Condenser (CND) Package
Users' Guide

The purpose of the MELCOR CND package is to model the effects of the Isolation Condenser System (ICS) and the Passive Containment Cooling System (PCCS), both of which use heat exchangers submerged in large water pools. Several older boiling water reactors (BWRs) and the proposed new simplified boiling water reactor (SBWR) contain isolation condensers to condense steam created in the core and return it to the primary system. Only the simplified boiling water reactor, however, contains the passive containment cooling system to provide steam suppression in the drywell in the event of a LOCA or when the depressurization valves are used to equalize the pressures of the reactor vessel and containment. This equalization is required so that water can drain to the reactor vessel from the gravity-driven cooling system pools located several meters above the top of the core. The CND package constitutes a subpackage within the ESF package. This Users' Guide provides basic information needed to run the CND model with the rest of MELCOR, including a detailed explanation of the user input and package output for MELGEN and MELCOR. Required and optional input, sensitivity coefficients, control function arguments, plot variables, and error messages are all covered.

More detailed information of the technique used to simulate the effects of the operation of the two types of condensers can be found in the CND Package Reference Manual.

Contents

List of Tables

List of Figures

1. Introduction

The input for the condenser model described here is based upon the concept that the MELCOR code should adequately represent the effects of the condensers under the boundary conditions that would be imposed by accidents. It is not intended that the MELCOR calculation should attempt to predict the performance of these heat exchanger-condenser systems based upon basic physical considerations; this is done by more sophisticated thermal hydraulic codes and is a task not compatible with the role that a fast-running PRA analytical tool should play. Furthermore, test calculations performed with MELCOR demonstrate that attempts to use the basic code "building block" approach to connect control volumes, flow paths, and heat sink structures as necessary to directly simulate the heat exchanger-condensers will result in code difficulties; these include oscillations in the predicted flows and energy exchanges, a demand for extremely small timesteps, and impractical large CPU and wall clock time consumption.

The condenser model was originally developed to model the passive containment cooling system (PCCS) and the isolation condenser system (ICS). Several older boiling water reactors and the new simplified boiling water reactor (SBWR) design contain isolation condensers to condense steam created in the core and return it to the primary system. However, only the SBWR utilizes the PCCS to provide steam suppression in the drywell in the event of a LOCA or when the depressurization valves are used to reduce the differential pressure between the reactor vessel and containment. Therefore, the model has an implied geometry and also contains limitations set forth by the normal operating characteristics of the PCCS and ICS. Their geometries are shown in Figure 1.1 and Figure 1.2.

For the ICS, the source volume is assumed to be the upper portion of the reactor vessel and the drain to be the reactor vessel annulus. For the PCCS, the source volume is assumed to be the volume representing the upper drywell and the drain volume to be any CVH volume located in the drywell. In either case, it is assumed that the drain volume is at approximately the same pressure as the source volume; therefore, the gravity head is sufficient to allow free flow of condensate from the condenser. It is important to note that a flow calculation to flush the condensers of noncondensible gases is performed based on the differential pressure between the source volume and the vent volume, but back flow through either the drain or vent line is not permitted.

Although the PCCS and ICS models were designed exclusively for SBWR applications, allowances have been made in the CND package input processing such that the PCCS and ICS condenser models can be used for either BWR or PWR reactor types.

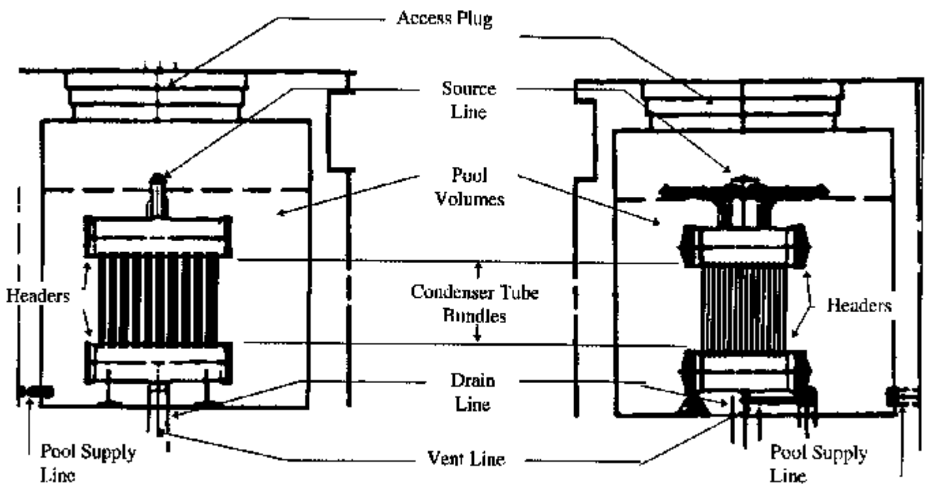

Figure 1.1 Typical Passive Containment Cooler Condenser (left) and Isolation Condenser (right)

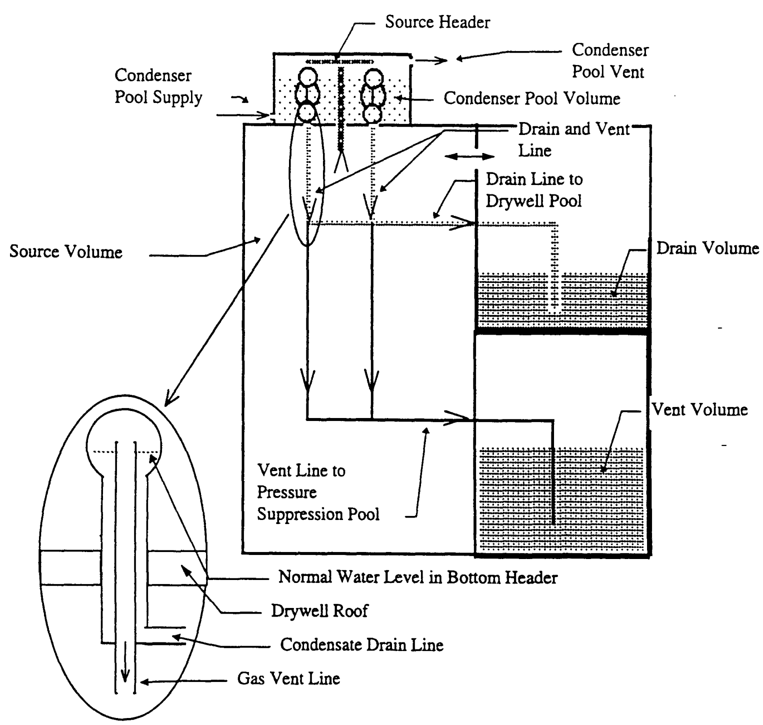

Figure 1.2 Example Flow Diagram of the Passive Containment Cooling System

The condenser model has been written to allow up to three (the maximum number of condensers contained in an SBWR) of the installed independent PCCS or ICS units to be in operation. If multiple units are installed, they are assumed to be identical. Because they may reject heat to different pools, however, the performance of the units may differ.

