101.2000   20.0000    0.0000    4.4400    4.4400
     7    7  7.0   20.6000    0.0141  101.3000   20.0000    0.0000   54.4400   54.4400
     7    7  8.0   22.2000    0.0141  101.3000    0.0000   13.6100  160.0000  166.3900
     7    7  9.0   23.3000    0.0136  101.3000   20.0000  105.5600  286.9400  354.7200
     7    7 10.0   22.8000    0.0141  101.3000   30.0000  111.1100  392.7800  479.7200
     7    7 11.0   24.4000    0.0146  101.2000   25.0000  116.6700  480.2800  583.6100
     7    7 12.0   24.4000    0.0141  101.2000   25.0000  179.4400  461.1100  630.8300
     7    7 13.0   25.6000    0.0141  101.1000   30.0000  436.3900  426.1100  844.1700
     7    7 14.0   26.7000    0.0147  101.1000   41.0000   99.1700  392.2200  483.6100
     7    7 15.0   27.2000    0.0152  101.0000   30.0000  184.4400  386.9400  541.3900
     7    7 16.0   26.7000    0.0141  101.0000   36.0000  376.9400  291.6700  560.8300
     7    7 17.0   26.7000    0.0141  100.9000   30.0000  618.6100  116.9400  461.9400
     7    7 18.0   26.1000    0.0141  100.9000   41.0000  474.4400  107.7800  288.3300
     7    7 19.0   25.0000    0.0141  100.9000   30.0000   72.7800   69.7200   83.8900
     7    7 20.0   23.3000    0.0147  100.9000   30.0000    0.0000    1.9400    1.9400
     7    7 21.0   22.8000    0.0147  100.9000   30.0000    0.0000    0.0000    0.0000
     7    7 22.0   22.8000    0.0147  100.9000   30.0000    0.0000    0.0000    0.0000
     7    7 23.0   22.2000    0.0153  100.9000   25.0000    0.0000    0.0000    0.0000
     7    7 24.0   21.7000    0.0153  100.8000   25.0000    0.0000    0.0000    0.0000
     7    8  1.0   21.1000    0.0147  100.8000   20.0000    0.0000    0.0000    0.0000
     7    8  2.0   20.6000    0.0142  100.8000   25.0000    0.0000    0.0000    0.0000
     7    8  3.0   20.0000    0.0137  100.7000   20.0000    0.0000    0.0000    0.0000
     7    8  4.0   19.4000    0.0137  100.7000   20.0000    0.0000    0.0000    0.0000
     7    8  5.0   19.4000    0.0132  100.8000   20.0000    0.0000    0.0000    0.0000
     7    8  6.0   18.9000    0.0132  100.8000   25.0000    0.0000   18.8900   18.8900
     7    8  7.0   20.0000    0.0137  100.8000   25.0000  128.0600  108.3300  145.2800
     7    8  8.0   21.7000    0.0141  100.9000   25.0000  383.0600  165.2800  346.1100
     7    8  9.0   22.8000    0.0147  100.9000   30.0000  570.0000  174.1700  539.1700
     7    8 10.0   24.4000    0.0147  100.9000   25.0000  634.7200  203.8900  699.7200
     7    8 11.0   25.6000    0.0147  100.8000    0.0000  685.2800  219.1700  825.8300
     7    8 12.0   27.2000    0.0119  100.8000   41.0000  682.7800  255.8300  901.1100
     7    8 13.0   27.2000    0.0086  100.8000   56.0000  655.2800  286.9400  914.1700
     7    8 14.0   27.2000    0.0092  100.8000   51.0000  559.7200  330.8300  846.1100
     7    8 15.0   26.7000    0.0107  100.8000   51.0000  480.5600  320.8300  723.3300
```

```
     7    8 16.0   26.1000    0.0095  100.8000   56.0000  142.7800  348.8900  450.5600
     7    8 17.0   25.6000    0.0092  100.8000   56.0000  447.7800  200.5600  450.2800
     7    8 18.0   25.6000    0.0092  100.8000   61.0000  591.6700  106.9400  331.6700
     7    8 19.0   23.3000    0.0092  100.9000   61.0000  321.1100   64.4400  126.6700
     7    8 20.0   21.1000    0.0082  100.9000   61.0000    0.0000    3.3300    3.3300
     7    8 21.0   20.0000    0.0082  101.0000   36.0000    0.0000    0.0000    0.0000
     7    8 22.0   19.4000    0.0082  101.1000   41.0000    0.0000    0.0000    0.0000
     7    8 23.0   18.9000    0.0085  101.1000   46.0000    0.0000    0.0000    0.0000
     7    8 24.0   18.3000    0.0085  101.1000   36.0000    0.0000    0.0000    0.0000
     7    9  1.0   17.8000    0.0085  101.1000   25.0000    0.0000    0.0000    0.0000
     7    9  2.0   17.2000    0.0085  101.0000   30.0000    0.0000    0.0000    0.0000
     7    9  3.0   15.0000    0.0088  101.0000   41.0000    0.0000    0.0000    0.0000
     7    9  4.0   15.0000    0.0088  101.1000   36.0000    0.0000    0.0000    0.0000
     7    9  5.0   15.0000    0.0088  101.1000   30.0000    0.0000    0.0000    0.0000
     7    9  6.0   16.1000    0.0092  101.2000   30.0000    1.6700   32.2200   32.5000
     7    9  7.0   18.9000    0.0095  101.2000   46.0000  327.2200   98.0600  192.2200
     7    9  8.0   19.4000    0.0099  101.2000   41.0000  546.3900  124.1700  381.6700
     7    9  9.0   21.1000    0.0099  101.2000   41.0000  626.6700  160.0000  560.5600
     7    9 10.0   22.2000    0.0102  101.3000   36.0000  703.3300  184.1700  732.7800
     7    9 11.0   23.9000    0.0106  101.3000   30.0000  779.1700  175.5600  864.7200
     7    9 12.0   25.0000    0.0102  101.2000   41.0000  796.9400  191.3900  944.1700
     7    9 13.0   25.0000    0.0099  101.2000   61.0000  751.6700  251.3900  970.5600
     7    9 14.0   25.6000    0.0095  101.2000   46.0000  496.3900  365.5600  822.2200
     7    9 15.0   26.7000    0.0099  101.1000   36.0000  393.8900  350.2800  680.0000
     7    9 16.0   25.0000    0.0095  101.1000   46.0000  346.3900  309.7200  556.6700
     7    9 17.0   25.6000    0.0092  101.1000   46.0000   30.8300  229.7200  246.9400
     7    9 18.0   25.0000    0.0076  101.2000   41.0000  177.7800  156.9400  224.4400
     7    9 19.0   23.9000    0.0085  101.2000   41.0000  183.3300   69.4400  104.7200
     7    9 20.0   21.7000    0.0082  101.3000   36.0000    0.0000    2.7800    2.7800
     7    9 21.0   20.6000    0.0082  101.3000   20.0000    0.0000    0.0000    0.0000
     7    9 22.0   21.1000    0.0088  101.4000   61.0000    0.0000    0.0000    0.0000
     7    9 23.0   18.9000    0.0079  101.4000   51.0000    0.0000    0.0000    0.0000
     7    9 24.0   19.4000    0.0079  101.4000    0.0000    0.0000    0.0000    0.0000
```

Listing 23. Interactive session to generate a weather data file artificially.

```
C:\HVACSIM20\WORK>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 file by program rdwdf)
 2 - to generate clear sky design data
 3 - to generate cloudy sky design data

=> 2
  Enter output file name (up to 40 characters)
 or carriage return for default name: hvacsim.met
=> onezone.met
  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 (%)
=> 101.3, 0.0, 80.0
  Enter minimum and maximum temperatures (C):
=> 20.0, 30.0
  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
---- End of creating weather file ------
```

Listing 24. The artificially generated weather data file (*onezone.met*)

