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MELCOR Model for an Experimental 17x17 Spent Fuel PWR Assembly

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MELCOR Model for an Experimental 17x17 Spent Fuel PWR Assembly

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Severe Accident Analysis

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ABSTRACT

A MELCOR model has been developed to simulate a pressurized water reactor (PWR) 17×17 assembly in a spent fuel pool rack cell undergoing severe accident conditions. To the extent possible, the MELCOR model reflects the actual geometry, materials, and masses present in the experimental arrangement for the Sandia Fuel Project (SFP). The report presents an overview of the SFP experimental arrangement, the MELCOR model specifications, demonstration calculation results, and the input model listing.

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ACRONYMS

CV	Control Volume
FL	Flow Path
HS	Heat Structure
OECD	Organization for Economic Co-operation and Development
PCT	Peak Cladding Temperature
PWR	Pressurized Water Reactor
SFP	Spent Fuel Pool / Sandia Fuel Project
SLPM	Standard Liters per Minute ($0^{o}C$ and 1 atm)
USNRC	US Nuclear Regulatory Commission

1. INTRODUCTION

The US Nuclear Regulatory Commission (USNRC) and the Organisation for Economic Co-operation and Development (OECD) have collaborated to investigate the behavior of pressurized water reactor (PWR) fuel assemblies under severe accident conditions in a spent fuel pool. In support of this effort, a MELCOR model has been developed to provide guidance in experimental design and planning. This report constitutes a summary of these modeling efforts. To the extent possible, the MELCOR model reflects the actual geometry, materials, and masses present in the Sandia Fuel Project (SFP) experimental arrangement. Section 2 presents an overview of the experimental geometry and materials. Section 3 describes the key components of the MELCOR model, and Section 4 presents a sample calculation. Finally, Appendix A provides a complete listing of the MELCOR model.

2. SFP MODEL DATA

Table 1 contains SFP model parameters based on characteristics of the experimental arrangement.

Table 1. SFP Model Parameters.

Fuel Lattice Parameters	Value
Fuel Outer Diameter (mm)	8.190
Swollen Fuel Outer Diameter (mm)	8.941
Fuel Cladding Inner Diameter (mm)	8.941
Fuel Cladding Outer Diameter (mm)	9.512
Fuel Cladding Thickness (mm)	0.572
Fuel Rod Pitch (mm)	12.60
Control Rod Guide Tube Inner Diameter (mm)	11.43
Control Rod Guide Tube Outer Diameter (mm)	12.19
Instrument Tube Inner Diameter (mm)	11.48
Instrument Tube Outer Diameter (mm)	12.24
Control Rod & Instrument Tube Thickness (mm)	0.381
Number of Fuel Rods per Assembly	264
Number of Control Rod Guide Tubes per Assembly	24
Number of Instrument Tubes per Assembly	1
Flow Area (m^2)	0.0272
Equivalent Hydraulic Diameter (mm)	11.19
MELCOR Modeling Parameters	**Value**
Fuel Filler Material	MgO
Fuel & Tube Cladding Material	Zirc
Nozzle Material	Stainless Steel
Spacers, Debris Catcher Material	Zirlo (treated as Zirc)
Heated Fuel Axial Length (m)	3.613
Fuel Rod & Tube Axial Length (m)	3.918
Inlet Nozzle Axial Length (m)	0.169
Total Assembly Axial Length (m)	4.047
Storage Cell Inner Diameter (mm)	221.3
Storage Cell Rack Thickness (mm)	1.905
Insulation Thickness (mm)	152.4
Baseplate Thickness (mm)	12.7
K, Coefficient of Flow Resistance	29.0
SLAM	114.6

The fuel in the experimental test assembly is simulated using compacted MgO that is uniformly heated by a nichrome heater element. In the upper 0.254 m unheated plenum of the simulated fuel rods and the lower unheated 0.051 m region, the MgO "fuel" filler is displaced by 3.175 mm diameter steel pins, as depicted in Figure 1.

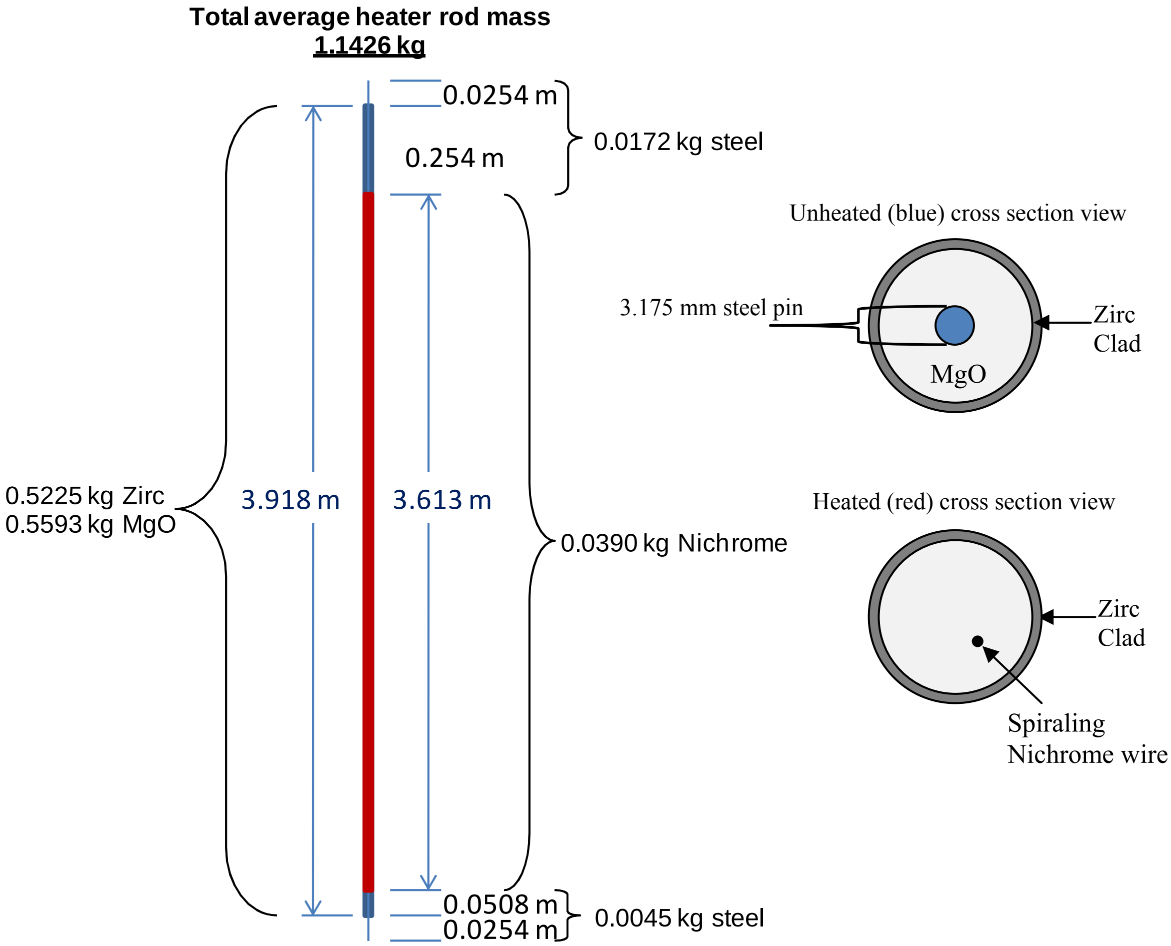


Figure 1. Heater Rod Geometry.

Spent fuel assemblies are contained within stainless steel storage cells (see Figure 2). The dimensions and geometry of the storage cell, along with the fuel assembly lattice, determine the flow area and hydraulic diameter in the SFP model.