2. Input Requirements

2.1 MELGEN Input

This section provides the input requirements for the CND package, including a short description of the input quantities and their units and default values, if any. Further description of the input variables and their meaning in the models can be found in the CND Package Reference Manual.

Input record identifiers for the CND model all begin with the character string "ESFCND."

ESFCND0100 – CVH Volumes that Interface with the PCCS
Required for Activation of the PCCS Condenser Model

This record identifies the CVH volumes that represent the heat sink for the heat exchangers (a total of three pools), the volume from which material is removed (drywell), the volume containing the vent (wetwell), and the volume containing the drain (GDCS pool).

(1) IVPCPL(1)* - CVH volume for the primary PCCS unit pool.
(type = integer, default = none, units = none)

(2) IVPCPL(2)* - CVH volume for the secondary PCCS unit pool.
(type = integer, default = none, units = none)

(3) IVPCPL(3)* - CVH volume for the third PCCS unit pool.
(type = integer, default = none, units = none)

(4) IVPCSO - CVH volume representing the drywell, i.e., the source for the PCCS units.

* A CVH volume number should be input for each of the three installed PCCS units. However, the same CVH volume number may be input for one or all of the PCCS unit pools.

(type = integer, default = none, units = none)

(5) IVPCVN - CVH volume representing the wetwell, i.e., the PCCS vent.
(type = integer, default = none, units = none)

(6) IVPCDN - CVH volume representing the GDCS pool(s), i.e., the PCCS drain.
(type = integer, default = none, units = none)

Initialization Characteristics of the PCCS Model
The presence of this input record acts as a flag to activate the PCCS model. If entered, then all remaining PCCS model input cards are processed. If this card is absent or if the value of 0 is entered for IVPCPL(1), then the storage area of the PCCS model variables in the ESF portion of the MELCOR database is skipped along with the definition of the PLOT variables unique to the PCCS model.

ESFCND0200 – Tabular Function for the Variation of Capacity
Required

This record provides the input for the variation in capacity caused by various containment conditions that would affect the operation of the PCCS heat exchanger. This does not include any effects of filling of the condenser volume with noncondensible gas (i.e., "bounding") because these effects are calculated by the model.

(1) IPCDPR - Tabular Function number that represents the variation in capacity due to the increase in differential pressure between the drywell (the volume from which the PCCS removes material) and the wetwell (the vent volume for the PCCS).
(type = integer, default = none, units = none)

(2) IPLTMP - Tabular Function number for the variation in capacity because of increase in noncondensible mole fraction in the PCCS for an ICS/PCC pool temperature of 323.16 K (50 $^\circ$C).

(3) IPCNCN - Tabular Function number for the variation in capacity because of increase in noncondensible mole fraction in the PCCS for an ICS/PCC pool temperature of 373.16 K (100 $^\circ$C)
(type = integer, default = none, units = none)

(4) IPSRPR - Tabular Function number for the variation in capacity because of a decrease in pressure in the PCCS source volume.
(type = integer, default = none, units = none)

Note: The Tabular Function IPCDPR should consist of differential pressures between the drywell and the wetwell and the corresponding coefficients that are to be used as multipliers to the maximum capacity to obtain the adjusted capacities of the PCCS. See CND Package Reference Manual Table 2.1.

The Tabular Functions IPLTMP and IPCNCN should consist of noncondensible gas mole fractions and the corresponding coefficients for ICS/PCC pool temperatures of 50 °C and 100 °C, respectively. See CND Package Reference Manual Tables 2.2 and 2.3.

The Tabular Function IPSRPR should consist of the pressure in the drywell and the corresponding coefficients that are to be used as multipliers to the maximum capacity to obtain the adjusted capacities of the PCCS. See CND Package Reference Manual Table 2.4.

ESFCND0300 – Geometric Input for the PCCS Vent Line
Required

This record provides the input for the geometric configuration of the PCCS vent line.

(1) ELBTVT - Elevation of the bottom of the vent line, assumed to be submerged in the volume normally occupied by the pressure suppression pool.
(type = real, default = none, units = m)

(2) VNTLND - Diameter of the vent line.
(type = real, default = none, units = m)

(3) VNTLEN - Total equivalent length of the PCCS vent line. No input is allowed for elbows. Therefore, a total equivalent length should be used in place of the actual length, as explained, for example, in Crane Technical Paper #410.
(type = real, default = none, units = m)

ESFCND0400 – PCCS Unit(s) Description
Required

This record provides the input for the description of the PCCS unit and the number of units that are in operation. A PCCS unit is defined as two heat exchangers with a single source line coming from the drywell and a combined exit line. The combined exit separates outside of the PCCS enclosure into separate drain and vent lines returning to the GDCS pool and the wetwell, respectively. If multiple units are in operation, they work in parallel, with separate but identical connecting lines.

(1) VOLPCS - Volume of one PCCS unit. It is assumed that the source line and the four barrels, located at the top and bottom of the tube bundles, are sufficiently insulated to preclude significant heat transfer from the steam to the ICS/PCC pool. Therefore, the input volume should be limited to the volume inside the two sets of tube bundles.
(type = real, default = none, units = m^3)

(2) PCMXPF - Maximum capacity of a single PCCS unit, two heat exchangers, when filled with saturated steam. The capacity provided here should correspond to the conditions for which multipliers of 1.00 are provided by the tabular functions identified in input record ESFCND0200.
(type = real, default = none, units = MW)

(3) NMPCCS - The number of PCCS units in operation, maximum of 3. If a negative value is input, then two special data files are produced (see Section 3). The heat loads for the PCCS units in operation are always assumed to be distributed evenly between the ICS/PCC pools corresponding to the number of units in operation starting with IVPCPL(1).
(type = integer, default = none, units = none)

(4) VLPCSL = Volume of one PCCS unit source line composed of the two barrels located at the top of the tube bundles, the source line, and the header. This volume is used in the determination of the minimum delta P between the PCCS and the drywell to cause return of the contents of the condenser tube to the drywell.
(type = real, default = none, units = m^3)

ESFCND0500 – CVH Volumes that Interface with the ICS
Required for Activation of the ICS Condenser Model

This record identifies the CVH volumes that represent the heat sink for the heat exchangers (a total of three pools), the volume from which material is removed (reactor vessel steam dome), the volume containing the vent (wetwell), and the volume containing the drain (reactor vessel annulus).