```
    7    7     38.85     77.03      5.00    2
    7    7  0.0   21.3000    0.0128  101.3000    0.0000    0.0000    0.0000    0.0000
    7    7  1.0   21.3000    0.0128  101.3000    0.0000    0.0000    0.0000    0.0000
    7    7  2.0   20.8000    0.0124  101.3000    0.0000    0.0000    0.0000    0.0000
    7    7  3.0   20.4000    0.0121  101.3000    0.0000    0.0000    0.0000    0.0000
    7    7  4.0   20.1000    0.0119  101.3000    0.0000    0.0000    0.0000    0.0000
    7    7  5.0   20.0000    0.0118  101.3000    0.0000  170.1502   23.4807   40.4957
    7    7  6.0   20.2000    0.0120  101.3000    0.0000  194.7813   26.8798   47.8847
    7    7  7.0   20.7000    0.0124  101.3000    0.0000  582.1419   80.3356  252.2150
    7    7  8.0   21.6000    0.0131  101.3000    0.0000  741.2581  102.2936  457.3346
    7    7  9.0   22.9000    0.0142  101.3000    0.0000  819.7220  113.1216  643.0477
    7    7 10.0   24.4000    0.0156  101.3000    0.0000  862.7645  119.0615  797.4857
    7    7 11.0   26.1000    0.0173  101.3000    0.0000  886.6649  122.3597  910.6406
    7    7 12.0   27.7000    0.0190  101.3000    0.0000  898.1992  123.9515  975.0670
    7    7 13.0   28.9000    0.0205  101.3000    0.0000  900.1130  124.2156  986.4938
    7    7 14.0   29.7000    0.0215  101.3000    0.0000  892.8299  123.2105  944.1614
    7    7 15.0   30.0000    0.0218  101.3000    0.0000  874.6891  120.7071  850.8807
    7    7 16.0   29.7000    0.0215  101.3000    0.0000  840.9759  116.0547  712.8135
    7    7 17.0   29.0000    0.0206  101.3000    0.0000  780.5695  107.7186  538.9755
    7    7 18.0   27.9000    0.0193  101.3000    0.0000  664.8447   91.7486  340.4997
    7    7 19.0   26.6000    0.0178  101.3000    0.0000  403.6763   55.7073  131.0875
    7    7 20.0   25.3000    0.0165  101.3000    0.0000  170.1502   23.4807   40.4957
    7    7 21.0   24.2000    0.0154  101.3000    0.0000    0.0000    0.0000    0.0000
    7    7 22.0   23.2000    0.0145  101.3000    0.0000    0.0000    0.0000    0.0000
    7    7 23.0   22.4000    0.0138  101.3000    0.0000    0.0000    0.0000    0.0000
    7    7 24.0   21.8000    0.0133  101.3000    0.0000    0.0000    0.0000    0.0000
    7    8  1.0   21.3000    0.0128  101.3000    0.0000    0.0000    0.0000    0.0000
    7    8  2.0   20.8000    0.0124  101.3000    0.0000    0.0000    0.0000    0.0000
    7    8  3.0   20.4000    0.0121  101.3000    0.0000    0.0000    0.0000    0.0000
    7    8  4.0   20.1000    0.0119  101.3000    0.0000    0.0000    0.0000    0.0000
    7    8  5.0   20.0000    0.0118  101.3000    0.0000  170.1502   23.4807   40.4957
    7    8  6.0   20.2000    0.0120  101.3000    0.0000  189.4346   26.1420   46.2459
    7    8  7.0   20.7000    0.0124  101.3000    0.0000  580.1869   80.0658  250.4581
    7    8  8.0   21.6000    0.0131  101.3000    0.0000  740.4184  102.1777  455.7845
    7    8  9.0   22.9000    0.0142  101.3000    0.0000  819.2831  113.0611  641.7191
    7    8 10.0   24.4000    0.0156  101.3000    0.0000  862.5037  119.0255  796.3788
    7    8 11.0   26.1000    0.0173  101.3000    0.0000  886.4948  122.3363  909.7438
    7    8 12.0   27.7000    0.0190  101.3000    0.0000  898.0789  123.9349  974.3557
    7    8 13.0   28.9000    0.0205  101.3000    0.0000  900.0196  124.2027  985.9312
    7    8 14.0   29.7000    0.0215  101.3000    0.0000  892.7477  123.1992  943.7010
    7    8 15.0   30.0000    0.0218  101.3000    0.0000  874.6019  120.6951  850.4693
    7    8 16.0   29.7000    0.0215  101.3000    0.0000  840.8578  116.0384  712.3941
    7    8 17.0   29.0000    0.0206  101.3000    0.0000  780.3615  107.6899  538.4907
    7    8 18.0   27.9000    0.0193  101.3000    0.0000  664.3658   91.6825  339.8946
    7    8 19.0   26.6000    0.0178  101.3000    0.0000  402.1967   55.5031  130.3312
    7    8 20.0   25.3000    0.0165  101.3000    0.0000  170.1502   23.4807   40.4957
    7    8 21.0   24.2000    0.0154  101.3000    0.0000    0.0000    0.0000    0.0000
    7    8 22.0   23.2000    0.0145  101.3000    0.0000    0.0000    0.0000    0.0000
    7    8 23.0   22.4000    0.0138  101.3000    0.0000    0.0000    0.0000    0.0000
    7    8 24.0   21.8000    0.0133  101.3000    0.0000    0.0000    0.0000    0.0000
```

5.1.3 Simulation work file (*onezone.sim*)

Listing 25. is the simulation work file generated by using HVACGEN. No interactive session is shown here.

5.1.4 Model definition file (*onezone.dfn*)

Listings 26 and **27** show the interactive session of running SLIMCON to create the model definition file and the resulting model definition file, respectively.

5.1.5 Boundary data file (*onezone.bnd*)

No *boundary* variable is used, but the boundary data file must exist in a simulation. Null value is used as seen in **Listing 28.**

5.1.6 Model information file (*onezone.model*)

Listing 29 shows the supplemental unit information file and **Listing 30** is the model information file obtained by executing UPD_INFO.

Listing 25. The simulation work file (*onezone.sim*).

```
ONE ZONE MODEL
   2                                              (Superblocks in simulation)
   0.100000E-03   0.100000E-04   0.200000E-03   0.100000E+01    (Error Tol.)
   2                                              (Blocks in SB# 1)
   8                                              (Units in BLK# 1)
   1  50 ----------------------------------------(Unit #,Type #)----------
    1    1    2    2    3    4    5    6    7    8    8    8    8
   10    3
   0.100000E+01   0.700000E+01
   2  51 ----------------------------------------(Unit #,Type #)----------
    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 ----------------------------------------(Unit #,Type #)----------
    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 ----------------------------------------(Unit #,Type #)----------
    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 ----------------------------------------(Unit #,Type #)----------
   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 ----------------------------------------(Unit #,Type #)----------
   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 ----------------------------------------(Unit #,Type #)----------
   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 ----------------------------------------(Unit #,Type #)----------
   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                                         (Units in BLK# 2)
  9  53 ----------------------------------------(Unit #,Type #)----------
  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                                         (Blocks in SB# 2)
  1                                         (Units in BLK# 3)
 10  52 ----------------------------------------(Unit #,Type #)----------
   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                         (Boundary Variables in simulation)

 13   0.900000E+03     (Reported Var. & Interval in SB# 1)
   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   0.900000E+03     (Reported Var. & Interval in SB# 2)
   5   30
   3    8
   1    1
  0   0
  0   0
```

```
**************** SUMMARY OF WORK FILE ***************
   2   3  10                                     (Superblocks, Blocks, Units)
   2   1
   3   1  12   5   0   0   8   3                 (Variables per category)
  32                                             (State Variables)
  13   2
```

Listing 26. SLIMCON run to create the model definition file.

```
C:\HVACSIM20\WORK>slimcon
 ----------------------------------------------------------
 *                                                        *
 *                    SLIMCON                             *
 *                                                        *
 * Converts simulation work file to model definition file *
 *             Version 6.0 ( April 10, 2007)              *
 *                                                        *
 ----------------------------------------------------------
 Enter the simulation file name (up to 46 characters)
 without any extension, or carriage return to end.
=> onezone
 Do you want to allow algebraic variables to be inputs
  and outputs of the same unit? (y/n) (default= no)
=>
----------------------------------------
 iu  itype nsaved iude nnin nnout nnpar
----------------------------------------
   1   50      0    0   13    2    2
   2   51     57    0    4    2   14
   3   51     57    0    4    2   14
   4   51     57    0    4    2   14
   5   51     57    0    4    2   14
   6   51     57    0    4    2   14
   7   51     57    0    4    2   14
   8   51     57    0    4    2   14
   9   53      0    0    6    0    6
  10   52      0    2   11    4   12

                   ========= SLIMCON SUMMARY ==========

             2 Superblocks in the simulation .......... maxsbk =  40 (  5.0%)
             3 Blocks in the simulation ............... maxblk =  50 (  6.0%)
             2 Differential equations in the simulation maxdeq =  90 (  2.2%)
           399 Saved variables in the simulation ...... maxsav =9000 (  4.4%)
            10 Units in the simulation ................ maxunt = 400 (  2.5%)
             8 Units in a single block ................ muntib =  40 ( 20.0%)
             2 Differential equations in one unit ..... mdeqiu =  10 ( 20.0%)
            13 Inputs or outputs in a single unit ..... minoiu =  50 ( 26.0%)
            14 Parameters in a single unit ............ mpariu =  30 ( 46.7%)
             2 Blocks in the largest superblock ....... mblkis =  20 ( 10.0%)
             2 Differential equations in one superblock mdeqis =  50 (  4.0%)
            32 State variables in the simulation ...... maxstv =3000 (  1.1%)
            14 Inputs or outputs in a single block .... minoib = 200 (  7.0%)
           118 Unit parameters in the simulation ...... maxpar =5000 (  2.4%)
             8 Simultaneous equations in a single block mseqib =  75 ( 10.7%)
             0 Simultaneous equations in one superblock mseqis =  20 (  0.0%)
             0 Time dependent boundary variables ...... maxbnd =  50 (  0.0%)
```

```
            0 Boundary conditions in one superblock .. mbndis =  50 (  0.0%)
           13 Reported variables in one superblock ... mrptis =  60 ( 21.7%)

Model definition file completed
Program Completed
```

Listing 27. The model definition file (*onezone.dfn*).

```
title: simulation title
 ONE ZONE MODEL
 nstate,nsblok: # of state variables, # of SBS
   32    2
 nsuper(s): # of blocks in each SB
    2    1
 state(i): vector of state variable initial values
   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
 ndent(i): state variable identification vector
    0    3    4   16   -1   -1   21   29
 nunits(b): # of units in each block B
    8    1    1
 njsslv(s): # of simultaneous eqs in each SB
    0    0
 njsolv(b): # of simultaneqou eqs in each block
    8    0    2
 isuper(s,i): array of block numbers in each SB
    1    2
    3
 iblock(b,i): array of unit numbers in each block
    1    2    3    4    5    6    7    8
    9
   10
 iunits(u): array of type #s for each unit
   50   51   51   51   51   51   51   51   53   52
 nin(u): number of inputs to unit u
   13    4    4    4    4    4    4    4    6   11
 in(u,i): array of input connections for unit U
    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
 nout(u): number of outputs from unit U
    2    2    2    2    2    2    2    2    0    4
 iout(u,i): array of output connections for unit U
```

```
  14   24
   8    0
   7    0
   6    0
   9    0
  11    0
  10   26
  12   25

   5   30   22   23
jssolv(s,i): array of variables solved
 simultaneously within each sb (between blocks)
   0
   0
jsolve(b,i): array of variables solved
 simultaneously within each block
   8    7    6    9   11   10   12   14
   0
   5   30
nde(u): # of differential eqs in unit U
   0    0    0    0    0    0    0    0    0    2
inde(u,i): de index for the ith de in unit U
   0
   0
   0
   0
   0
   0
   0
   0
   0
   1    2
idevar(d): variable index for de #d
   5   30
isaved(u): index of first saved var. for unit U
   1    1   58  115  172  229  286  343  400  400
jpar(u): index of first parameter for unit U
   1    3   17   31   45   59   73   87  101  107
npar,nsaved: # of parameters & saved variables
 118  399
par(i): array of parameters for all units
  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
nbound: # of time-dependent boundary variables
   0
ibound(i) state variable indices of boundary variables.

nreprt(s): # of reported variables in each SB
  13    2
treprt(s): reporting interval for each SB
  0.900000E+03   0.900000E+03
ireprt(i): indices of reported variables
ident1: category # of reported variables
ident2: position in category of reported variables
   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
rtolx,atolx, xtol,ttime: error tolerances
  0.100000E-03   0.100000E-04   0.200000E-03   0.100000E+01
ifzopt(s): sb variable unfreezing option vector
   0    0
insopt(s): sb input scan option vector
   0    0
```

Listing 28. The boundary data file (*onezone.bnd*).

```
0.0
```

Listing 29. The supplemental unit information file (*onezone.inf*).

```
  1  One zone envelope
  2  Ceiling
  3  Floor
  4  West wall
  5  East wall
  6  North wall
  7  South wall
  8  South window
  9  Weather
 10  Zone
```

Listing 30. The model information file (*onezone.model*).