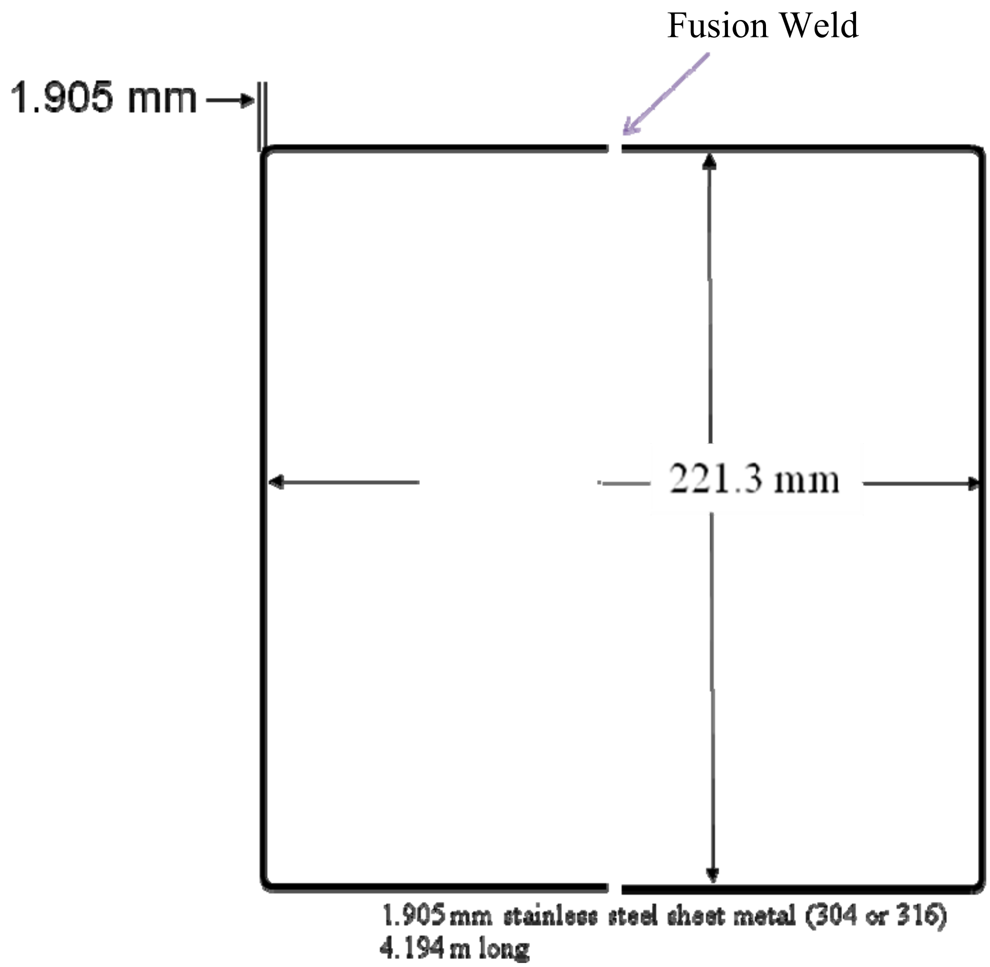


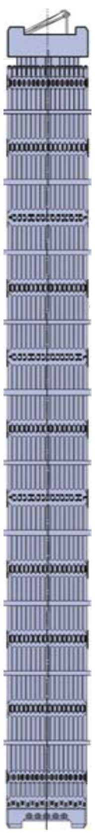
Figure 2. Storage Cell Geometry.

3. MELCOR SFP MODEL DESCRIPTION AND NODALIZATION

The MELCOR SFP fuel assembly model was developed to accurately represent the experimental assembly, materials, and masses. However, due to experimental design constraints or practicality, the SFP fuel assembly and rack have unique features not found in an actual spent fuel pool, e.g. UO_2 fuel simulated by MgO. In addition, the fuel behavior model in MELCOR does not have provisions for unique experimental features or are beyond the scope of the modeling capabilities. Consequentially, each of these design and modeling exceptions are noted.

The experimental models use compacted MgO that is uniformly heated by nichrome wire as simulated UO_2 fuel. Within the MELCOR input, the thermo-physical properties of UO_2 fuel were replaced with MgO properties. The decay power is simulated using a uniform fission product decay power distribution. Since MELCOR has no input options for nichrome or steel mass in the fuel or cladding regions of the fuel rod model, these components are neglected in the MELCOR model. The total neglected mass is calculated to be 16.05 kg (35.4 lbs) of steel and nichrome. The MgO filler is packed into the Zircaloy cladding; therefore, no fuel-cladding gap is modeled in the experiment or the MELCOR model.

The SFP MELCOR model uses the SFP-PWR type core option in MELCOR. The SFP-PWR and SFP-BWR core types are new core model options available in MELCOR Version 1.8.6. The core model is composed of 17 total axial levels and 1 radial ring. Two axial nodes are in the lower plenum: one for the baseplate and one representing the pipe under the baseplate. Above the baseplate is one node for the lower nozzle, followed by 12 nodes for the active (heated) core region. Above the active core are two more axial levels for the plenum region (unheated) and the top nozzle. Figure 3 shows an axial diagram of the SFP assembly and a description of the structures contained within each axial level. Figure 3 also illustrates the core, control volume (CV), and flow path (FL) nodalization of the model.

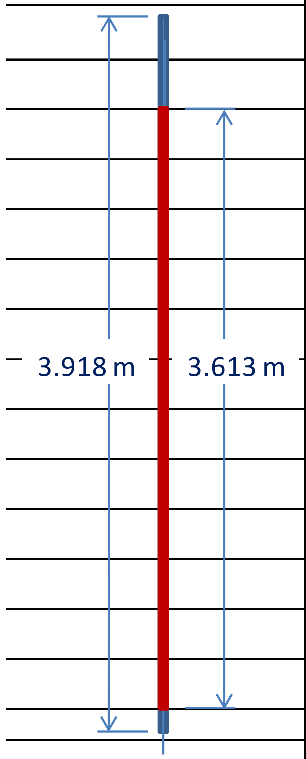


Axial Level		Core Cell #	CV #	FL #	Core & CV Heights inches	m
					164.8976	4.1884
17	top nozzle, top of racks	COR117	CV108	FL109 (out)	159.3012	4.0463
16	unheated plenum region, to exit nozzle	COR116		FL108	154.9035	3.9346
15	heated fuel 12	COR115	CV107		143.0494	3.6335
14	heated fuel 11	COR114		FL107	131.1952	3.3324
13	heated fuel 10	COR113	CV106		119.3410	3.0313
12	heated fuel 9	COR112		FL106	107.4869	2.7302
11	heated fuel 8	COR111	CV105		95.6327	2.4291
10	heated fuel 7	COR110		FL105	83.7785	2.1280
9	heated fuel 6	COR109	CV104		71.9244	1.8269
8	heated fuel 5	COR108		FL104	60.0702	1.5258
7	heated fuel 4	COR107	CV103		48.2160	1.2247
6	heated fuel 3	COR106		FL103	36.3619	0.9236
5	heated fuel 2	COR105	CV102		24.5077	0.6225
4	heated fuel 1	COR104		FL102	12.6535	0.3214
3	lower nozzle, debris grid	COR103	CV101	FL101	6.5	0.1651
2	baseplate, lower nozzle	COR102	CV010		6.0	0.1524
1	pipe, below baseplate	COR101		FL002 (in)	0.0	0.0

Figure 3. MELCOR SFP Nodalization.