(1) IVICPL(1)* - CVH volume for the primary ICS unit pool.
(type = integer, default = none, units = none)

(2) IVICPL(2)* - CVH volume for the secondary ICS unit pool.
(type = integer, default = none, units = none)

(3) IVICPL(3)* - CVH volume for the third ICS unit pool.
(type = integer, default = none, units = none)

(4) IVICSO - CVH volume representing the reactor vessel upper steam dome, i.e., the source for the ICS units.
(type = integer, default = none, units = none)

(5) IVICVN - CVH volume representing the wetwell, i.e., the ICS vent.
(type = integer, default = none, units = none)

(6) IVICDN - CVH volume representing the reactor downcomer, i.e., the ICS drain.
(type = integer, default = none, units = none)

Initialization Characteristics of the ICS Model
The presence of this input record acts as a flag to activate the ICS model. If entered, then all remaining ICS model input cards are processed. If this card is absent or if the value of 0 is entered for IVPCPL(1), then the storage area of the ICS model variables in the ESF portion of the MELCOR database is skipped along with the definition of the PLOT variables unique to the ICS model.

ESFCND0600 – Tabular Function for the Variation of Capacity for the ICS
Required

This record provides the input for the variation in capacity caused by various containment conditions that would affect the operation of the ICS heat exchanger. This does not include any effects of filling of the condenser volume with noncondensible gas (i.e., "bounding") because these effects are calculated by the model.

(1) IICDPR - Tabular Function number that represents the variation in capacity due to the increase in differential pressure between the reactor

* A CVH volume number should be input for each of the three installed ICS units. However, the same CVH volume number may be input for one or all of the ICS unit pools.

vessel (the volume from which the ICS removes material) and the wetwell (the vent volume for the ICS).
(type = integer, default = none, units = none)

(2) IILTMP - Tabular Function number for the variation in capacity because of increase in noncondensible mole fraction in the ICS for an ICS/PCC pool temperature of 323.16 K (50 $^\circ$C).
(type = integer, default = none, units = none)

(3) IICNCN - Tabular Function number for the variation in capacity because of increase in noncondensible mole fraction in the ICS for an ICS/PCC pool temperature of 373.16 K (100 $^\circ$C)
(type = integer, default = none, units = none)

(4) IISRPR - Tabular Function number for the variation in capacity because of a decrease in pressure in the ICS source volume.
(type = integer, default = none, units = none)

Note: The Tabular Function IICDPR should consist of differential pressures between the reactor vessel and the wetwell and the corresponding coefficients that are to be used as multipliers to the maximum capacity to obtain the adjusted capacities of the ICS.

The Tabular Functions IILTMP and IICNCN should consist of noncondensible gas mole fractions and the corresponding coefficients for ICS/PCC pool temperatures of 50 $^\circ$C and 100 $^\circ$C, respectively.

The Tabular Function IISRPR should consist of the pressure in the reactor vessel and the corresponding coefficients that are to be used as multipliers to the maximum capacity to obtain the adjusted capacities of the ICS. See CND Package Reference Manual Table 3.1.

ESFCND0700 – Geometric Input for the ICS Vent Line
Required

This record provides the input for the geometric configuration of the ICS vent line.

(1) ELVICT - Elevation of the bottom of the vent line, assumed to be submerged in the volume normally occupied by the pressure suppression pool.
(type = real, default = none, units = m)

(2) VNTICD - Diameter of the vent line.
(type = real, default = none, units = m)

(3) VNTICL - Total equivalent length of the ICS vent line. No input is allowed for elbows. Therefore, a total equivalent length should be used in place of the actual length, as explained, for example, in Crane Technical Paper #410.
(type = real, default = none, units = m)

(4) ICCFL2 - Control function number that controls the operation of the ICS. A control function value of other than zero simulates opening of the drain line valves activating the ICS model.
(type = integer, default = none, units = none)

ESFCND0800 – ICS Unit(s) Description
Required

This record provides the input for the description of the ICS unit and the number of units that are in operation. An ICS unit is defined as two heat exchangers with a single source line coming from the reactor vessel, two drain lines that merge before returning to the reactor vessel downcomer, and two vent lines that merge before returning to the wetwell. If multiple units are in operation, they work in parallel, with separate but identical connecting lines.

(1) VOLIC - Volume of one ICS unit. It is assumed that the source line and the four barrels, located at the top and bottom of the tube bundles, are sufficiently insulated to preclude significant heat transfer from the steam to the ICS/PCC pool. Therefore, the input volume should be limited to the volume inside the two sets of tube bundles.
(type = real, default = none, units = m^3)

(2) PFICMX - Maximum capacity of a single ICS unit, two heat exchangers, when filled with saturated steam. The capacity provided here should correspond to the conditions for which multipliers of 1.00 are provided by the tabular functions identified in input record ESFCND0600.
(type = real, default = none, units = MW)

(3) NMIC - The number of ICS units that are currently in operation, maximum of 3. If a negative value is input, then two special data files are produced (see Section 3). The heat loads for the ICS units in operation are always assumed to be distributed evenly between

the ICS/PCC pools corresponding to the number of units in operation starting with IVICPL(1).
(type = integer, default = none, units = none)

(4) VNSTP(1) - Reactor vessel pressure at which the vent line valves open.
(type = real, default = none, units = Pa)

(5) VNSTP(2) = Reactor vessel pressure reset point for the ICS vent line valves (pressure at which the valves close).
(type = real, default = none, units = Pa)

(6) VNSTP(3) - Minimum time delay before the vent line valves are allowed to close. A control function may also be used to control the operation of the ICS vent valve by making VNSTP(3) the negative of the control function number.
(type = real, default = none, units = s)

(7) VLICSL - Volume of one ICS unit source line composed of the two barrels located at the top of the tube bundles, the source line, and the steam header. This volume is used in the determination of the minimum delta P between the ICS and the reactor vessel steam dome to cause return of the contents of the condenser tubes to the reactor vessel.
(type = real, default = none, units = m^3)

2.2 MELCOR Input

Input records ESFCND0400 and ESFCND0800, defined in the previous sections for MELGEN, may also be included in MELCOR input but are not required. If input, then all values must be present. In effect, insertion of this record allows for modifying of the number of PCCS or ICS units in operation on MELCOR restarts. However, the number of units in operation is limited to the number of ICS/PCCS pools defined on input record ESFCND0100 for the PCCS and record ESFND0500 for the ICS. Also, the creation of the external data files can be controlled by changing the sign of the NMPCCS or NMIC variable in the MELCOR input upon restart.