```
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 -----  One zone envelope
 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 -----  Ceiling
 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)
           0.00000     orient: azimuth angle of normal to surface & south
           0.00000     tilt:   tilt angle: flat roof=0, floor=180 (degree)
           0.00000     grf:    ground reflectivity (-)
           0.00000     irofs:  outer surface roughness index: 1=stucco,...
```

```
          0.00000     absos:  solar absorptance of outer surface (-)
         0.600000     absis:  short wave absorptance of inner surface(-)
         0.900000     emitis: emissivity of the inner surface (-)
          0.00000     transm: transmittance of the glass window (-)
          0.00000     sc:     shading coeff. of the glass window (-)

UNIT   3      TYPE  51 -----  Floor
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)
          0.00000     orient: azimuth angle of normal to surface & south
          180.000     tilt:   tilt angle: flat roof=0, floor=180 (degree)
          0.00000     grf:    ground reflectivity (-)
          0.00000     irofs:  outer surface roughness index: 1=stucco,...
          0.00000     absos:  solar absorptance of outer surface (-)
         0.600000     absis:  short wave absorptance of inner surface(-)
         0.900000     emitis: emissivity of the inner surface (-)
          0.00000     transm: transmittance of the glass window (-)
          0.00000     sc:     shading coeff. of the glass window (-)

UNIT   4      TYPE  51 -----  West wall
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)
          0.00000     grf:    ground reflectivity (-)
          0.00000     irofs:  outer surface roughness index: 1=stucco,...
          0.00000     absos:  solar absorptance of outer surface (-)
         0.600000     absis:  short wave absorptance of inner surface(-)
         0.900000     emitis: emissivity of the inner surface (-)
          0.00000     transm: transmittance of the glass window (-)
          0.00000     sc:     shading coeff. of the glass window (-)

UNIT   5      TYPE  51 -----  East wall
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)
          0.00000     grf:    ground reflectivity (-)
          0.00000     irofs:  outer surface roughness index: 1=stucco,...
          0.00000     absos:  solar absorptance of outer surface (-)
         0.600000     absis:  short wave absorptance of inner surface(-)
         0.900000     emitis: emissivity of the inner surface (-)
          0.00000     transm: transmittance of the glass window (-)
          0.00000     sc:     shading coeff. of the glass window (-)

UNIT   6      TYPE  51 -----  North wall
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)
          0.00000     grf:    ground reflectivity (-)
          0.00000     irofs:  outer surface roughness index: 1=stucco,...
          0.00000     absos:  solar absorptance of outer surface (-)
         0.600000     absis:  short wave absorptance of inner surface(-)
         0.900000     emitis: emissivity of the inner surface (-)
          0.00000     transm: transmittance of the glass window (-)
          0.00000     sc:     shading coeff. of the glass window (-)

UNIT   7      TYPE  51 -----  South wall
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)
          0.00000     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 (-)
          0.00000     transm: transmittance of the glass window (-)
          0.00000     sc:     shading coeff. of the glass window (-)

UNIT   8      TYPE  51 -----  South window
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)
          0.00000     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,...
          0.00000     absos:  solar absorptance of outer surface (-)
          0.00000     absis:  short wave absorptance of inner surface(-)
          0.00000     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
Weather input

1     INPUTS:
       TEMPERATURE     12 - tamb:   ambient (outdoor) air temperature (C)
       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
Zone model

1     INPUTS:
       PRESSURE         1 - piag:   gauge pressure of zone air
       TEMPERATURE      1 - tia:    zone air dry-bulb temperature
       HUMIDITY         1 - wia:    humidiy ratio of zone air
       PRESSURE         2 - psag:   gauge pressure of supply air
       FLOW             1 - msa:    mass flow rate of supply air
       TEMPERATURE     11 - tsa:    supply air dry-bulb temperature
       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.]
       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 ->     0.00000                (kPa)
PRESSURE         2 ->     0.00000                (kPa)
PRESSURE         3 ->     101.300                (kPa)
FLOW             1 ->     0.00000                (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 ->     0.00000                (-)
CONTROL          5 ->     1.00000                (-)
POWER            1 ->     0.00000                (kW)
POWER            2 ->     0.00000                (kW)
POWER            3 ->     0.00000                (kW)
POWER            4 ->     0.00000                (kW)
POWER            5 ->     0.00000                (kW)
POWER            6 ->     0.00000                (kW)
POWER            7 ->     0.00000                (kW)
POWER            8 ->     0.00000                (kW)
HUMIDITY         1 ->    0.740000E-02            (kg/kg)
HUMIDITY         2 ->    0.740000E-02            (kg/kg)
HUMIDITY         3 ->    0.740000E-02            (kg/kg)
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:


SUPERBLOCK 1      REPORTING INTERVAL    900.000
```

```
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    900.000
TEMPERATURE      1
HUMIDITY         1
```

5.2 Building Shell Simulation using MODSIM

A building shell simulation requires two simulation runs. A 24-hour time history of heat flux transfer functions of shell surfaces is determined in the first simulation and saved in the final *state* variable file (*hvacsim.fin*) to be used as initialization of a main simulation. In this first simulation, the maximum time step of simulation is the time step for building shell computation. The stopping time of simulation is 86400 s (one day).

After renaming or copying the final *state* variable file (*hvacsim.fin*) into the initialization file (*hvacsim.ini*), execute MODSIM again to perform the main simulation. The maximum time step can be much smaller than the shell time step, and the stopping time can be many days or weeks. The interactive sessions of these two simulations are shown in **Listing 31**. The simulation summary and output files are shown in **Listings 32** and **33**. After sorting the simulation output file *superblock* by *superblock*, the simulation results are plotted as shown in **Figures 12-14.** Note that there are some discrepancies between the current results and the old results reported in Reference 4. Revisions in the thermal property data result in changes to the values of conduction transfer functions and heat fluxes. Consequently slightly different outputs were obtained. With the simulation control input data files as given in **Listings 34** and **35**, MODSIM can be executed using the redirecting method. Two steps for the building shell simulation using the redirecting method are shown in **Listing 36**.

Listing 31. Interactive session of running MODSIM in two steps for building shell simulation.

```
C:\HVACSIM20\WORK>copy hvacsim.ctf onezone.ctf
        1 file(s) copied.

C:\HVACSIM20\WORK>modsim

       *************************************************
       *                                               *
       *   MODSIM   : A MODular SIMulation program     *
       *      Main program of HVACSIM+ package         *
       *                                               *
       *                 version 20.0                  *
       *                                               *
```

```
       * National Institute of Standards & Technology  *
       *   Gaithersburg, Maryland 20899-8631  U.S.A.   *
       *                                               *
       *************************************************


 Enter minimum time step, maximum time step, and simulation stopping time:
=> 0.1 900.0 86400.0
  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 :
=> 0.0
 Use same file names for all files? (y/n) <y>
=> y
 Enter the name for all files to open or
hit carriage return for default filename <hvacsim>
=> onezone

      File name : onezone.dfn

      File name : onezone.bnd

      File name : onezone.fin

      File name : onezone.out

      File name : onezone.sum

      File name : onezone.ctf

      File name : onezone.met
  -- The outputs can be written to the output file
  -- based on either simulation time or reported time.

 Do you want to use reported time for outputs <n>?
=> y

 Do you wish to disable freezing variable feature <n>?
=> n

 Do you want diagnostic information to be written <n>?
=> n
 Would you like to monitor simulation on screen? <n>
=> n
   ------- simulation begins ---------
--  first weather data set has been read
time=    900.00
time=   1800.00
time=   2700.00
time=   3600.00

--------------------- ( Many lines are deleted. ) -------------------------
```

```
time=  84600.00
time=  85500.00
time=  86400.00
 --Final state file has been written -----
   ------------End of simulation ---------
Program Completed
Press Enter to Continue.


C:\HVACSIM20\WORK>copy onezone.fin onezone.ini
Overwrite onezone.ini? (Yes/No/All): y
        1 file(s) copied.

C:\HVACSIM20\WORK>modsim

       *************************************************
       *                                               *
       *   MODSIM   : A MODular SIMulation program     *
       *      Main program of HVACSIM+ package         *
       *                                               *
       *                 version 20.0                  *
       *                                               *
       * National Institute of Standards & Technology  *
       *   Gaithersburg, Maryland 20899-8631  U.S.A.   *
       *                                               *
       *************************************************


 Enter minimum time step, maximum time step, and simulation stopping time:
=> 0.1 900.0 172800.0
  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 :
=> 0.0
 Use same file names for all files? (y/n) <y>
=> y
 Enter the name for all files to open or
hit carriage return for default filename <hvacsim>
=> onezone

      File name : onezone.dfn

      File name : onezone.bnd

      File name : onezone.ini

      File name : onezone.fin

      File name : onezone.out

      File name : onezone.sum

      File name : onezone.ctf
```

```
      File name : onezone.met
  -- The outputs can be written to the output file
  -- based on either simulation time or reported time.

 Do you want to use reported time for outputs <n>?
=> y

 Do you wish to disable freezing variable feature <n>?
=> n

 Do you want diagnostic information to be written <n>?
=> n
 Would you like to monitor simulation on screen? <n>
=> n
   ------- simulation begins ---------
--  first weather data set has been read
time =    900.0 snsq - iteration not making good progress.iblk=  1
time=    900.00
time=   1800.00
time=   2700.00
time=   3600.00

--------------------- ( Many lines are deleted. ) -------------------------

time= 170100.00
time= 171000.00
time= 171900.00
time= 172800.00
 --Final state file has been written -----
   ------------End of simulation ---------
Program Completed
```

Listing 32. The simulation summary file (*onezone.sum*).