Material masses are allocated appropriately in MELCOR to model the experimental setup, and properly distributed across the axial mesh to conserve each material's total mass, as depicted in Table 2. MgO mass is input as UO_2 fuel mass at reduced density (ρ_{MgO} / ρ_{UO2} = 2950.1 kg/m^3 / 10960.0 kg/m^3). Zircaloy mass in the cladding and debris catcher, and Zirlo mass from the grids, are input as Zircaloy cladding component mass. Zircaloy mass from the control rod guide tubes and instrument tubes are input as Zircaloy non-supporting structure component mass (KNS). The bottom stainless steel nozzle is input as steel supporting structure mass, while the mass of the top nickel alloy nozzle is neglected in the model due to its low mass. To improve the heat transfer modeling of the experimental facility, the rack and surrounding insulation are modeled using heat structures. As mentioned before, the mass of steel pins in the unheated regions of the MgO fuel, and the nichrome wire in the heated region of the fuel, are not included in the MELCOR model.

Table 2. MELCOR SFP Mass Distribution



	Height (m)	---------- Mass Distribution, per assembly (kg) ----------						
Cell #	4.188	MgO	Zirc	Zirc KNS	Steel clad*	Nichrome*	SS Rack	SS Structure
COR117	4.046	4.733	5.941	0.419	2.731	0	1.936	0
COR116	3.935	3.715	3.933	0.257	1.819	0	1.494	0
COR115	3.633	11.167	11.300	0.692	0	0.858	4.027	0
COR114	3.332	11.167	11.300	0.692	0	0.858	4.027	0
COR113	3.031	11.167	11.300	0.692	0	0.858	4.027	0
COR112	2.730	11.167	11.300	0.692	0	0.858	4.027	0
COR111	2.429	11.167	11.300	0.692	0	0.858	4.027	0
COR110	2.128	11.167	11.300	0.692	0	0.858	4.027	0
COR109	1.827	11.167	11.300	0.692	0	0.858	4.027	0
COR108	1.526	11.167	11.300	0.692	0	0.858	4.027	0
COR107	1.225	11.167	11.300	0.692	0	0.858	4.027	0
COR106	0.924	11.167	11.300	0.692	0	0.858	4.027	0
COR105	0.622	11.167	11.300	0.692	0	0.858	4.027	0
COR104	0.321	11.167	11.300	0.692	0	0.858	4.027	0
COR103	0.165	5.198	4.152	0.294	1.197	0	2.090	5.271
COR102	0.152	0	0	0	0	0	0	4.295
COR101	0	0	0	0	0	0	0	0
	total (kg):	147.650	149.621	9.271	5.748	10.298	53.841	9.566
	total (lb):	325.512	329.858	20.438	12.672	22.704	118.699	21.089
	total assembly weight including steel clad and nichrome =						***850.973 lbs***	
	total MELCOR assembly weight (no steel clad and nichrome) =						***815.596 lbs***	

* there is no MELCOR input option for steel or nichrome in the clad/fuel region

4. DEMONSTRATION CALCULATION

The demonstration SFP calculation consists of an 8 hour, 5.0 kW heat-up followed by a 4 hour cool down period. The heater power from the nichrome heater element terminates after the 8 hour heating period.

As shown in Figure 4, peak cladding temperature in this demonstration reaches about 800 K, at which point the heater has been on for 8 hours. The nichrome then ceases heating and the assembly cools. This calculation is indicative of an experiment that does not ignite the spent fuel cell model. Figure 5 depicts cladding temperatures as the SFP rack cell heats and then cools, at each axial level. It shows that the highest PCT for the calculation occurs in core cell 114 at 3.332 to 3.633 meters of elevation.

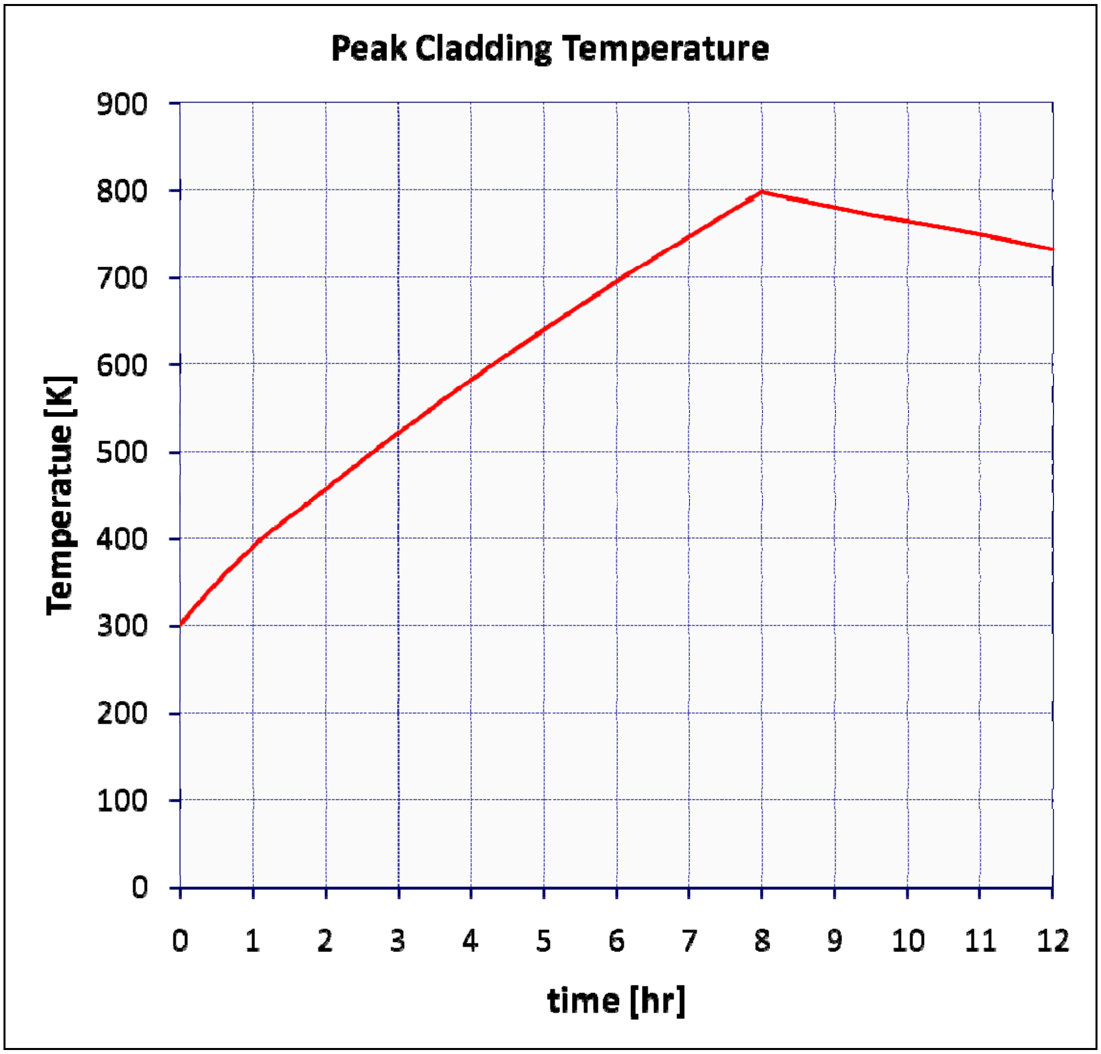


Figure 4. SFP Peak Cladding Temperature.