3. Special Output Data Files

The CND package has the capability to produce data files containing detailed performance data, see Table Table 3.1. The file names are currently defined within the code, and may be unacceptable for some PC systems.

If a negative value is input for NMPCCS (record ESFCND0400), then two special data files are produced by the PCCS model routine CNDRNI. The first data file is named

'PLOT.DAT.' The second is 'PLOTSPECIAL.DAT.' These data files include detailed information on the performance of the PCCS units that are in operation for every timestep. In both files, the time is printed in Column 1.

The PLOT.DAT file contains the overall performance characteristics of the PCCS units that are in operation. The second column is the amount of power transferred to the ICS/PCC pools, E2ADIC. The amount of power transferred to each individual pool can be determined by dividing E2ADIC by the number of PCCS units in operation. The third column is the maximum capacity that can be used if the PCCS has not become blocked; PLTCEF. The difference between PLTCEF and E2ADIC is the amount of power that could not be utilized during the current timestep because of noncondensible gas blocking of the PCCS.

The fourth column provides the total flow of material from either the drywell or the PCCS through the vent line to the wetwell, PLTIFL. The fifth column is the amount of noncondensible gases that flow through the vent line to the wetwell, PLTNF. The difference between PLTIFL and PLTNFL is the flow of uncondensed steam through the vent.

The sixth column, PLTVLL, is the amount of void left in the PCCS at the end of the current timestep (see CND Reference Manual for information concerning the significance of this variable). The seventh column, PRPSOU, is the noncondensible mole fraction in the source volume determined by using partial pressures. The last two variables (columns eight and nine) are the differential pressure between the drywell and the wetwell, DELPRE, and the differential pressure required to produce flow between the drywell and the wetwell, REQPRE.

The data file PLOTSPECIAL.DAT contains information useful for detailed analysis of various internal calculational steps performed by the PCCS model. As before, the first column provides the time. The second column (ENCDCL) is the power used to cool any noncondensible gases that remained in the PCCS at the end of the previous timestep, to the ICS/PCC pool temperature.

The third and fourth columns contain the powers associated with the materials that are vented to the wetwell. The first of these variables is the power given up to the pressure suppression pool by the fog or uncondensed steam or by heating/cooling of the noncondensible gases passing through the water to the wetwell atmosphere, PS_WW_PL. The second variable is the amount of power added to the wetwell atmosphere; this is the power associated with the noncondensible gases at equilibrium with the temperature of the wetwell pool, PS_WW_ATM.

The fifth column provides the pressure in the PCCS at the beginning of the timestep after the iterative operation of filling the PCCS is performed, PRPCS_2. PRPCS_2 should be the same as the sixth variable, the pressure in the drywell, P_DRYWELL.

The four subsequent columns, seven through ten, provide the amount of steam before and after the call to the equilibration routine, STM_MASS_BEF and STM_MAS_AFT, and the amount of fog before and after the call to the equilibration routine, FOG_MAS_BEF and FOG_MAS_AFT.

Column eleven is the temperature of the noncondensible gases that remain in the PCCS from the end of the previous timestep, TATPCS_1. This is followed by the temperature of the PCCS gases after the call to the equilibration routine, TATPCS_2 in column twelve. The temperature of the drywell, T-DRYWELL, is provided in column thirteen. Finally, the number of iterations performed in filling the PCCS, NCOUNT, is listed in the last column.

If a negative value is input for NMIC (record ESFCND0800) then two special data files are produced by the modeling routine CNDRN1. The first of these data files for the ICS is named "PLOT.RX.DAT." The second is "PLOTSPECIAL.RX.DAT." Similar to the corresponding files for the PCCS, these data files include detailed information on the performance of the ICS units that are in operation every timestep. Table 3.1 gives a short description of each variable in the four data files.

The ICS data files contain exactly the same information as described previously for the PCCS, except that the source volume is the reactor vessel instead of the drywell.

A data set is produced every time the PCCS and ICS models are called; therefore, if a fallback occurs, one or more data point sets will be produced for the same beginning time. To remove the timestep information rejected by the fallback maneuver and to improve the appearance of the data files, a separate post processor was written to change the data over to a format that could be easily placed into either a consistent plotting package or a spreadsheet package.

Upon running the post-processor program, POST, the program prompts the user for both the input and output file names. If the input file does not exist or the output file does, the program requests the user to confirm the entry. The output will be in a form that can be placed into various plotting packages that are capable of accepting columns of data in ASCII format.