```
          ***** 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 humt

 initial state vector:

  pres:
      0.00000        0.00000        101.300

  flow:
      0.00000

  temp:
      20.0001        20.5646        20.9086        20.9108        20.5734
      22.0071        20.5731        21.1417        20.0000        21.0353
      20.0000        21.6693

  ctrl:
      1.00000        1.00000        1.00000        0.00000        1.00000

  powr:
     4.000000E-02   0.135232       0.177709        0.00000        0.00000
      0.00000        0.00000        0.00000
```

```
 humt:
    7.400014E-03   7.400000E-03   1.318133E-02

 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   temp 10
temp 12   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   temp 10

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:
temp 10   powr  3

parameters:
     1.0000         7.0000

unit   2     type 51

  4 inputs:
temp  1   temp 10   temp  9   ctrl  5

  2 outputs:
temp  4   null  0

parameters:
     1.0000         1.0000         1.0000         1.0000         37.210
     0.0000         0.0000         0.0000         0.0000         0.0000
    0.60000        0.90000         0.0000         0.0000

unit   3     type 51

  4 inputs:
temp  1   temp 10   temp  9   ctrl  5

  2 outputs:
temp  3   null  0

parameters:
     1.0000         2.0000         1.0000         2.0000         37.210
     0.0000         180.00         0.0000         0.0000         0.0000
    0.60000        0.90000         0.0000         0.0000

unit   4     type 51

  4 inputs:
temp  1   temp 10   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         0.0000         0.0000         0.0000
    0.60000        0.90000         0.0000         0.0000

unit   5     type 51

  4 inputs:
temp  1   temp 10   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         0.0000         0.0000         0.0000
    0.60000        0.90000         0.0000         0.0000

unit   6     type 51

  4 inputs:
temp  1   temp 10   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         0.0000         0.0000         0.0000
    0.60000        0.90000         0.0000         0.0000

unit   7     type 51

  4 inputs:
temp  1   temp 10   temp  6   ctrl  4

  2 outputs:
temp  6   powr  5

parameters:
     1.0000         6.0000         2.0000         4.0000         18.400
     0.0000         90.000        0.20000         2.0000        0.60000
    0.60000        0.90000         0.0000         0.0000

unit   8     type 51

  4 inputs:
temp  1   temp 10   temp  8   ctrl  4

  2 outputs:
temp  8   powr  4

parameters:
     1.0000         7.0000         2.0000         5.0000         6.0000
     0.0000         90.000        0.20000         6.0000         0.0000
     0.0000         0.0000        0.95000        0.85000

***** block  2 *****

 0 simultaneous equations; variables:

unit   9     type 53

  6 inputs:
temp 12   humt  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   humt  1

 0 simultaneous equations; variables:

***** block  3 *****

 2 simultaneous equations; variables:
temp  1   humt  1

unit  10     type 52

 11 inputs:
pres  1   temp  1   humt  1   pres  2   flow  1   temp 11   humt  2   powr  3
ctrl  1   ctrl  2   ctrl  3

  4 outputs:
temp  1   humt  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 =       0.100  tmax =     900.000  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=    900.00
temp  2   temp  3   temp  4   temp  5   temp  6   temp  7   temp  8   temp 10
  22.8      27.6      24.8      22.7      24.3      22.7      25.3      21.0
temp 12   powr  3   powr  6   powr  7   powr  8
  21.7     0.187      0.00      0.00      0.00

********** SUPERBLOCK  2 **********
time=    900.00
temp  1   humt  1
  20.9     7.516E-03

********** SUPERBLOCK  2 **********
time=   1800.00
temp  1   humt  1
  22.8     7.629E-03

********** SUPERBLOCK  1 **********
time=   1800.00
temp  2   temp  3   temp  4   temp  5   temp  6   temp  7   temp  8   temp 10
  22.4      23.8      23.2      22.4      24.1      22.4      23.6      23.2
temp 12   powr  3   powr  6   powr  7   powr  8
  21.6     0.574      0.00      0.00      0.00

********** SUPERBLOCK  2 **********
time=   2700.00
temp  1   humt  1
  23.7     7.742E-03

********** SUPERBLOCK  1 **********
```

```
time=   2700.00
temp  2   temp  3   temp  4   temp  5   temp  6   temp  7   temp  8   temp 10
  22.2      22.9      22.8      22.1      23.9      22.1      23.0      22.8
temp 12   powr  3   powr  6   powr  7   powr  8
  21.4    -1.678E-02  0.00      0.00      0.00

********** SUPERBLOCK  2 **********
time=   3600.00
temp  1   humt  1
  24.0     7.854E-03

********** SUPERBLOCK  1 **********
time=   3600.00
temp  2   temp  3   temp  4   temp  5   temp  6   temp  7   temp  8   temp 10
  22.0      22.7      22.6      22.0      23.8      22.0      22.6      22.6
temp 12   powr  3   powr  6   powr  7   powr  8
  21.3    -0.271      0.00      0.00      0.00
```

Listing 33. The simulation output file (*onezone.out*).

```
SUPERBLOCK 1    900.00
    22.7689        27.5906        24.8002        22.7290        24.3389
    22.7287        25.2990        21.0368        21.7440       0.186918
    0.00000        0.00000        0.00000
SUPERBLOCK 2    900.00
    20.8761       7.519144E-03
SUPERBLOCK 2   1800.00
    22.7966       7.631347E-03
SUPERBLOCK 1   1800.00
    22.1512        22.9318        22.7652        22.1494        23.9234
    22.1494        22.9529        22.8063        21.4415      -1.671911E-02
    0.00000        0.00000        0.00000
SUPERBLOCK 2   2700.00
    23.7598       7.744590E-03
SUPERBLOCK 1   2700.00
    22.0239        22.7012        22.5775        22.0331        23.8129
    22.0330        22.6222        22.6455        21.3000      -0.270597
    0.00000        0.00000        0.00000
SUPERBLOCK 2   3600.00
    23.9931       7.856909E-03
SUPERBLOCK 1   3600.00
    21.9378        22.6198        22.4793        21.9547        23.7174
    21.9544        22.4457        22.5566        21.1652      -0.374308
    0.00000        0.00000        0.00000
SUPERBLOCK 2   4500.00
    23.8194       7.966517E-03
SUPERBLOCK 1   4500.00
    21.8566        22.5247        22.3980        21.8784        23.6149
    21.8779        22.2938        22.4683        21.0369      -0.346931
    0.00000        0.00000        0.00000
SUPERBLOCK 2   5400.00
    23.5564       8.072672E-03
SUPERBLOCK 1   5400.00
    21.7736        22.4148        22.3189        21.7980        23.5027
    21.7974        22.1367        22.3740        20.9152      -0.292846
    0.00000        0.00000        0.00000
SUPERBLOCK 2   6300.00
    23.3787       8.173795E-03
SUPERBLOCK 1   6300.00
    21.6953        22.3177        22.2470        21.7211        23.3884
    21.7203        21.9906        22.2856        20.8001      -0.264776
    0.00000        0.00000        0.00000
SUPERBLOCK 2   7200.00
    23.2674       8.271983E-03
SUPERBLOCK 1   7200.00
```

```
    21.6250        22.2377        22.1836        21.6516        23.2769
    21.6507        21.8722        22.2072        20.6914      -0.255266
    0.00000        0.00000        0.00000
SUPERBLOCK 2   8100.00
    23.1777       8.367425E-03
SUPERBLOCK 1   8100.00
    21.5625        22.1688        22.1268        21.5895        23.1699
    21.5886        21.7696        22.1369        20.5889      -0.249601
    0.00000        0.00000        0.00000
SUPERBLOCK 2   9000.00
    23.1005       8.460276E-03
SUPERBLOCK 1   9000.00
    21.5070        22.1079        22.0751        21.5341        23.0681
    21.5331        21.6920        22.0738        20.4919      -0.246865
    0.00000        0.00000        0.00000
SUPERBLOCK 2   9900.00
    23.0287       8.550673E-03
SUPERBLOCK 1   9900.00
    21.4572        22.0523        22.0274        21.4843        22.9715
    21.4833        21.6237        22.0160        20.4001      -0.243560
    0.00000        0.00000        0.00000
SUPERBLOCK 2  10800.00
    22.9637       8.638764E-03
SUPERBLOCK 1  10800.00
    21.4123        22.0013        21.9828        21.4393        22.8801
    21.4383        21.5611        21.9630        20.3133      -0.240724
    0.00000        0.00000        0.00000

--------------------( Many lines are deleted. ) ------------------------------------------