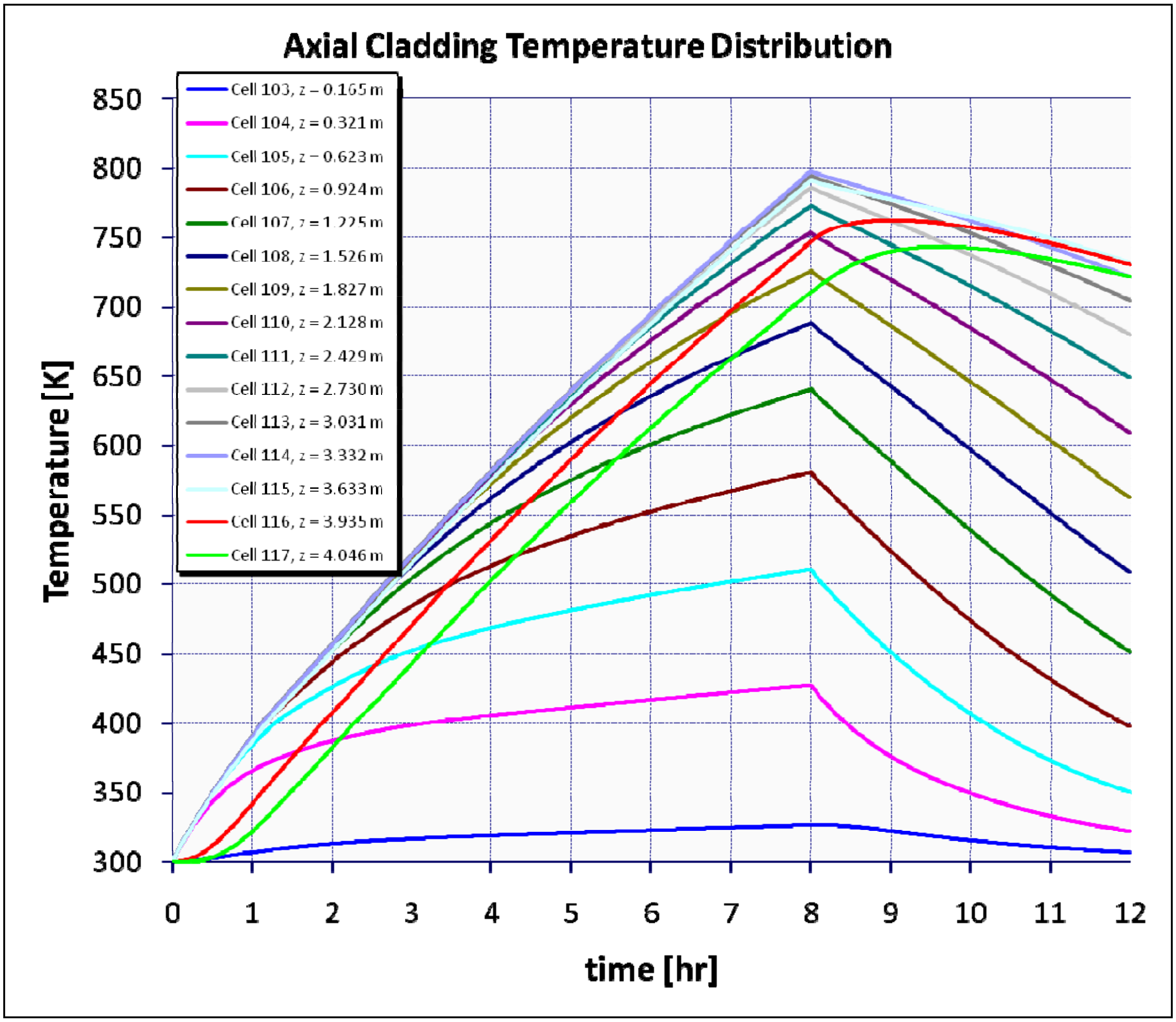


Figure 5. SFP Cladding Axial Temperatures at Each Core Cell Level.

Figure 6 shows the energy balance of the model, where the green curve confirms the heater power terminating after 8 hours. The change in the convective power and radial heat transfer between 1 to 2 hours is likely due to change in the correlation used to calculate the convective heat transfer coefficient. However, this assumption has not been verified. The flow rate of the assembly in standard liters per minute (SLPM) is portrayed by Figure 7. As the rods heat the surrounding air, the oxidation of the Zircaloy cladding will increase. Figure 8 depicts the increasing thicknesses of the zirconium-oxide layers on the fuel cladding at each axial node. Two hours after heating terminates the oxide layer thicknesses begin to level off. In Figure 8, COR-DROXD-CL.101 is the oxide thickness on the cladding in core cell 101, the lower-most core cell under the baseplate. Likewise, COR-DROXD-CL.117 is the oxide thickness on the cladding in core cell 117, the exit nozzle and highest core cell. The cladding in core cell 114, located at 3.332 to 3.633 meters in elevation, has the highest oxide layer thickness of approximately 1.9 µm.

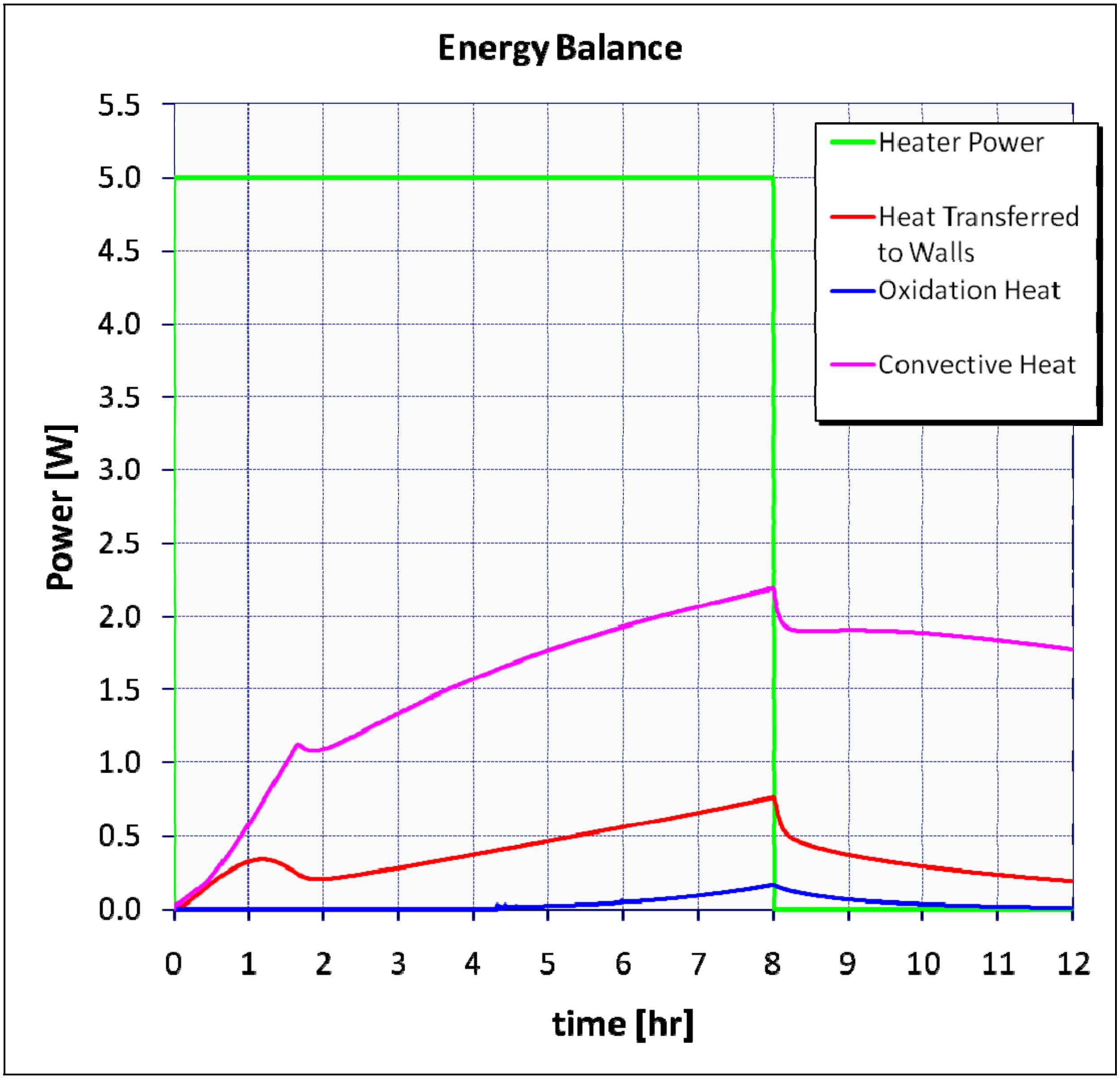


Figure 6. SFP Rack Energy Balance.