Table 3.1 Description of Variables in ICS/PCCS Data Files

PLOT.DAT			
	Variable Name	Units	Description
1	TIME	s	Beginning of timestep value
2	E2ADIC	W	Power transferred to the ICS/PCC pools
3	PLTCEF	W	Maximum capacity of the PCCS unit(s) in operation
4	PLTIFL	kg/s	Flow rate of material through the vent line(s)
5	PLTNFL	kg/s	Flow rate of noncondensible gases through the vent line(s)
6	PLTVLL	m^3	Void left in the PCCS at the end of the current timestep
7	PRPSOU	(no units)	Mole fraction of noncondensible gases in source volume
8	DELPRE	Pa	Differential pressure between the source volume (drywell) and the vent volume (wetwell)
9	REQPRE	Pa	Minimum differential pressure required to produce flow
PLOTSPECIAL.DAT			
	Variable Name	Units	Description
1	TIME	s	Beginning of timestep value
2	ENCDCL	W	Power used to cool any noncondensible gases that remained in the PCCS at the end of the previous timestep, to the ICS/PCC pool temperature
3	PW_WW_PL	W	Power passed to the pressure suppression pool
4	PW_WW_ATM	W	Power passed to the wetwell atmosphere
5	PRPCS_2	Pa	Pressure in the PCCS after the iterative filling operation
6	P_DRYWELL	Pa	Pressure in the drywell
7	STM_MAS_BEF	kg	Steam mass before the equilibration of the material in the condenser
8	STM_MAS_AFT	kg	Steam mass after the equilibration of the material in the condenser
9	FOG_MAS_BEF	kg	Fog mass before the equilibration of the material in the condenser
10	FOG_MAS_AFT	kg	Fog mass after the equilibration of the material in the condenser
11	TATPCS_1	K	Temperature of noncondensible gases that remain in the PCCS from the end of the previous timestep
12	TATPCS_2	K	Temperature of the PCCS gases after equilibration of the material in the condenser
13	T-DRYWELL	K	Temperature of the gases in the drywell
14	NCOUNT	(no units)	Number of iterations performed in filling the PCCS
PLOT.RX.DAT			
	Variable Name	Units	Description
1	TIME	s	Beginning of timestep value
2	E2ADIC	W	Power transferred to the ICS/PCC pools
3	PLTCEF	W	Maximum capacity of the ICS unit(s) in operation
4	PLTIFL	kg/s	Flow rate of material through the vent line(s)
5	PLTNFL	kg/s	Flow rate of noncondensible gases through the vent line(s)

Table 3.1 Description of Variables in ICS/PCCS Data Files

6	PLTVLL	m^3	Void left in the ICS at the end of the current timestep
7	PRPSOU	(no units)	Mole fraction of noncondensible gases in source volume
8	DELPRE	Pa	Differential pressure between the source volume (reactor vessel) and the vent volume (wetwell)
9	CLRPRE	Pa	Differential pressure required to clear the water column from the vent line in the wetwell pool
PLOTSPECIAL.RX.DAT			
	Variable Name	Units	Description
1	TIME	s	Beginning of timestep value
2	ENCDCL	W	Power used to cool any noncondensible gases that remained in the ICS at the end of the previous timestep, to the ICS/PCC pool temperature
3	PW_WW_PL	W	Power passed to the pressure suppression pool
4	PW_WW_ATM	W	Power passed to the wetwell atmosphere
5	PRIC_2	Pa	Pressure in the ICS after the iterative filling operation
6	P_RPV	Pa	Pressure in the reactor vessel
7	STM_MAS_BEF	kg	Steam mass before the equilibration of the material in the condenser
8	STM_MAS_AFT	kg	Steam mass after the equilibration of the material in the condenser
9	FOG_MASS_BEF	kg	Fog mass before the equilibration of the material in the condenser
10	FOG_MAS_AFT	kg	Fog mass after the equilibration of the material in the condenser
11	TATIC_1	K	Temperature of noncondensible gases that remain in the ICS from the end of the previous timestep
12	TATIC_2	K	Temperature of the ICS gases after equilibration of the material in the condenser
13	T-RPV	K	Temperature of the gases in the reactor vessel
14	NCOUNT	(no units)	Number of iterations performed in filling the ICS

4. Plot Variables and Control Function Arguments

The plot variables and control function arguments included in the ESFCND package are listed below, along with a brief description of each. Within slashes (/ /) a 'p' indicates a plot variable and a 'c' indicates a control function argument. Also, these variables, unlike other MELCOR plot variables, are in lower case, and must be entered as such as input to HISPLT—lower case enclosed in quotes.

esf-pccs-vntfl	/p/	The integrated total flow through the PCCS vent line into the pressure suppression pool. (units = kg)

esf-pccs-toteng	/p/	Integrated energy added to the ICS/PCC pools (PCCS heat sink). (units = J)
esf-pccs-totstm	/p/	Cumulative steam removed from the drywell. (units = kg)
esf-ics-vntfl	/p/	The integrated total flow through the ICS vent line into the pressure suppression pool. (units = kg)
esf-ics-toteng	/p/	Integrated energy added to the ICS/PCC pools (ICS heat sink). (units = J)
esf-ics-toststm	/p/	Cumulative steam removed from the reactor vessel. (units = kg)

5. Example Input

The following are sample MELGEN input records for the CND package and associated control functions. An example MELCOR input deck follows.