SUPERBLOCK 2 169200.00
    23.9381       1.827490E-02
SUPERBLOCK 1 169200.00
    21.9976        22.8677        23.0474        22.0428        24.3781
    22.0409        22.9062        22.8295        22.2383      -0.263689
    0.00000        0.00000        0.00000
SUPERBLOCK 2 170100.00
    23.8469       1.824120E-02
SUPERBLOCK 1 170100.00
    21.9391        22.7900        22.9650        21.9831        24.2464
    21.9813        22.7904        22.7514        22.0846      -0.260572
    0.00000        0.00000        0.00000
SUPERBLOCK 2 171000.00
    23.7609       1.820589E-02
SUPERBLOCK 1 171000.00
    21.8841        22.7163        22.8863        21.9270        24.1207
    21.9252        22.6812        22.6774        21.9402      -0.257703
    0.00000        0.00000        0.00000
SUPERBLOCK 2 171900.00
    23.6797       1.816908E-02
SUPERBLOCK 1 171900.00
    21.8324        22.6464        22.8110        21.8741        24.0006
    21.8724        22.5776        22.6072        21.8029      -0.255051
    0.00000        0.00000        0.00000
SUPERBLOCK 1 172800.00
    21.7890        22.5948        22.7448        21.8299        23.8903
    21.8282        22.4920        22.5483        21.8000      -0.272467
    0.00000        0.00000        0.00000
SUPERBLOCK 2 172800.00
    23.5657       1.813192E-02
```

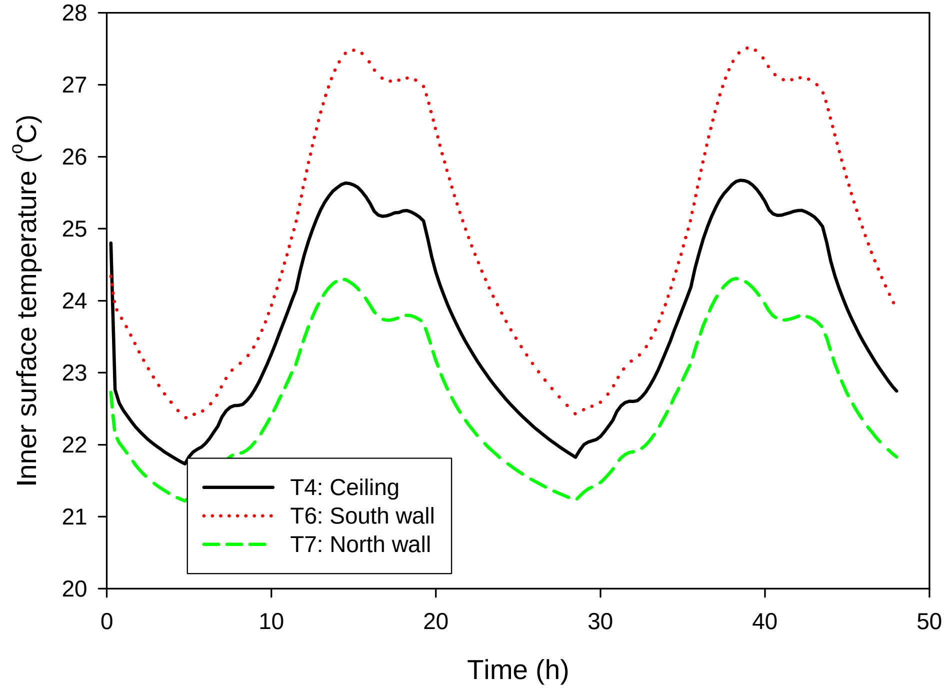

Figure 12. Inner surface temperatures of the single-zone model.

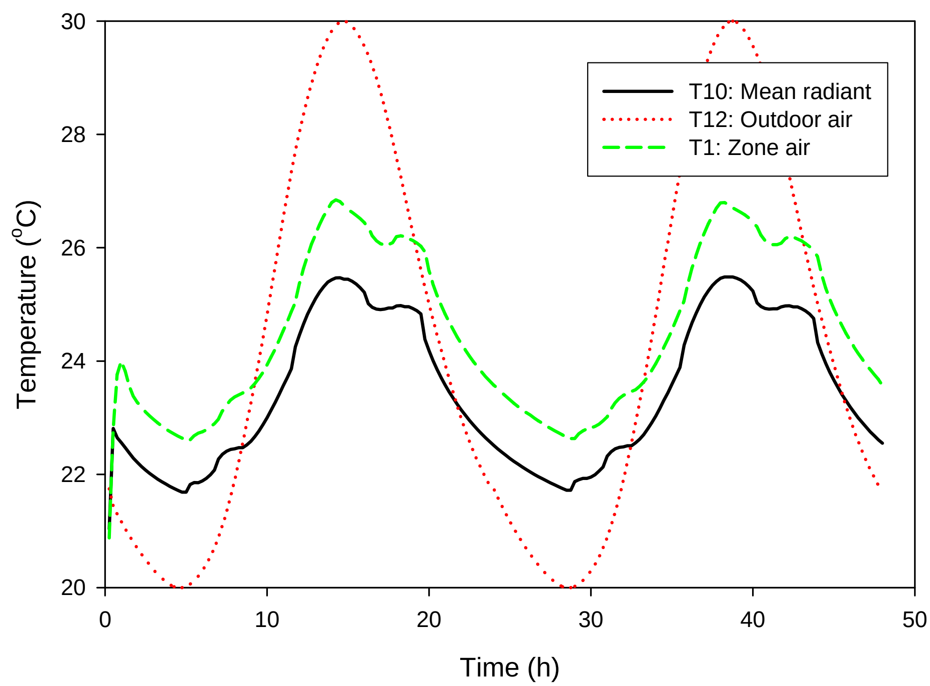

Figure 13. The outdoor air, zone air, and mean radiant temperatures of the single-zone model.

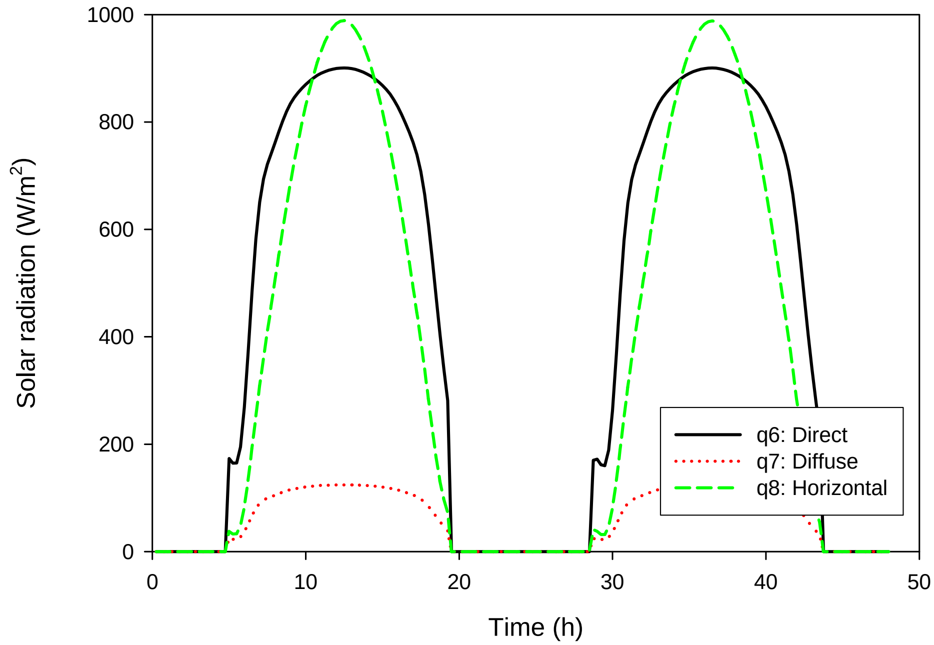

Figure 14. Artificially generated solar radiation influxes.

Listing 34. The simulation control input data in path 1.

```
0.1 900. 86400.         ( tmin, tmax, tstop )
y                       ( building shell use )
n                       ( initialization file use )
y                       ( shell only )
1                       ( superblock number for shell )
0.0                     ( beginning time of day )
n                       ( default file use )
onezone.dfn
onezone.bnd
onezone.fin
onezone.out
onezone.sum
ctfdata.dat
onezone.met
y                       ( reporting time for output )
n                       ( disabling freezing variable feature )
n                       ( diagnostic information )
n                       ( monitoring on screen )
```

Listing 35. The simulation control input data in path 2.

```
0.1 900. 172800.        ( tmin, tmax, tstop )
y                       ( building shell use )
y                       ( initialization file use )
1                       ( superblock number for shell )
0.0                     ( beginning time of day )
n                       ( default file use )
onezone.dfn
onezone.bnd
onezone.ini
onezone.fin
onezone.out
onezone.sum
ctfdata.dat
onezone.met
y                       ( reporting time for output )
n                       ( disabling freezing variable feature )
n                       ( diagnostic information )
n                       ( monitoring on screen )
```

Listing 36. Batch job of running MODSIM with the simulation control input data files.

```
C:\HVACSIM20\work1>modsim < path_1_onezone.inp

       *************************************************
       *                                               *
       *   MODSIM   : A MODular SIMulation program     *
       *      Main program of HVACSIM+ package         *
       *                                               *
       *                 version 20.0                  *
       *                                               *
       * National Institute of Standards & Technology  *
       *   Gaithersburg, Maryland 20899-8631  U.S.A.   *
       *                                               *
       *************************************************


 Enter minimum time step, maximum time step, and simulation stopping time:
=>   Is the building shell model used? <n>
=>   Will the initialization file be called? <n>
=>  Simulate building shell only? <n>
=>    Only the superblock containing the building model will be called.

  What is the index number of the superblock for the building shell?
=>   isshel = 1

 Enter the time of day (in hours after midnight)
 at which the simulation is to begin :
=>  Use same file names for all files? (y/n) <y>
=>  Enter the name of the model definition file,
or carriage return for default name:  hvacsim.dfn
=>  Enter the name of the boundary variable file,
or carriage return for default name:  hvacsim.bnd
=>  Enter the name of the final state file,
or carriage return for default name:  hvacsim.fin
```

```
=>  Enter the name of the output data file,
or carriage return for default name:  hvacsim.out
=>  Enter the name of the simulation summary file,
or carriage return for default name:  hvacsim.sum
=>  Enter the name of the ctf file,
or carriage return for default name:  hvacsim.ctf
=>  Enter the name of the weather data file,
or carriage return for default name:  hvacsim.met
=>   -- The outputs can be written to the output file
  -- based on either simulation time or reported time.

 Do you want to use reported time for outputs <n>?
=>
 Do you wish to disable freezing variable feature <n>?
=>
 Do you want diagnostic information to be written <n>?
=>  Would you like to monitor simulation on screen? <n>
=>    ------- simulation begins ---------
--  first weather data set has been read
time=    900.00
time=   1800.00
time=   2700.00
time=   3600.00
time=   4500.00
time=   5400.00
time=   6300.00
time=   7200.00
time=   8100.00
time=   9000.00

-------------------- (Many lines are deleted.)-------------------------------

time=  83700.00
time=  84600.00
time=  85500.00
time=  86400.00
 --Final state file has been written -----
   ------------End of simulation ---------
Program Completed
Press Enter to Continue.

C:\HVACSIM20\work1>copy onezone.fin onezone.ini
        1 file(s) copied.

C:\HVACSIM20\work1>modsim < path_2_onezone.inp

       *************************************************
       *                                               *
       *   MODSIM   : A MODular SIMulation program     *
       *      Main program of HVACSIM+ package         *
       *                                               *
       *                 version 20.0                  *
       *                                               *
       * National Institute of Standards & Technology  *
       *   Gaithersburg, Maryland 20899-8631  U.S.A.   *
       *                                               *
       *************************************************



 Enter minimum time step, maximum time step, and simulation stopping time:
=>   Is the building shell model used? <n>
=>   Will the initialization file be called? <n>
=>
```

```
  What is the index number of the superblock for the building shell?
=>   isshel = 1

 Enter the time of day (in hours after midnight)
 at which the simulation is to begin :
=>  Use same file names for all files? (y/n) <y>
=>  Enter the name of the model definition file,
or carriage return for default name:  hvacsim.dfn
=>  Enter the name of the boundary variable file,
or carriage return for default name:  hvacsim.bnd
=>  Enter the name of the initial state file,
or carriage return for default name:  hvacsim.ini
=>  Enter the name of the final state file,
or carriage return for default name:  hvacsim.fin
=>  Enter the name of the output data file,
or carriage return for default name:  hvacsim.out
=>  Enter the name of the simulation summary file,
or carriage return for default name:  hvacsim.sum
=>  Enter the name of the ctf file,
or carriage return for default name:  hvacsim.ctf
=>  Enter the name of the weather data file,
or carriage return for default name:  hvacsim.met
=>   -- The outputs can be written to the output file
  -- based on either simulation time or reported time.