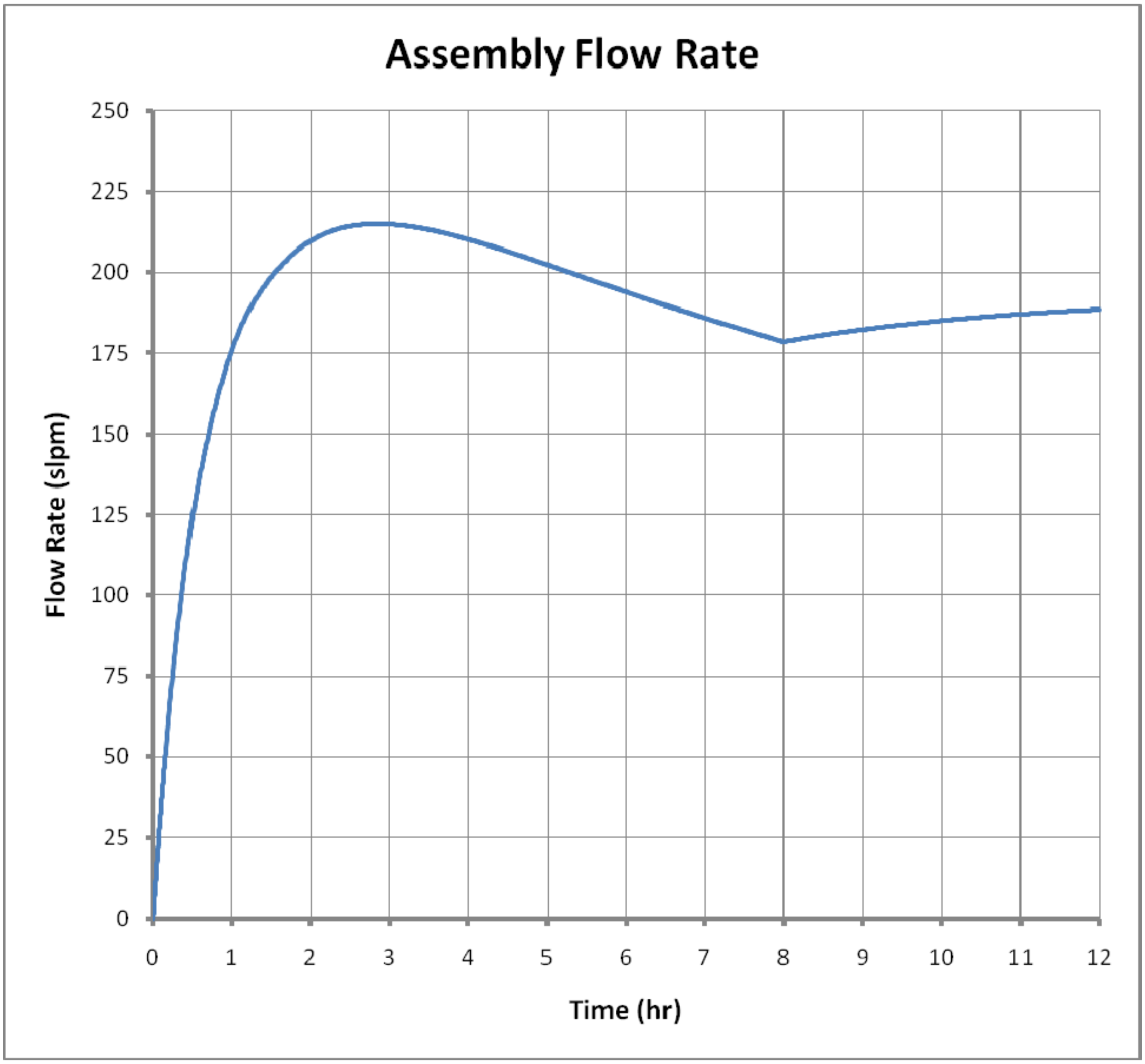


Figure 7. Flow Rate in Standard Liters per Minute.

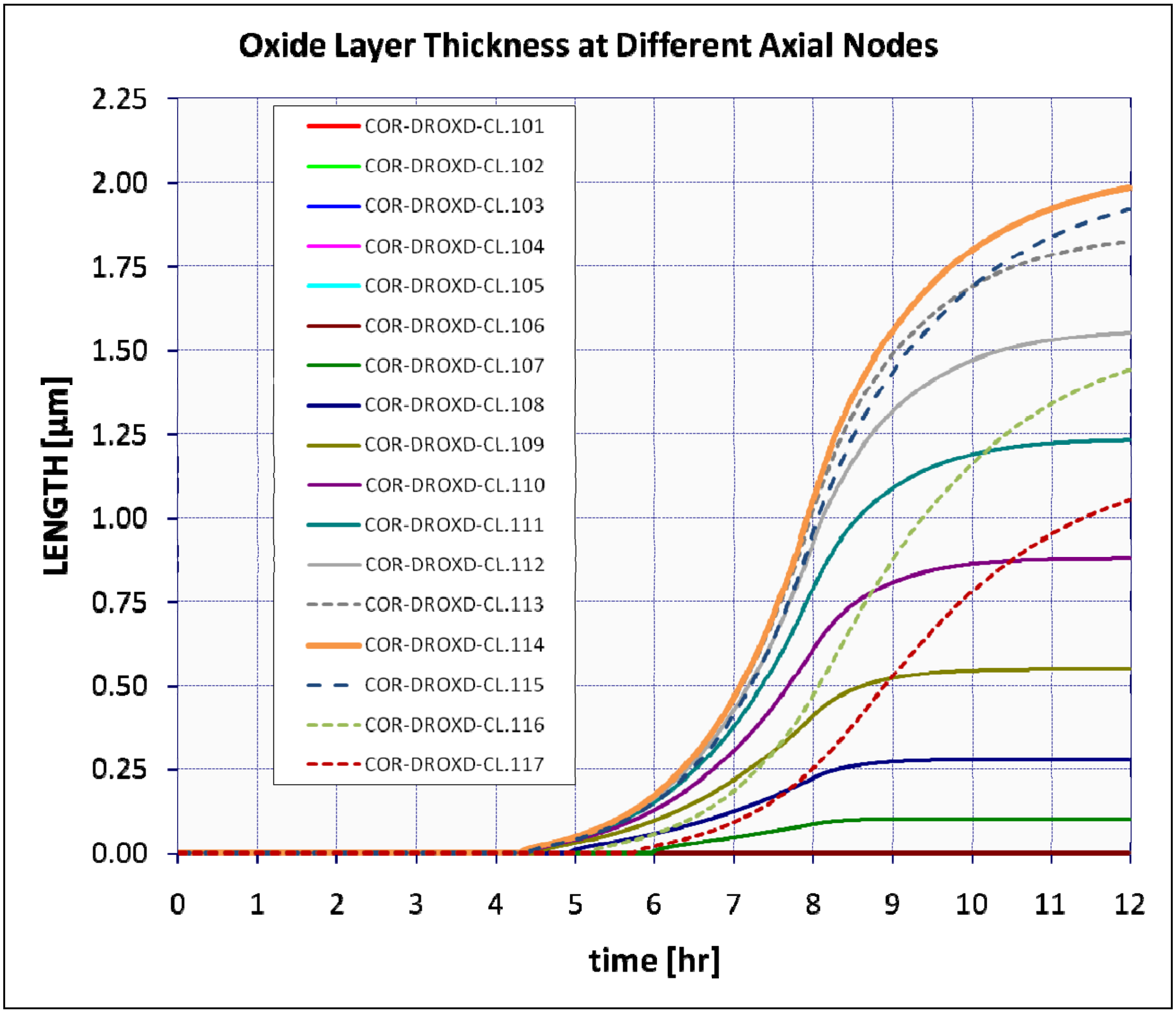


Figure 8. Cladding Oxide Layer Thicknesses.