5.1 Example MELGEN Input

```
*******************************************************************
*
*   Ivpcpl - cvh volumes receiving heat transfer from PCCS
*   Ivpcso - cvh volume from which the source is taken for the PCCS
*   Ivpcvn - cvh volume containing the vent line from the PCCS
*   Ivpcdn - cvh volume containing the drain line from the PCCS
**         ivpcpl(1)  ivpcpl(2)  ivpcpl(3)  ivpcso     ivpcvn     ivpcdn
esfcnd0100  400        401        402        210        230        240
*
tf30300    'PCCS Source pres'   14   1.0  0.0
*
*          Pressure        Multiplier to
*                               PCCS
*          Pa                Performance
*
tf30311    0.00E+00        0.0000
tf30312    6.11E+02        0.0000
tf30313    5.00E+04        0.0000
tf30314    1.00E+05        0.0000
*   For pressures below .15 MPa the saturation
*   temperature is below 100 C; therefore,
*   no heat transfer is allowed
tf30315    1.50E+05        0.4250
```

```
tf30316    2.00E+05        0.6660
tf30317    2.50E+05        0.8495
*  Base operating pressure is approx. 0.3 MPa
tf30318    3.00E+05        1.0000
*  at higher pressure the steam is more
*  dense; therefore, the pccs becomes
*  more effective
tf30319    3.50E+05        1.1289
tf30320    4.00E+05        1.2425
tf30321    4.50E+05        1.3450
tf30322    5.00E+05        1.4386
tf30323    6.50E+05        1.6807
tf30324    7.00E+05        1.7518
*
*  ipcdpr -  variation in efficiency due to difference in
*            differential pressure between the drywell and
*            wetwell
*  ipltmp -  variation in efficiency due to increase of
*            noncondensible partial pressure in the pccs
*            for a pool temperature of 50 degree C
*  ipcncn -  variation in efficiency due to increase of
*            noncondensible partial pressure in the pccs
*            for a pool temperature of 100 degree C
*  ipsrpr -  variation in efficiency due to decrease in source
             pressure
*               ipcdpr    ipltmp    ipcncn    ipsrpr
esfcnd0200      300        301       302       303
*
*  The base case is chosen to be the PCCS at the following
*  conditions:
*  IC/PCCS pool Temperature = 100 C
*  Delta P = 15.4 Kpa
*  a NC Mole Fraction of 0.0
*  and a base capacity of 10.6 MWt
*
*    values from ge  for a typical pccs unit
tf30000    'delp rduct pccs'    5    1.0  0.0
*          pa – verification in capacity
tf30010         0.0   0.9434    7500.0    0.9434    15400.    1.00
tf30011     23400.0   1.0094    1.0e+06   1.0094
*
*  values from ge for a ic/pccs pool
*  temperature of 50 c
tf30100    'nncn rd 50 pccs'    21   1.0  0.0
*          mole fraction of noncondensibles – variation in cap.
tf30110    0.00     2.2547  0.0071   1.5094  0.0287    1.3302
tf30111    0.0570   1.1981  0.1142   1.0377  0.1718    0.9085
tf30112    0.2290   0.7925  0.2861   0.6887  0.3429    0.5962
tf30113    0.3999   0.5123  0.4571   0.4368  0.5140    0.3689
tf30114    0.5718   0.3075  0.6289   0.2509  0.6852    0.1981
```

```
tf30115    0.7429   0.1491   0.8006   0.1028   0.8568    0.0620
tf30116    0.9141   0.0266   0.9708   0.0012   1.0000    0.0000
*
*  values from ge for a ic/pccs pool
*  temperature of 100 c
tf30200    'nncn rd 100 pccs'   16   1.0  0.0
*          mole fraction of noncondensibles - variation in cap.
tf30210    0.00     1.0000   0.0071   0.9434   0.0287    0.7726
tf30211    0.0570   0.6858   0.1142   0.5811   0.1718    0.4972
tf30212    0.2290   0.4255   0.2861   0.3585   0.3429    0.2962
tf30213    0.3999   0.2396   0.4571   0.1868   0.5140    0.1387
tf30214    0.5718   0.0926   0.6289   0.0514   0.6852    0.0152
tf30215    1.0      0.0000
*
*
*  elbtvt - elevation of the bottom of the vent line from pccs
*  vntlnd - the minimum diameter of the vent line in meters
*  vntlen - the vent line length in meters
*               elbtvt     vntlnd     vntlen
esfcnd0300      9.350      .25451          62.67
*
*  volpcs - volume of one unit of the pccs in m**3
*  pcmxpf - maximum performance at design operating conditions MWt
*  nmpccs - number of pccs units operating
*  vlpcsl - volume of one unit of the pccs source line in m**3
*               volpcs     pcmxpf     nmpccs     vlpcsl
esfcnd0400      1.58       10.6         3        2.01
*******************************************************************
*


*  Ivicpl - cvh volumes receiving heat transfer from ICS
*  Ivicso - cvh volume from which the source is taken for the ICS
*  Ivicvn - cvh volume containing the vent line from the ICS
*  Ivicdn - cvh volume containing the drain line from the ICS
**         ivicpl(1)  ivicpl(2)  ivicpl(3)  ivicso     ivicvn     ivicdn
esfcnd0500  300        301        302        160        230        100
*
*  variation values from ge for a ic/pccs pool
*  temperature of 50 c obtained from PCCS data.  Upper value
*  limited to 1.5 for a mole fraction of 0.0
tf31100    'nncn rd 50 ics'      2   1.0  0.0
*          mole fraction of noncondensibles - variation in cap.
tf31110    0.00     1.5      0.0071   1.5094   0.0287    1.3302
tf31111    0.0570   1.1981   0.1142   1.0377   0.1718    0.9085
tf31112    0.2290   0.7925   0.2861   0.6887   0.3429    0.5962
tf31113    0.3999   0.5123   0.4571   0.4368   0.5140    0.3689
tf31114    0.5718   0.3075   0.6289   0.2509   0.6852    0.1981
tf31115    0.7429   0.1491   0.8006   0.1028   0.8568    0.0000
tf31116    0.9141   0.0266   0.9708   0.0012   1.0000    0.0000
```

```
*
tf30400    'ICS Source pres'    46   1.0  0.0
*
*          Pressure         Multiplier to
*                                ICS
*          Pa                 Performance
*
tf30411    0.00E+00        0.0000
tf30412    6.11E+02        0.0000
tf30413    5.00E+04        0.0000
tf30414    1.00E+05        0.0000
*  For pressures below .15 MPa the saturation
*  temperature is below 100 C; therefore,
*  no heat transfer is allowed
tf30415    1.50E+05        0.1080
tf30416    2.00E+05        0.1692
tf30417    2.50E+05        0.2159
tf30418    3.00E+05        0.2541
tf30419    3.50E+05        0.2869
tf30420    4.00E+05        0.3157
tf30421    4.50E+05        0.3418
tf30422    5.00E+05        0.3655
tf30423    6.50E+05        0.4271
tf30424    7.00E+05        0.4451
tf30425    7.50E+05        0.4624
tf30426    8.00E+05        0.4787
tf30427    8.50E+05        0.4943
tf30428    9.00E+05        0.5092
tf30429    9.50E+05        0.5237
tf30430    1.00E+06        0.5376
tf30431    1.10E+06        0.5643
tf30432    1.20E+06        0.6507
tf30433    1.30E+06        0.6139
tf30434    1.40E+06        0.6368
tf30435    1.50E+06        0.6591
tf30436    1.75E+06        0.6661
tf30437    2.00E+06        0.6980
tf30438    2.25E+06        0.7259
tf30439    2.50E+06        0.7512
tf30440    3.00E+06        0.7956
tf30441    3.50E+06        0.8328
tf30442    4.00E+06        0.8645
tf30443    5.00E+06        0.9159
tf30444    6.00E+06        0.9556
tf30445    7.00E+06        0.9883
tf30446    7.20E+06        0.9942