 Do you want to use reported time for outputs <n>?
=>
 Do you wish to disable freezing variable feature <n>?
=>
 Do you want diagnostic information to be written <n>?
=>  Would you like to monitor simulation on screen? <n>
=>    ------- simulation begins ---------
--  first weather data set has been read
time =    900.0 snsq - iteration not making good progress.iblk=  1
time=    900.00
time=   1800.00
time=   2700.00
time=   3600.00
time=   4500.00
time=   5400.00
time=   6300.00
time=   7200.00
time=   8100.00
time=   9000.00

-------------------- (Many lines are deleted.)-------------------------------

time= 169200.00
time= 170100.00
time= 171000.00
time= 171900.00
time= 172800.00
 --Final state file has been written -----
   ------------End of simulation ---------
Program Completed
Press Enter to Continue.
```

6. Useful Information

- ***State* variable freezing and *block* inactivation**

  During a simulation, a *state variable* may reach steady state, i.e. cease to vary with time. If such a state variable is to be solved simultaneously, computation time may be wasted. Removing the variable at steady state from the set of simultaneous equations to save computation time is referred to as *freezing* the variable. After a variable is frozen, it can be returned to the set of simultaneous equations at a later time for calculation. This returning is referred to as *unfreezing*. The unfrozen variable varies with respect to time.

  If all of the simultaneous equations in a *block* are frozen and all of its *block* inputs are frozen, the block is inactive. A block is marked active as soon as one of block inputs becomes unfrozen. See p. 4 of Reference 2.

- **Convergence of the equation solver**

  When a set of equations are solved simultaneous using the nonlinear equation solver, SNSQ, convergence is a problem particularly at the beginning of a simulation, since the initial conditions are arbitrarily chosen by a user. The Gauss-Newton's method which is implemented in SNSQ fails to converge if the initial estimate is too far from the final value. Choosing the appropriate error tolerance, *xtol*, for the equation solver as well as properly estimating the initial values of state variables are important factors in achieving a good convergence. As a rule of thumb, the error tolerance may be equal to or greater than the sum of relative error, *rtolx*, and absolute error, *atolx*. See p. 5 of Reference 2 and p. 16 of Reference 4.

- **Selection of maximum and minimum time step**

  The use of a variable time step and the variable order integration technique in solving ordinary differential equations can reduce computation time. Under certain conditions, a variable time step that is too large can result in erratic values. Reducing the variable time step can eliminate this problem. A user must determine a minimum time step and a maximum time step. The choice of minimum and maximum time steps influence the accuracy and stability of the simulation and computation time. A simulation that contains no differential equation will always proceed at the maximum time step. See p. 6 of Reference 2 and pp. 17-23 of Reference 4.

- **Error tolerances and integration time interval**

  The relative error tolerance, *rtolx*, and the absolute error tolerance, *atolx*, are used in integrating differential equations and choosing the time step size. They are also used in determining when to *freeze* or *unfreeze state* variables. Default values are provided in HVACGEN. Since these default values are chosen arbitrarily, a user may select other values for a particular simulation by trial and error.

The integration time interval, *ttime*, is the time interval between the initial and final time considered in the integration using the backward differential formula. The default value is provided in HVACGEN, but other value may be selected. See pp. 7-8 of Reference 2 and p. 23 of Reference 4.

- **<u>Selection of *iostat*</u>**

Iostat is an input and output status vector given in TYPEn component model.
On entry of a TYPEn subroutine, this vector contains the status of the input variables. On exit, the vector flags whether the output variable is to be frozen or unfrozen. *Iostat* for output variables should always be set to either 0 to enable *freezing* or 1 to disable *freezing*. Set the *iostat* vector size as the same as the number of elements of the output variable vector. See p. 14 of Reference 2.

Possible values of *iostat* are as follows:

-4	time independent boundary condition
-3	time independent boundary condition
-2	frozen output (not solved simultaneously)
-1	output (not solved simultaneously)
0	solved simultaneously, may not be frozen
1	solved simultaneously, may be frozen
2	frozen
3	unfrozen

- **<u>Selection of options for *superblocks*</u>**

Superblocks are assumed to be only weakly coupled. No simultaneous equations are solved between *superblocks*. *Superblocks* are allowed to evolve independently in time.
When the input *scan* option, *insopt*, is set to be equal to 1, all *superblock* inputs are scanned after each time step. This selection increases both the accuracy and the computational requirement of a simulation. When *insopt* is set to 0, each *superblock* is called at times determined by the time step control algorithm, regardless of any changes in its inputs at intermediate times. The value of *insopt* influences the coupling between *superblocks*, and has no effect on a simulation with only a single *superblock*. See pp. 5-6 of Referece 2.

The *superblock* variable *freezing* option, *ifzopt*, determines which *superblock* equations are recalculated when a *superblock* equation unfreezes. The *freezing* option influences the strength of coupling between *superblocks*, and has no effect on simulations with a single *superblock*. Possible values of *ifzopt* are 0, 1, or 2.

If *ifzopt* = 0, a state variable which is unfrozen in a *superblock* equation is not put back into the equation set until the next time step.
If *ifzopt* = 1, any unfrozen variables are put back into the *superblock* equation set and the calculation is repeated.

If *ifzopt* = 2, all *superblock* equations are put back into the equation set and the calculation is done again.

The higher the option value is, the greater the computation time. Accuracy increases as the option value increases. In some case, depending upon the structure of *block/superblock*, the errors introduced when *ifzopt* is 0 or 1 are acceptable. But in other cases, this selection results in serious errors. Choosing the high option value of 3 may be required for satisfactory accuracy. See p. 6 of Reference 2 and p. 22 of Reference 3.

- **<u>Size of simulation</u>**

The size of simulation is mainly limited by the array sizes of variables in MODSIM.
The array sizes can be changed in the modules, HVACSIM_PAR and MODSIM_HEAD. Great care should be given to ensure that a variable has the same array size in both files. Selecting only component models which are needed in a simulation can also reduce the size of the simulation. This selection can be done by modifying the subroutine SELECT. During SLIMCON run, actual array sizes and maximum allocated array sizes are displayed. See pp. 6-7 of Reference 2 and p. 37 of Reference 3.

- **<u>Blocking *superblocks* and *blocks*</u>**

In setting up a simulation work file, it is very important to achieve proper *blocking*. A system of equations in a block is solved simultaneously. In order to obtain a good simulation, closely related component models should be put together in a *block*. The variables that are not solved simultaneously in a *block* can be solved in a *superblock*. The connection between *superblocks* is not tight. *Superblocks* are allowed to evolve independently in time. See p. 5 of Reference 2 and p.10 of Reference 4. All *blocks* and *units* related to the building shell components (subroutines TYPE50, TYPE51, TYPE52, and TYPE53) should be placed in one *superblock*. During simulations, the building shell superblock is called at the same time step as the time interval for calculating the conduction transfer functions. See pp. 11-12 of Reference 4.

- **<u>Dealing with differential equations – two different approaches</u>**

Originally, the variable time step and variable order integration techniques were introduced in solving sets of ordinary differential equations in MODSIM. See pp. 17-23 of Reference 4. Later another exact integration method using a fixed time step was introduced using the DIFF routine. The fixed time step must be small enough for good simulations. The component models developed for ASHRAE 825 project [5] utilized the exact integration method, and the numbers of differential equations that appeared in the component model configuration file, *typar.dat*, are set to be zero.

- **<u>Modification of simulation work file using a text editor</u>**

Sometimes it is much easier to use a text editor instead of using HVACGEN for editing the simulation work file, *hvacsim.sim*. When editing is performed, the numbers shown in *summary of work file* must be matched with the changes made in the main body. Otherwise HVACGEN or SLIMCON can not access the edited file.

- **<u>Editing *superblocks*</u>**

In the current version of HVACGEN, *superblocks* can be created, but they cannot be deleted or inserted once a simulation work file has been created. This kind of editing can be done by using a text editor. Make sure that the numbers shown in *summary of work file* of the simulation work file agree with the numbers in the main body of the file.

- **<u>Work involved in modification of a component model</u>**

When an existing component model, TYPEn, is to be modified, the following steps may be needed.

(1) Make changes in the code of TYPEn as needed using an editor. Make sure that the numbers of inputs, outputs, parameters, saved variables, and differential equations are correct. If changes on outputs are made, the values of the *iostat* vector should be checked.
(2) Make sure that the TYPEn subroutine is called by the SELECT subroutine.
(3) Check whether the array sizes of variables in the modules, HVACSIM_PAR and MODSIM_HEAD reflect the changes made in TYPEn.
(4) Check whether the numbers of saved variables, differential equations, inputs, and outputs in the component model configuration file, *typar.dat*, agree with the those numbers presented in the TYPEn. The index numbers of inputs and outputs, and the parameter numbers in *typar.dat* should be checked. The descriptions of inputs, outputs, and parameters in *typar.dat* must be enclosed by single quotation marks.
(5) Compile and link the source code to generate the executable code of MODSIM. If the HVACSIM_PAR module is updated, recompile and link HVACGEN and SLIMCON.
(6) Update *hvacsim.sim* by using HVACGEN.
(7) Create *hvacsim.dfn* by using SLIMCON.
(8) If desired, make the updated *hvacsim.model* for documentation. Check the information in *hvacsim.inf* for correctness.

A similar approach could be used when one or more component models are created.

- **<u>Real time application</u>**

The MODSIM program can be used in a real time application. In such a case, it is very important that simulations must be performed within the specified time interval. If the computation time takes longer than the time interval, the program run stops without giving any error message. The maximum time step of MODSIM can be the same as the given time interval. It may be helpful to use a computer with a fast processor and reduced input and output (I/O) operations. Reducing the number of variables that are solved simultaneously can also shorten the computation time.