5. REFERENCES

[1] Gauntt, R. O., Cash, J.E., Cole, R. K.,. Erickson, C. M, Humphries, L.L., Rodriguez, S. B., Young, M. F., 2005, "MELCOR Computer Code Manuals, Vol. 1: Primer and User's Guide, Version 1.8.6," NUREG/CR 6119, Vol. 1, Rev. 3, U.S. Nuclear Regulatory Commission, Washington, DC.

APPENDIX A. MELCOR INPUT FILES

A.1 MELGEN and MELCOR Input

sfp.gen MELGEN Input File:

```
title     'SFP'
jobid     'SFP Separate Effects Model'
*
restartf  'sfp.rst'
outputf   'sfpg.out'
diagf     'sfpg.dia'
stopf     'sfp.stp'
*
r*i*f ..\cvh.gen
r*i*f ..\cor.gen
r*i*f ..\dch.gen
r*i*f ..\ncg.gen
r*i*f ..\mp.gen
r*i*f ..\mp_mgo.gen
r*i*f ..\rn.gen
r*i*f ..\hs.gen
r*i*f ..\stop.gen
*
allowreplace
*
tstart 0.
*
r*i*f ..\ic_air.gen
*
dchdecpow    cf-100
dchoperpow   5000.0
dchfpow      5000.0 0.0 0.0
*
*
cf09600  Time   L-GE           2  1.0  0.0
cf09601  .FALSE.
cf09605 'LATCH'
cf09611  1.0     0.0    time           * Time
cf09612  0.0 28800.0    time       * Time = 8 hours
*
cf09700  PCT    L-GE           2  1.0  0.0
cf09701  .FALSE.
cf09705 'LATCH'
cf09711  1.0     0.0    cfvalu.60  * PCT in Ring 1
cf09712  0.0  99999.0    time       *
*
cf09800  PCT    L-OR           2  1.0  0.0
cf09801  .FALSE.
cf09805 'LATCH'
cf09811  1.0     0.0    cfvalu.96  * Time > 8 hours
cf09812  1.0     0.0    cfvalu.97  *
*
cf09900  'Burn-out'  L-A-IFTE  3  1.0  0.0
cf09901  1.0
cf09910  1.0   0.0   cfvalu.98
cf09911  0.0   0.0   time
cf09912  0.0   1.0   time            * Power stays on
*
```

```
cf10000  Power  multiply   2  1.0     0.0
cf10010  0.0  5000.0    time       * Specified power
cf10014  1.0     0.0    cfvalu.99  *
*
*  Revision 2 Breakaway oxidation kinetics timing
*
r*i*f ..\core-lifetime.gen
r*i*f ..\core-sc.gen
*
sc10171   1017  -12.58   1    * Plox coefficient for breakaway
*
.
```

<u>sfp.cor MELCOR Input File:</u>

```
title     'SFP'
jobid     'SFP Separate Effects Model'
*
restartf  'sfp.rst'
outputf   'sfp.out'
diagf     'sfp.dia'
stopf     'sfp.stp'
plotf     'sfp.ptf'
messagef  'sfp.mes'
*
cpulim    1000000.
cpuleft   100.
*
tend     43200.0  * 12 hours
CYMESF   10   10000
*
*       start   dtmax  dtmin   edit  plot  restart
time1     0.0    0.1   1.e-6   1.e6  10.0   1.e6    * air
time2   600.0    0.1   1.e-6   1.e6  30.0   1.e6  * air
*
*   Extra Core Package Edits
*
*         ITEMP IMASS IVOL  IASUR IPMV  IPOW
COREDV01  1     1     1     1     1     1
*
*   Core Package Physics Switches
*
*         IRAD  ICND  ICNV  IOXD  IDRP  ITDZ  IB4C  IRDS  IDEJ  ISPR
cortst01  0     0     0     0     0     0     1     0     1     0
*
*  IDEJ  - No ejection to a cavity
*  B4C   - No B4C reactions
*
restart   -1
*
* cvhtrace
*
* sc40552   4055  5.e-1 2    * HS convergence
sc44013   4401  15.0  3       * Max number of vel. iterations
sc44151   4415   1.0  1        * Use "fast" (iterative, sparse)
.
```