* Base operating pressure is approx. 7.4 MPa
tf30447    7.40E+06        1.0000
tf30448    7.60E+06        1.0054
tf30449    7.80E+06        1.0106
```

```
tf30450   8.00E+06       1.0156
tf30451   8.20E+06       1.0204
tf30452   8.40E+06       1.0252
tf30453   8.60E+06       1.0298
tf30454   8.80E+06       1.0340
tf30455   9.00E+06       1.0381
tf30456   1.00E+07       1.0568
*
*
* no variation in performance is assumed for increase delta p in
* the vent line
tf31000   'delp rduct ics'     2    1.0  0.0
*         pa – variation in capacity
tf31010        0.0  1.00 1.0e+06   1.00
*
*
* iicdpr   – variation in efficiency due to difference in diffential
*            pressure between the reactor vessel and
*            wetwell
* iiltmp   - variation in efficiency due to increase of
*            noncondensible partial pressure in the ics
*            for a pool temperature of 50 degree C
*  iicncn - variation in efficiency due to increase of
*            noncondensible partial pressure in the ics
*            for pool temperature of 100 degree C
*  ipsrpr - variation in effiency due to decrease
            in source pressure
**        iicdpr    iiltmp    iicncn    iisrpr
esfcnd0600  310        311       302       304
*
* Values for IICDPR, IILTMP, IICNCN, have not been obtained from
* GE, thus the same values for the PCCS are used for the ICS
*
* elvict   – elevation of the bottom of the vent line from ics
* vnticd   – the minimum diameter of the vent line in meters
* vnticl   – the vent line length in meters
* iccfl2   - control function indicating initiation of the ICS,
*            a non-zero number initiates operation
*            the value can be + or –
*         elvict    vnticd    vnticl    iccf12
esfcnd0700  9.5      0.01885    17.4       805
*
* volic    - volume of one unit of the ics in m**3
* pficmx   - maximum performance at design operating conditions MWt
* nmic     - number of ics units operating
* vnstp(1)   opening reactor vessel pressure for ics vent Pa
* vnstp(2)   reset reactor vessel pressure for ics vent Pa
* vnstp(3)   time delay before which the vent can not close
*            if vnstp(3) is negative then a CF value must be
*            provided that controls the function of the vent valve
```

```
* vlicsl   - volume of one unit of the ics source line in m**3
*            volic   pficmx nmic  vnstp(1)   vnstp(2)   vnstp(3)   vlicsl
esfcnd0800  0.7368  30.0    3   7.653e6    7.584e6    240.0      2.986
*
*
*******************************************************************
*
*******************************************************************
*
**  The following cf's are an example of the use of the CF logic
**
**  to approximate the ics vent valve operation
*******************************************************************
*
*******************************************************************
*
*
cf30100 true 1-ge 2   1.0   0.0
cf30101 .true.
cf30110 1.0  100.0 time * 100 + current time
cf30111 0.0    0.0 time * zero
**
cf30200 false 1-ge 2 1.0   0.0
c30201  .false.
cf30210 -1.0   0.0 time    * negative of the current time
cf30211  1.0 100.0 time    * 100 + current time
**
cf30300 vnt-vlv-open 1-ge 2  1.0     0.0
cf30301 .false.
cf30310 1.0 0.0   cvh-p.160 * pressure in reactor vessel, CVH volume
160
cf30311 0.0 7.65e06 time    * upper set point of vent valve
**
cf30400 vnt-vlv-clos 1-ge 2 1.0 0.0 * note:  since 1-1e is not supported
*                                            both values had to be
*                                            multiplied by (-1) then the
*                                            1-ge input type could
*                                            be utilized
*
cf30401 .true.
cf30410 -1.0 0.0       cvh-p.160 * pressure in reactor vessel
cf30411 0.0  -7.584e06 time          * lower set point for vent valve
closure
**
cf30500 inv-timer 1-not  1 1.0   0.0
cf30501 .false.
cf30510 1.0  0.0 cfvalu.313
**
cf30600 chk-tim-init 1-and 2    1.0   0.0
cf30601 .false.
```

```
cf30610 1.0  0.0 cfvalu.303
cf30611 1.0  0.0 cfvalu.305
**
cf30700 init-tim  1-1-ifte 3    1.0   0.0
cf30701 .false.
cf30710 1.0  0.0 cfvalu.306 * check to see if p>set point and .not.timer
cf30711 1.0  0.0 cfvalu.301 * set the timer equal to true
cf30712 1.0  0.0 cfvalu.313 * set the timer equal to its old value
**
cf30800 set-cls-tim  1-a-ifte 3 1.0   0.0
cf30801 0.0
cf30810 1.0 0.0 cfvalu.306 * check to see if p>set point and .not.timer
cf30811 1.0 60.0 time      * set the closure time to current time + 60s
cf30812 1.0 0.0 cfvalu.308 * set the closure time to the old value
**
cf30900 vlv-open 1-a-ifte 3 1.0 0.0
cf30901 0.0
cf30910 1.0  0.0 cfvalu.303     * check to see if p>set point
cf30911 0.0  1.0 time      * set the valve opening to 1.0
cf30912 1.0  0.0 cfvalu.312     * set the opening to the old value
**
cf31000 timer-out 1-ge 2  1.0   0.0
cf31001 .true.
cf31010 1.0  0.0 time      * current time
cf31011 1.0  0.0 cfvalu.308     * time valve can close
**
cf31100 chk-cls-cnd 1-and 2 2.0 0.0
cf31101 .true.
cf31110 1.0  0.0 cfvalu.304  * true if pressure has dropped
cf31111 1.0  0.0 cfvalu.310  * true if timer has passed current time
**
cf31200 cls-vent-vlv 1-a-ifte 3 1.0  0.0
cf31201 0.0
cf31210 1.0  0.0 cfvalu.311 * if true close valve
cf31211 0.0  0.0 time       * value of zero
cf31212 1.0  0.0 cfvalu.309 * valve is open set to the old value
**
cf31300 reset-timer 1-1-ifte 3  1.0   0.0
cf31301 .false.
cf31310 1.0  0.0   cfvalu.311   * if true close valve
cf31311 1.0  0.0   cfvalu.302   * set timer to false value
cf31312 1.0  0.0   cfvalu.307   * valve is open set to the old value
**
*******************************************************************
*
*******************************************************************
*
*               TRIP FOR RPV WATER LEVEL 2
*******************************************************************
*
```

```
*********************************************************************
*
*
* The following are the control functions that are used to initiate the
* operation of the ICS
*
* >>>>
* First, test to see if the collapsed water level has fallen to L2.
* >>>>
*
CF80300 'LEVEL-2-TEST' L-GE 2   1.    0.
CF80301 .TRUE.  * initial value
CF80305 'LATCH' * Latch False When water level drops below L2
CF80306 2 'Collapsed Water Level Has Dropped Below L2'
CF80310 1.0  0.0 CVH-CLIQLEV.100 * collapsed liquid level in annulus
CF80311 0.0  13.593 TIME
*
* >>>>
* Second, trap and hold the time at which the level reaches L2
* >>>>
* Following function will trip-on-reverse when CF800 fires, yielding
* a negative value, the absolute value of which is the time (s)
* since trip.
*
CF80400'L2-TIME-LATCH'  TRIP         1    1.   0.
CF80401 0.      * initial value
CF80405 'NORMAL'
CF80410 1.0  0.0  CFVALU.803
* >>>>
* Third, trap and hold the absolute value of CF804. This will be the
* actual time since the vessel water level dropped to L2.
* >>>>
CF80500 'TIME-OF-L2'  ABS   1   1.    0.
CF80501 0.
CF80505 'NORMAL'
CF80510 1.0  0.0  CFVALU.804
```