➢ **Mixed language**

Other programming language such as C++ or BASIC can call MODSIM after converting the main program of MODSIM into a subroutine. Necessary items should be passed through an argument. The MODSIM subroutine along with associated Fortran subroutines and functions need to be linked as a DLL file.

➢ **Location of *state variable* array elements**

Sometimes it is useful to find the location of elements of the *state variable* array when categories and index numbers are known. For instance, it is quite a difficult task to add one or more reported variables in a large simulation work file by using HVACGEN. Instead, a user can edit the simulation work file by using a text editor and adding the state variable location, category number, and index number of the reported variable in that particular category. See Table 2. The STATE_LOCATION program reads an input data file as NAMELIST input format and produces a tabled file.

➢ **Some equations of the component models of an air-handling unit**

Reference 10 also shows some equations of the component models used in modeling an air-handling unit referring to Reference 5.

7. References

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8. Appendix: List of Source Code Files in the HVACSIM+ Program Package

File Name	Program Name	Description
Modsim.f90	**MODSIM**	Main program of MODSIM
Modsim_head.f90	PRECISION1	Precision module
	MODSIM_HEAD	Module for global variables and array sizing
Modino.f90	BOUNDS	Read time-dependent boundary variables
	INDATA	Enter input data for a simulation
	OPNFIL	Open input and output files
	RCONF	Read the model definition and initialization files
	REPORT	Generate the report file
	SUMARY	Write the summary of configuration of simulation
	VLAB	Return labels and numbers
Modblk.f90	ASEMBL	Assemble *block* inputs and outputs
	BACTIV	Control *block* activity
	FRZVAR	Freeze variables
	INPUTS	Assign *state* variables to inputs of *unit*
	INSCAN	Scan inputs of *superblocks*
	INTLIZ	Initialize simulation
	OUTPUT	Store outputs from *unit*
	RESTAT	Reset outputs of *block*
	UNFREZ	Check frozen variables
Modbdf.f90	BAKDIF	Calculate derivative
	CALN	Compute the minimum time step
	ECNTRL	Calculate truncation errors, time step, and integration order
	IPERM	Permutated vectors
	NORDER	Increase or decrease the order of integration
	PREDIK	Calculate predicted values for the next time step
	RESET	Reset the differential equation integrator
	SAVECO	Save and replace coefficients
	UPDATE	Update coefficients for BACDIF and PRDIK
Modeqt.f90	BLOCK	Calculate a new *state* vector by calling a *block*
	FNC	Calculate the residual function for *block*
	SUPERB	Calculate a new *state* vector by calling a *superblock*
	SUPFNC	Calculate the residual function for *superblock*
Select.f90	SELECT	Call TYPEn subroutines
Snsqa.f90	SNSQ	Find a zero of a system of nonlinear functions
	SNSQ1	The same as SNSQ but called by BLOCK subroutine
	SNSQ2	The abbreviated version of SNSQ
Snsqb.f90	DOGLEG	Determine the convex combination x of the Gauss-Newton and scaled gradient directions
	ENORM	Calculate the Euclidean norm of x
	QFORM	Accumulate orthogonal matrix Q from the computed QR

	QRFAC	QR factorize of matrix using Householder transformations
	R1MPYQ	Compute A*Q for a given matrix A
	R1UPDT	Determine an orthogonal matrix Q
Snsqc.f90	FDJAC1	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 local computer environment
Rdenv.f90	RDENV	Read weather data and conduction transfer functions. Interpolate hourly data using the spline interpolation
	SPLINE	Second derivatives for the spline interpolation
	SPEVAL	Interpolation using the cubic spline method
Datetime.f90	DATETIME	Read system clock and return time as integers
Hvacgen1.f90	**HVACGEN**	Main program of HVACGEN
	DATAIN	Verify input information
	COPMOD	Input data processor
	CHECK	Check whether the parsed word is a number
	REWORD	Check whether the input is reserved word
	REMAIN	Control transfer to the requested module
	HOLDIT	Produce a pause for acknowledgment of error display
	SCROLL	Make a screen display paused when the screen is full
	OKAY	Check whether an existing value is acceptable
	RITE	Display console message and menu
	PROMPTD	Provide index labels corresponding to category numbers
Hvacgen2.f90	CREATE	Control transfer to the proper routine for create mode
	CRUNIT	Create a *unit*
	CRBLK	Create a *block*
	CRSUP	Create a *superblock*
	CRSIM	Call CRSIM1, CRSIM2, CRSIM3 and CRSIM4
	CRSIM1	Enter simulation title, and error tolerances
	CRSIM2	Enter initial values of *state* variables
	CRSIM3	Enter boundary information
	CRSIM4	Enter reported variable information
	RECRT	Call a proper module according to the entry of reserved words
	TYPES	List TYPEn available in *typar.dat* file
Hvacgen3.f90	FSAVE	Call the routine for saving the created file
	READIN	Select the module for reading a file
	OPNFIL	Enter the file name and opening the file
	RDUNT	Read the file of *unit* with the extension *unt*
	RDBLK	Read the file of *block* with the extension *blk*
	RDSIM	Read the file of simulation work with the extension *sim*
	SAVUNT	Write information to the *unit* file
	SAVBLK	Write information to the *block* file
	SAVSIM	Write information to the simulation work file

	TYPEIN	Create a direct access file for *typar.dat* and read information from the direct access file
Hvacgen4.f90	VIEW	Control transfer to the proper routine for view mode
	VEWUNT	View inputs, outputs, and parameters of the *unit*
	VEWBLK	View the information of the *block*
	VEWSIM	Provide the menu for different view options
	STRUCT	View the structure of the simulation setup
	VARVAL	View the initial values of *state* variables
	BOUND	View the boundary information
	RPTVAR	View the reported variables
	ERRORS	View the error tolerances, and the freezing and scan options
	REVIEW	Direct either help or abort mode
	VEWALL	View all the information of simulation work file
Hvacgen5.f90	EDIT	Control transfer to the proper routine for edit mode
	EDUNT	Edit information in the *unit*
	EDSIM	Edit information in the simulation
	EDTITL	Edit the title
	EDSTR	Call the routine for editing the structure
	EDVAL	Edit the initial values of *state* variables
	EDBND	Edit the boundary information
	INSERT	Enter the index of a *boundary* variable
	DELETE	Delete the index of a *boundary* variable
	EDREP	Edit the *reported variable* information
	PRCHNG	Edit the *reported interval*
	RPINRT	Enter the index of a *reported variable*
	RPDELT	Delete the index of a *reported variable*
	EDERR	Edit the error tolerance and the *freezing* and *scan* options
	REEDT	Call the help routine
Hvacgen6.f90	INSSIM	Call the routine for inserting or replacing *unit* or *block*
	INSUNT	Insert a *unit*
	INSCHK	Give the number of *units* in the *block*
	INSBLK	Insert a *block*
	INSCK2	Give the information of *superblock* and unit to INSBLK
	RECALC	Recalculate the new position of the variable in state vector after an insertion
	TYPINF	Get the information of input and output categories from the *typar.dat* file
	REBND	Calculate the new position in the state vector of the boundary variables
	REREPT	Calculate the new position in the state vector of the reported variables
	DELSIM	Call the routine for deleting a *unit* or *block* from a simulation
	DELUNT	Delete a *unit* from the simulation setup
	DELBLK	Delete a *block* from the simulation setup
	DELCHK	Check the *unit* number to be deleted

	DELCK2	Check the *block* number to be deleted
	REPSIM	Call the routine for replacing a *unit* in the simulation
	REPUNT	Replace a *unit* in the simulation
	HELP	Describe available commands in the HVACGEN program
	EXTBLK	Save the information in the *block* of the simulation file in a *block* file
Hvaccomm.f90	HVACSIM_PAR	Array sizing of global variables
	HVACCOMM	Global variable module
Hvacgen.inc		Include portion to HVACGEN
Slimcon.f90	**SLIMCON**	Main program of the SLIMCON program to generate a *model definition* file using a *simulation work* file with the extension *sim*
	FILEOP	Open the input and output files
	TYPAR	Get information from the *typar.dat* file
	REPORT	Display the configuration parameters along with the maximum values assigned
	VARCHK	Check whether any of the time-dependent boundary variables are solved simultaneously
	OUTCHK	Check if two or more outputs are assigned to a single state variable
	TDBVIS	Find the largest number of time-dependent boundary variables in any one *superblock*
Slimcomm.f90	SLIM	Global variable module
Upd_info.f90	**UPD_INFO**	Add supplemental information to the *viewsave.txt* file
Rdwdf.f90	**RDWDF**	Main program to read a whole year weather data file
	RDWDF_HEAD	Global variable module
	RDWTP	Position and check weather data file
	RDSOLM	Read the NOAA SOLMET format data
	RDTMY	Read the NOAA Typical Meteorological Year (TMY) format data
	RDTRY	Read the NOAA Test Reference Year (TRY) format data
	RDWYEC	Read the ASHRAE Weather Year for Energy Calculations (WYEC) format data
	RDWYEC2	Read the ASHRAE Weather Year for Energy Calculations 2 (WYEC2) format data
	WRTFIL	Write output data
	JDS	Evaluate Julian date
Crwdta.f90	**CRWDTA**	Main program to create the weather data file
	CRWDTA_COMM	Global variable module
	WTPINP	Read the output file of the RDWDF program
	WF	Compute humidity ratio in terms of dew point temperature and pressure
	SOLAR	Generate artificial weather data of solar radiation
	DB	Generate design day outdoor dry-bulb temperature for summer

	HUMIDITY	Calculate humidity ratio assuming constant relative humidity
	COPYFL	Write outputs on the weather data file
Ctfgen.f90	**CTF**	Main program to create the conduction transfer function (CTF) data file
	PRECISION1	Precision module
	CTF_COMM	Global variable module
	MAKE_CTF	Create a CTF data file for MODSIM
	THERMP	Add new data of thermal properties of building materials in the thermal property data file
	BANKTP	Make a temporary direct access file of the thermal property data
	DER	Calculate the total construct and total derivative matrices, and determining residue elements for a non-zero root
	DUMPRF	Print description of conductive layers, values of roots, conduction transfer functions, and heat flux transfer functions
	ERRORX	Print error messages
	ILLINI	Calculate roots in the interval using modified false position method
	INITRF	Call subroutines related to calculation of conduction transfer functions
	MARIX	Evaluate the conduction matrix for a multilayered slab
	RFCOMP	Compute conduction transfer and heat flux transfer functions for multilayered constructs
	SEARCH	Determine the upper and lower bounds within which a root must exist
	ZERORE	Calculate zero residue of elements
Sortsb.f90	**SORTSB**	Program to sort the raw output data file *superblock* by *superblock*
Airpr.f90	CPCVA	Specific heat of air at constant pressure and volume
	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
Water.f90	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
Refrigpr.f90	REFRIG_HEAD	Global variables module
	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 pressure
	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 heat of refrigerant at constant volume and pressure vs. specific volume and temperature
Types.f90	TYPE1	Fan and pump
	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