A.2 Core Input – cor.gen

```
*****************************************************************************************
* SFP COR input
*****************************************************************************************
*
* Storage cells - Westinghouse 17x17
*
*****************************************************************************************
*----------------------------------------------------------------------------------------
*****************************************************************************************
*   Fuel assembly (Vantage + Enhancments)
*
*                # of      Clad OD             Clad ID
*                 Rods   [in]     [m]        [in]     [m]
*   17x17         264   0.3745  0.009512    0.352   0.008941
*   Thimbles (GT)   24   0.480   0.012192    0.450   0.011430  Upper fat portion
*                        0.439   0.011151                      Lower skinny portion
*   Instr Rod       1    0.482   0.012243    0.452   0.0114808
*
*   Clad thickness        = 0.0225"
*   GT(and IT)clad thick  = 0.0150"
*   Rod pitch             = 0.49606" (old = 0.563")
*   Grids                 = 11 + inlet P-grid
*                           or P-grid + 8 grids + 3 IFMs
*              NOTE: 2 of the "8 grids" are modified spacers w/o vanes at top and bottom 1.5"
*
*   Fuel radius = 0.0041, but if swelled to inner clad radius:
*                then Fuel radius = (0.008941 m)/2 = 0.0044704 m
*
*   Clad radius = (0.009512 m)/2 = 0.0047562 m
*
*
*   Axial distances
*   ----- ---------
*   Fuel pin length       = 142.25" (active "heated" fuel length)
*   Rod/Tube length       = 154.25"
*   Inlet box             = 2.383"
*   End cap (bottom)      = 0.130"
*   End cap (top)         = 0.130"
*   Exit nozzle           = 3.475"
*
*
*   17x17 Assemblies
*
* General ==================================================================
*
* NRAD   -> # radial rings
* NAXL   -> # axial nodes (total)
* NTLP   -> # lower plenum axial levels
* NCVOL  -> # cvh volumes in the core and lower plenum
* NLH    -> # temperature nodes in the lower head
* NLHTA  -> # of lower head segments in the flat portion of the lower head
* NPNTOT -> # representative lower head penetrations
*          NRAD  NAXL  NTLP  NCVOL  NLH  NLHTA  NPNTOT  NINSLH  NNHTR
COR00000   1     17    2     9      11    1      0       0       0
*
* ---------------------------------------------------
* core geometry
* ---------------------------------------------------
*          RFUEL       RCLAD       DRGAP    PITCH    DXCAN   DXSS
COR00001   0.0044704   0.0047562   0.0      0.0126   0.0     0.00244
*
* ---------------------------------------------------
* vessel parameters
* ---------------------------------------------------
* ILHTYP = 1 = flat lower head
```

```
*          RCOR      RVLH      RVESS    ILHTYP  ILHTRN  DZRV    DZLH
COR00001A  0.129547  0.129547  0.129547   1      1      2.006350  2.006350
*          HLST      HCSP
COR00001B  0.1524    0.1524   * 0.1524 m = COR102's elevation
*
* ---------------------------------------------------
* core type/poison
* ---------------------------------------------------
*          IRTYP    MCRP
COR00002   SFP-PWR  B4C  *  B4C closest match for racks
*
* ---------------------------------------------------
* radiative exchange factors
* ---------------------------------------------------
*          FCNCL    FSSCN   FCELR   FCELA   FLPUP
COR00003   0.15     1.0     1.0     0.1     0.1
*
* ---------------------------------------------------
* transfer process, fission power, grap conductance
* ---------------------------------------------------
*  NTPCOR=0 ---> no TP  (lower head will not fail and eject debris)
*  ICFFIS=0 ---> no fission power
*  ICFGAP=0 ---> no fuel-cladding gap resistance
*          NTPCOR ICFFIS ICFGAP
COR00004   0
*
* ---------------------------------------------------
* candling heat transfer coefficients (W/m^2-k)
* ---------------------------------------------------
*           UO2     Zirc    SS      ZrO2    SS ox  poison
*          HFRZUO  HFRZZR  HFRZSS  HFRZZX  HFRZSC HFRZCP
COR00005   2500.   2500.   2500.   2500.   2500.  2500.
*
* ---------------------------------------------------
* override small core fluid vol > CV fluid vol error
* ---------------------------------------------------
* COR00006 0 0 0 0 1
*
* ---------------------------------------------------
* in-vessel falling debris quench model
* ---------------------------------------------------
* HDBH2O - heat trans coeff. from in-vessel falling debris to pool
* PPFAIL - differential pressure between lower plenum vol. and reactor cavity that will FAIL the
lower head
* IAXSUP - the axial level number of the core cell containing the core support plate
* VFALL  - velocity of falling debris
*          HDBH2O   PPFAIL IAXSUP  VFALL
COR00012   100.0    2.e7   2       1.0
*
* =============================================================================
*
* ---------------------------------------------------
* control structures, support
* ---------------------------------------------------
COR000NS  ROD     ZIRC
*
* =============================================================================
*  Ko    = 0.07
*  Plate = 0.5"
*
*         ISSMOD  THICK   AKM0   AKM1
CORZ02SS  PLATEG  0.0127  0.07   0.576 * Baseplate
CORZ03SS  PLATEG  TSFAIL  1700.0       * Lower nozzle (fails when melts)
*
* ---------------------------------------------------
* axial core geometry -> z = BOTTOM axial level
* ---------------------------------------------------
*           z     dz   dummy pordv
*        ------ ------ ----- -----
*        4.1884 m (top of the racks)
*  Active fuel  = 142.25", dz =  142.25/12 = 11.8541667"
```

```
CORZ1701 4.0463 0.1421 0.0 0.4 * Top nozzle and top of racks
CORZ1601 3.9346 0.1117 0.0 0.4 * Rods to exit nozzle
CORZ1501 3.6335 0.3011 0.0 0.4 * Fuel level 12
CORZ1401 3.3324 0.3011 0.0 0.4 * Fuel level 11
CORZ1301 3.0313 0.3011 0.0 0.4 * Fuel level 10
CORZ1201 2.7302 0.3011 0.0 0.4 * Fuel level  9
CORZ1101 2.4291 0.3011 0.0 0.4 * Fuel level  8
CORZ1001 2.1280 0.3011 0.0 0.4 * Fuel level  7
CORZ0901 1.8269 0.3011 0.0 0.4 * Fuel level  6
CORZ0801 1.5258 0.3011 0.0 0.4 * Fuel level  5
CORZ0701 1.2247 0.3011 0.0 0.4 * Fuel level  4
CORZ0601 0.9236 0.3011 0.0 0.4 * Fuel level  3
CORZ0501 0.6225 0.3011 0.0 0.4 * Fuel level  2
CORZ0401 0.3214 0.3011 0.0 0.4 * Fuel level  1
CORZ0301 0.1651 0.1563 0.0 0.4 * lower nozzle
CORZ0201 0.1524 0.0127 0.0 0.4 * 0.50" baseplate + lower nozzle
CORZ0101 0.0000 0.1524 0.0 0.4 * 6" - top of liner to bot of baseplate
*
*
* Uniform Axial power density profile ==========================================
*
*        fzpow
*        -----
CORZ1603 0.000  Unheated
CORZ1503 1.000  12
CORZ1403 1.000  11
CORZ1303 1.000  10
CORZ1203 1.000   9
CORZ1103 1.000   8
CORZ1003 1.000   7
CORZ0903 1.000   6
CORZ0803 1.000   5
CORZ0703 1.000   4
CORZ0603 1.000   3
CORZ0503 1.000   2
CORZ0403 1.000   1
CORZ0303 0.000
CORZ0203 0.000
CORZ0103 0.000
*
*
* Radial ring outer radius =====================================================
*   A = (9.04*2.54/100)^2 m^2 = 0.052724 m^2
*   A = pi*r^2
*   r = sqrt( A / pi ) = 0.129547 m
*
*          RINGR
CORR0100   0.129547
*
* Radial ring areas ============================================================
* (not required)
* SFP cell pitch = 9.04"
*
*   Pitch  = [9.04]^2 = 0.05272 m^2
*
* CORR0101 0.05272  * 1 storage cell
*
* Upper boundary heat structures ===============================================
*
CORR0102 11701
*
* Radial power fission fraction ===============================================
*
CORR0103 1.
*
* CVH/COR Channel/Bpass Connections ============================================
*
COR11701        -1     108    108  * Top nozzle and top of racks
COR11601        -1     108    108  * Unheated rods
*
COR11501       104     107    107  * 12th Fuel level
```

```
COR11401       104     107    107  * 11th Fuel level
COR11301       104     106    106  * 10th Fuel level
COR11201       104     106    106  *  9th Fuel level
*
COR11101       104     105    105  *  8th Fuel level
COR11001       104     105    105  *  7th Fuel level
COR10901       104     104    104  *  6th Fuel level
COR10801       104     104    104  *  5th Fuel level
*
COR10701       104     103    103  *  4th Fuel level
COR10601       104     103    103  *  3rd Fuel level
COR10501       104     102    102  *  2nd Fuel level