5.2 Example MELCOR Input

```
*********************************************************************
*
*                PCCS Input
* decrease the number of pccs in operation from 3 to 2
*
* volpcs   - volume of one unit of the pccs in m**3
* pcmxpf   - maximum performance at design operating conditions MWt
* nmpccs   - number of pccs units operating
* vlpcsl   - volume of one unit of the pccs source line in m**3
*           volpcs   pcmxpf     nmpccs     vlpcsl
esfcnd0400   1.58     10.6       2          2.01
```

```
*
*              ICS Input
* decrease the number of ics in operation from 3 to 1
* also start to use the control function logic to control
* the operation of the vent valves
*
*    volic    - volume of one unit of the ics in m**3
     pficmx   - maximum performance at design operating conditions MWt
     nmic     - number of ics units operating
     vnstp(1)   opening reactor vessel pressure for ics vent Pa
     vnstp(3)   time delay before which the vent can not close if
                vnstp(3) is negative then a CF value must be
                provided that controls the function of the vent valve
     vlicsl   - volume of one unit of the ics source line in m**3
*          volic  pficmx  nmic  vnstp(1)   vnstp(2)   vnstp(3)   vlicsl
esfcnd0800  0.7368  30.0   1    7.653e6    7.584e6    -311       2.986
```

6. CND Model Output

In general, the CND model output is self-explanatory. The integrated mass transfer through the vent to the CVH volume representing the suppression pool, the integrated energy transfer to the condenser pools, and the integrated mass of steam removed from the source are output for each condenser type.

7. Diagnostics and Error Messages

Diagnostic messages will be written by MELGEN to report errors or inconsistencies in input. Typical errors include errors in record format and failure to supply all required input records. Inconsistencies between input to different packages are also identified; each of the volumes that a condenser connects to must be defined; any tabular functions or control functions referred to by the condenser model must be properly defined.

No restart file will be written until all errors identified during input processing have been corrected. This does not, of course, assure that the accepted input properly describes the physical system that the user intended to model. The analyst should always examine the initial edit produced by MELGEN prior to running MELCOR.

Messages from MELCOR report problems encountered during the time advancement of a calculation. If an error is severe, the calculation will be stopped and a restart dump written corresponding to conditions at the beginning of the fatal timestep.

Error or warning messages may be issued during execution of MELCOR for any number of reasons. These include: an attempt by the Condenser package to subtract more mass of energy than is contained in the associated CVH control volume, an attempt to add more mass or energy to a CVH volume than is allowed, and errors found in tabular or control functions. Execution will continue, with a reduced system timestep, when it makes sense to do so; the request for a system fallback will be noted with one of the following messages:

```
TIMESTEP CUT IN CND PACKAGE
TOO LARGE A MASS SINK GENERATED

TIMESTEP CUT IN CND PACKAGE
TOO LARGE AN ENERGY SINK GENERATED

TOO LARGE AN ENERGY SINK GENERATED IN ATMOSPHERE
TIMESTEP CUT IN CND PACKAGE
```

When a problem is encountered with a tabular function or a control function, one of the following messages will be produced by routine CNDRN1:

`tabular function error in subroutine cndrn1:50C`

An error occurred when trying to determine the capacity reduction factor, determined from a user-defined tabular function, for a pool temperature of 50°C.

`tabular function error in subroutine cndrn1:100C`

An error occurred when trying to determine the capacity reduction factor, determined from a user-defined tabular function, for a pool temperature of 100°C.

`tabular function error in subroutine cndrn1:FLOW`

An error occurred when trying to determine the capacity reduction factor, determined from a user-defined tabular function, for the differential pressure between the source and the vent CVH volumes.

`tabular function error in subroutine cndrn1:PRES`

An error occurred when trying to determine the capacity reduction factor, determined from a user-defined tabular function, for the pressure in the source volume.

`tabular function error in subroutine cndrn1:vnstp`

An error occurred when trying to determine the status of the vent valve from a user-defined control function (a value greater than zero means the valve is open).

Once the condenser is filled from the source volume, an initial pass is made through an equilibration routine. The equilibration routine that is utilized is CVTWGE. CVTWGE is the routine used by the CVH package to equilibrate the CVH volumes when the equilibrium option is used on card CVnnn00, i.e., *Tpool = Tatmos*. If an error occurs in evaluating the properties of the materials in the condenser, the following error message will be sent"

```
error from call to CVTWGE in subroutine cndrnl
```

In addition to this message, this error condition will result in a restart file being written and immediate termination of the calculation.

As explained in Section 2.4 of the Condenser Package Reference Manual, an iteration process is used to fill the condenser; however, to prevent an infinite loop, the logic is limited to a maximum number of iterations. If the pressure of the source volume is not obtained within the allowable limit, the following error message is produced:

```
message from subroutine cndrnl
iteration process failed
```

Two energy balance checks are performed during MELCOR execution. The first is performed to ensure that the equilibration routine conserves energy. If energy is not conserved, then the following message is produced:

```
cndrnl:internal energies out of bound
```

The second check is an overall energy balance on the package. The energy error is defined as the current energy minus the integrated energy transferred to the package plus the integrated energy transferred from the package. The relative energy error is given by the energy error divided by the sum of the current energy and the integrated energy transferred out of the package. If the relative energy error exceeds 0.5 percent, the following message is written:

```
*******************************************
Message from CNDRN2
CND Package Energy Balance Greater than 0.5%
*******************************************
```