	TYPE11	Hot water to air heating coil
	TYPE12	Cooling or dehumidifying coil
	TYPE13	Three-way valve
	TYPE14	Evaporative humidifier
	TYPE15	Room model with constant zone loads
	TYPE16	Sticky proportional controller
	TYPE17	Mixing damper 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
Utility.f90	HYSTER	Hysteresis of actuators
	DELAY	Transport delay in ducting component
	SUFED	Coefficients for the polynomial of the efficiency of heat exchanger fin
	BESI	Modified Bessel function I(x)
	BESK	Modified Bessel function K(x)
	POLFIT	Polynomial fitting
Typesa.f90	TYPE30	Cooling coil duty from inlet conditions
	TYPE33	Moist air mixing dampers and merger
	TYPE34	Multiplier
	TYPE35	Mean values of temperatures and humidity ratios
	TYPE36	Reset schedule
	TYPE39	Time-of-day control with zone demand reset
Typesb.f90	TYPE50	Zone envelope (building shell)
	TYPE51	Building surface (building shell)
	TYPE52	Zone model (building shell)
	TYPE53	Weather input (building shell)
Utilityb.f90	CP	Specific heat of moist air
	DENSIT	Density of moist air

	PWF	Vapor pressure of moist air
	AIREX	Air exchange rate
	WSATF	Humidity ratio at saturation state
	HISCF	Convective heat transfer coefficient of the inner surface
	HOSF	Convective plus radiant heat transfer coefficient of the outer surface
	HISRF	Radiant heat transfer coefficient of the inner surface
	VIEW	View factors using the mean radiant temperature network method
Blc_head.f90	BLC_HEAD	Global variable module
Blc.f90	TYPE62	Fossil fuel-fired hot water boiler with a domestic hot water heating coil
	TYPE63	Hot water coil with constant wall temperature
	TYPE64	Boiler burner and circulating pump controls
Utility_blc.f90	CPF	Combustion product specific heat
	GEF	Gas emissivity
	GS	Gas/Sink exchange area
	HCOVF	Convective heat transfer coefficient
	PRDPP	Combustion products
	PRDPR	Viscosity and conductivity of combustion product
	TAFF	Adiabatic flame temperature
	TAB1	Determine Y(x1) value from tabulated y vs. x values
Plant.f90	TYPE122	Static boiler
	TYPE124	Chiller
	TYPE143	Cooling tower
	TYPE144	Chiller sump
	TYPE145	Cooling tower
	TYPE146	Chiller sump temperature
	TYPE179	Cooling tower controller
	TYPE200	Mixing of water flows
	TYPE201	Adding electric powers
	TYPE202	Integrator of thermal power for energy
	TYPE203	Relative humidity and wet-bulb temperature
ASH_sensor.f90	TYPE301	Temperature sensor
	TYPE302	Humidity sensor
	TYPE303	Flow rate sensor
	TYPE304	Total pressure sensor
	TYPE305	Static pressure sensor
ASH_element.f90	TYPE321	Motor-driven actuator
	TYPE322	Damper
	TYPE323	Damper - calculates flow rate
	TYPE324	Mixing box (implicit flow)
	TYPE325	Mixing box
	TYPE326	Mixing box with minimum OA damper (implicit flow)

	TYPE327	Mixing box with minimum outside air damper
	TYPE328	Two port control valve
	TYPE329	Two port control valve
	TYPE330	Three port mixing valve
	TYPE333	Variable speed drive
ASH_fluid.f90	TYPE341	Fluid resistance
	TYPE342	Fluid resistance - calculates flow rate
	TYPE345	Flow split
	TYPE346	Asymmetric flow split
	TYPE348	Flow merge
	TYPE349	Room air mass balance
	TYPE350	Fan or pump
	TYPE351	Fan or pump (implicit flow)
	TYPE352	Fan or pump - temperature rise
	TYPE353	Fan or pump (implicit flow) - temperature rise
ASH_heatmass.f90	TYPE362	Dynamic or steady state heating and cooling coil
	TYPE366	Ideal heating of fluid stream
	TYPE367	Mixing of two moist air streams
	TYPE368	Mixing of six moist air streams
	TYPE369	Supply and return air flow rates
ASH_building.f90	TYPE401	Two time constant room model (no plenum)
	TYPE402	Room with plenum return
	TYPE403	Room with plenum and ducted return (analytical integration)
	TYPE404	Room with plenum and ducted return (numerical integration)
	TYPE411	Room (no plenum, no interzone flows)
	TYPE412	Room with plenum return (no interzone flows)
	TYPE413	Room with plenum and ducted return (analytical integration)
	TYPE414	Room with plenum and ducted return (numerical integration)
ASH_performance.f90	TYPE461	Fanger PMV and PPD
	TYPE462	Heat Meter
	TYPE463	Energy Meter
ASH_control.f90	TYPE441	PID controller
	TYPE481	Supply fan control
	TYPE482	Return fan volume matching control
	TYPE483	Return fan reset control
	TYPE484	Minimum outside air damper control
	TYPE485	Modulated mixed air damper control
	TYPE486	Supply air temperature control
	TYPE487	Economizer control
	TYPE488	Low temperature override control
	TYPE489	Supply air temperature reset
	TYPE490	VAV room temperature control with reheat
ASH_composite.f90	TYPE521	Dynamic or steady state coil and two port valve - calculates water-side inlet pressure from flow rate

	TYPE522	Dynamic or steady state coil and two port valve - calculates water-side flow rate from inlet pressure
	TYPE523	Dynamic or steady state coil and three port valve
	TYPE524	Dynamic or steady state coil and three port valve
	TYPE525	Motorized pressure-independent VAV box
	TYPE526	Pressure-independent VAV box - calculates flow
	TYPE527	Pressure-independent VAV box (implicit flow)
	TYPE528	Flow split and pressure-independent VAV box
Utility_ashrae.f90	DIFFEQ	Analytical integration
	LICOILAB	Dynamic heating and cooling coil
	LICOILDY	Dynamic heating and cooling coil
	LICOILSS	Steady state Liege heating and cooling coil
	EFFECTIV	Calculate the effectiveness of different heat exchanger configurations
	AIRCOEFF	Calculate the convective heat transfer coefficient on the air side
	AIRFINRES	Calculate the heat exchange resistance on the air side of a fin-tube heat exchanger
	VISCWAT	Calculate the dynamic viscosity of water as a function of temperature
	WATERRES	Calculate water-side heat transfer coefficient and thermal resistance
	BYPASFAC	Calculate the by-pass factor on the air side
	CAPRATIO	Capacity rate ratio and the minimum capacity rate from the capacity rates on the air and water side
	LIMITHR	Check that the humidity ratio at the outlet of a coil does not exceed saturation value and recalculate outlet conditions if necessary
	WETOUTCO	Calculate the condition of the outlet air from a wet coil, limiting the outlet humidity ratio to the saturation value while conserving enthalpy
	DRYOUTCO	Calculate the outlet air condition for a dry coil
	TSHOBF	Calculate the effective surface temperature, outlet enthalpy and bypass factor for a wet coil from the inlet conditions and the duty
	QEFFNTU	Calculate duty for air-water heat exchangers
	QAIRSIDE	Calculate the air-side resistance, by-pass factor and heat transfer
	QWATSIDE	Calculate the water-side resistance from the total resistance and the air-side resistance and calculate the water-side heat transfer
	COILCAP	Calculate the heat capacity of the fins, tubes and water in a fin-tube heat exchanger
	ABSVALUE	Absolute value
	SQROOT	Square root
	SUM	Sum first and second arguments
	DIFF	Subtract second argument from first argument
	PRODUCT	Product of first and second arguments
	QUOTIENT	Quotient of first and second arguments
	AVERAGE	Average of first n elements of a vector
	SUMARRAY	Sum of first n elements of a vector

SMALLEST	Minimum of first n elements of a vector
BIGGEST	Maximum of first n elements of a vector
LOGICNOT	Logical compliment
LOGICAND	Logical AND of first and second arguments
LOGICOR	Logical OR of first and second arguments
LOGICXOR	Exclusive OR of first and second arguments (XOR)
RETOLOG	Convert a real to a Boolean
LOGTORE	Convert a Boolean to a real
ENTHALPY	Calculate the specific enthalpy of moist air at standard pressure
WETBULB	Calculate the wet bulb temperature of moist air at standard pressure
DEWPOINT	Calculate the dew point temperature of moist air at standard pressure
CLIP	Limit the first argument to the range defined by the second and third arguments
SWITCH	Select the second argument if the first argument is true, else select the third argument
SPAN	Rescale
DEADBAND	Determine the effective setpoint in the presence of a deadband
COMPARE	Compare two real numbers
COMPHYS	Compare two real numbers using a deadband
PIDCONT	Discrete-time Proportional plus Integral plus Derivative controller
MOISTMIX	Calculate the temperature and humidity ratio produced by mixing up to six moist air streams
DPQUDLIN	Calculate pressure drop from flow rate and quadratic resistance- use linear flow relationship at low flow
DPLIN	Calculate pressure drop from flow rate and quadratic resistance at low flow - use linear flow relationship
DPQUD	Calculate pressure drop from flow rate and quadratic resistance
WQUDLIN	Calculate flow rate from pressure drop and turbulent resistance
WLIN	Calculate flow rate from pressure drop and turbulent resistance at low flow - use laminar flow relationship
WQUD	Calculate flow rate from pressure drop and turbulent resistance
RLINPORT	Calculate hydraulic resistance of a linear port in a control valve
REQPPORT	Calculate hydraulic resistance of an equal percentage port in a control valve
RDAMPER	Calculate resistance of damper using Legg's correlation
INTERPAR	Determine coefficients of interpolation function
YQUAD	Evaluate quadratic function $ax^2 + bx + c$
FLOWMERG	Calculate the outlet flow rate and the inlet pressures for a flow merge, given the outlet pressure and the inlet flow rates
FLOWSPLT	Calculate the outlet flow rates and the inlet pressure for a flow split, given the outlet pressures and the inlet flow rate
SPEDLIM	Apply upper and lower limits to actuator speed

	HYSTRSIS	Hysteresis of actuators
	FPWS	Saturation pressure over liquid water for the temperature range of 0 deg C to 200 deg C
	FTDEW	Dew point temperature or saturation temperature as a function of the humidity ratio
	FPWW	Partial pressure of water vapor as a function of the humidity ratio and of the barometric pressure
	FWPW	Humidity ratio as a function of the vapor pressure and the barometric pressure
	FWPHI	Humidity ratio as a function of the air dry bulb temperature and the relative humidity
	FWTWB	Humidity ratio as a function of the air dry bulb temperature and of the air wet bulb temperature
	FWHA	Humidity ratio as a function of the air dry bulb temperature and of the air enthalpy
	FTDB	Air dry bulb temperature as a function of the humidity ratio and of the air enthalpy
	FPHI	Relative humidity as a function of the dry air temperature and the humidity ratio
	FHAIR	Enthalpy of moist air
	FHSAT	Air saturation enthalpy as function of saturation temperature
	FTSAT	Saturation temperature as a function of the air saturation enthalpy
	FTWB	Air wet bulb temperatures as a function of the air dry bulb temperature, the humidity ratio and the barometric pressure
	FTAIR	Temperature of moist air
	ELAPSED	Calculate elapsed time from current and initial second and millisecond values
	TCORRECT	Correct time expressed in integer second and millisecond subtracting a real time interval
	RFILE	Read values of simulation variables from a file
ahu_wbe.f90	TYPE107	Holder for data storage allocation
	TYPE108	Holder for data storage allocation for the 6-zone model of VCBT controllers
	TYPE365	Mixing of three moist air streams
	TYPE371	Mixing box
	TYPE428	Room (analytical integration)
	TYPE471	Supply fan control
	TYPE480	Return fan volume matching control
	TYPE492	Supply air temperature control
	TYPE493	Supply air temperature reset
	TYPE496	VAV room temperature control with reheat
	TYPE497	Modulated mixed air damper control
	TYPE499	Air damper control
	TYPE504	Read inputs from a file
	TYPE530	Dynamic or steady state coil and three port valve
utility_wbe.f90	PID	PID controller module
	RSCLFR	Rescale
	RSCLTO	Rescale

XLIMAT	Limit
ADD	Add
ICOMP	Compare
IHYST	Cooling tower fan limiting
ITIMER	Timer