COR10401        -1     102    102  *  1st Fuel level
*
COR10301        -1     101    101  *  Bottom nozzle
COR10201        -1      10     10  *  Fuel plate
COR10101        -1      10     10  *  Beneath the base plate
*
*
*******************************************************************************
*******************************************************************************
*   Flow Area and Hydraulic Diameter
*   ---- ---- --- --------- --------
*   Assembly HD = (4 * FlowArea)/ PW
*
*   Tube Area = 264 x pi/4 x OD^2 = 29.0802 in^2   <= Fuel rod
*             +  24 x pi/4 x OD^2 = 4.3429  in^2   <= GT (Top)
*            or  24 x pi/4 x OD^2 = 3.6327  in^2   <= GT (Bottom)
*             +  1  x pi/4 x OD^2 = 0.18247 in^2   <= IT
*             =  33.606 in^2 (Top)
*             =  32.895 in^2 (Bottom)
*                (= nonflow / assembly cross-section blocked area)
*
*   PW     = 264 x pi x OD = 310.603 in   <= Fuel rod
*          +  24 x pi x OD = 36.1911 in   <= GT (Top)
*         or  24 x pi x OD = 33.0998 in   <= GT (Bottom)
*          +   1 x pi x OD = 1.5142  in   <= IT
*          +   4 x ID      = 34.92   in   <= Rack wall
*          =  383.23 in (Top)
*          =  380.14 in (Bottom)
*
*   FA     = (8.73")^2 - (33.606 in^2) = 42.607 in^2 (Top)     [0.0274885 m^2]
*          = (8.73")^2 - (32.895 in^2) = 43.318 in^2 (Bottom)  [0.0279467 m^2]
*
*   AFLOWC ->
*   ---------
*   FA Ring 1 = 0.0274885 m^2
*
*   HD     = 4 * FA / PW = 4 x 42.607 in^2 / 383.23 in = 0.4447 in (Top)    [0.011295877 m]
*          = 4 * FA / PW = 4 x 43.318 in^2 / 380.14 in = 0.4558 in (Bottom) [0.011577562 m]
*
*
* \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
*   ASCELR ->
*   ---------
*          9.04" = 0.22962 m
*   Ring 1 =  4 x 0.22962 x 0.301096 m = 0.27655 m^2
*
*   outer diameters:
*   clad-OD      = 0.0095123 m
*   fuel-OD      = 0.0089408 m
*   GT-top-OD    = 0.0121920 m
*   GT-bottom-OD = 0.0111506 m
*   cell-ID      = 0.2217420 m
*
* water-surface contact areas:
* SA(Cladding) = pi*D * 264 * dz = pi*(0.0095123m)* 264 rods *(0.301096m)= 2.375440102
m^2/assembly/level
* SA(Fuel)     = pi*D * 264 * dz = pi*(0.0089408m)* 264 rods *(0.301096m)= 2.232723407
m^2/assembly/level
```

```
* SA(GT)       = pi*D *  24 * dz = pi*(0.0121920m)* 24 tubes *(0.301096m)= 0.276783893
m^2/assembly/level(Top)
* SA(GT)       = pi*D *  24 * dz = pi*(0.0111506m)* 24 tubes *(0.301096m)= 0.253141936
m^2/assembly/level(Bottom)
* SA(RK Ring 1)= 4*ID * dz * 2   =  4*(0.2217420m)* (0.301096 m)*2       = 0.534124738
m^2/assembly/level
* //////////////////////////////////////////////////////////////////////////////
*
* Ring 1 .....................................................................
* Level 3 Assembly inlet .......................................................
*
*  No Fuel, inlet nozzle box
*  Scale amounts by Cell 104 amounts x 0.21189267       = 0.0638m / 0.301096m
*  ASCELR = ASRK (one side)  = 0.26706 m^2 x 0.21189267  = 0.056589 m^2
*  Weight of bottom nozzle   = 12.592 lb (weighed)      = 5.27074 kg (zirc)
*  Weight of debris grid     = 3.158 lb  (weighed)      = 1.43244 kg (zirc)
*  Top/Bottom grid weights   = 0.93 kg
*
* ---------------------------------------------------
* KFU - fuel component masses
* ---------------------------------------------------
*           UO2      Other
COR103KFU  5.198445   0.0 * Fuel
*
* ---------------------------------------------------
* KCL - cladding component masses
* ---------------------------------------------------
*           ZR     Inconel  ZrO2
COR103KCL  2.719428   0.0   0.0 * Cladding, end pieces, inconel grid
*
* ---------------------------------------------------
* KRK - rack component masses
* ---------------------------------------------------
*            SS      CP    Zr  SSOX ZrO2
COR103KRK  2.094282  0.0  0.0  0.0  0.0
*
* ---------------------------------------------------
* KSS - supporting structure component masses
* ---------------------------------------------------
*            SS       Zr SSOX ZrO2
COR103KSS  6.703188  0.0  0.0  0.0 * Bottom nozzle + protective grid
*
* ---------------------------------------------------
* KNS - non-supporting structure component masses
* ---------------------------------------------------
*        XMNSSS XMNSCP XMNSZR XMNSSX XMNSZX
COR103KNS  0.0  0.0  0.29362  0.0  0.0
*
* ---------------------------------------------------
* 04 - equivalent diameters , 04C - rack equiv diameter
* ---------------------------------------------------
* CL = clad ; OS = other structure ; PD = particulate debris ; NC = canister inside equiv
diameter
* NB = canister outside equiv diameter ; SS = supporting structure ; NS = nonsupporting structure
* PB = particulate debris in bypass of a BWR equiv diameter
*           DHYCL DHYOS DHYPD DHYCNC  DHYCNB    DHYSS    DHYNS    DHYPB
COR10304 0.011296  0.0  0.01 0.011296 0.011296 0.011296 0.011296 0.011296
*
* RK = SFP rack component equiv. diameter
*            DHYRK
COR10304C 0.011296
*
* ---------------------------------------------------
* 05 - cell boundary and flow areas
* ---------------------------------------------------
* ASCELR = area of outer radial cell boundary = 4*pi*D*dz = (SA rack / 2)
* AFLOWC = channel flow area
* AFLOWB = bypass flow area of a BWR, will be added to AFLOWC in a PWR
*            ASCELR AFLOWC AFLOWB
COR10305  0.138633  0.027489  0.0
*
```

```
* -------------------------------------------------
* 06 - surface area , 6C - rack surface areas
* -------------------------------------------------
* FU = fuel ; CL = clad ; OS = other structure ; CN = canister
* SS = supporting structure ; NS = nonsupporting structure
*               ASFU   ASCL    ASOS ASCN ASSS ASNS
COR10306  1.15901527  1.23310  0.0  0.0  0.1  0.143679579
* ASRK -> rack surface area
COR10306C 0.277266
*
*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_
*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_
*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_
* Ring 1 ..................................................................
* Levels 4 - 15 Active fuel region ........................................
*
*
*           UO2    Other
COR104KFU 11.166952 0.0
*
*
COR104KCL 11.299595 0.0 0.0 * Cladding + grids
*
*       XMNSSS XMNSCP XMNSZR   XMNSSX XMNSZX
COR104KNS  0.0  0.0  0.691821954  0.0  0.0
*
*           SS       CP   Zr   SSOX ZrO2
COR104KRK  4.034418  0.0  0.0  0.0  0.0
*
*         DHYCL    DHYOS    DHYPD  DHYCNC   DHYCNB   DHYSS    DHYRK    DHYPB
COR10404 0.011296 0.011296  0.01  0.011296 0.011296 0.011296 0.011296 0.011296
*          DHYRK
COR10404C 0.011296
*
*          ASCELR    AFLOWC AFLOWB
COR10405  0.267062  0.027489  0.0
*
*            ASFU    ASCL   ASOS ASCN ASSS    ASNS
COR10406  2.232723  2.37544  0.0  0.0  0.0  0.276783893
*           ASRK
COR10406C 0.534125
*
*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_
*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_
*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_*_
* Ring 1 ..................................................................
* Level 16 Unheated Rod Section ...........................................
*           UO2   Other
COR116KFU 3.715075 0.0
*
*             ZR   Inconel ZrO2
COR116KCL  3.932932  1.54  0.0
*
*        XMNSSS XMNSCP XMNSZR   XMNSSX XMNSZX
COR116KNS  0.0  0.0  0.256650886  0.0  0.0
*
*            SS       CP   Zr SSOX ZrO2
COR116KRK  1.496681  0.0  0.0  0.0  0.0
*
*           DHYRK
COR11604C  0.011296
*
*          SS    Zr  SSOX ZrO2
COR116KSS  0.0  0.0  0.0  0.0
*
*          DHYCL    DHYOS   DHYPD DHYCNC    DHYCNB   DHYSS     DHYRK   DHYPB
COR11604 0.011296 0.011296  0.01  0.011296 0.011296 0.011296 0.011296 0.011296
*
*          ASCELR AFLOWC AFLOWB
COR11605 0.099074 0.027489 0.0
*
```

```
*          ASFU      ASCL     ASOS  ASCN ASSS ASNS
COR11606 0.828292  0.88123657  0.0  0.0  0.0  0.102680799
*
*          ASRK
COR11606C 0.198149
*
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
*
* Ring 1 ............................................................
* Level 17 Top nozzle + top of racks ....................................
*
*
*           UO2      Other
COR117KFU 4.732813   0.0
*
*            ZR   Inconel ZrO2
COR117KCL  5.941123  0.0  0.0
*
*           SS       CP    Zr SSOX ZrO2
COR117KRK  1.939522  0.0  0.0  0.0  0.0
*
*             SS      Zr  SSOX ZrO2
COR117KSS  5.711635  0.0  0.0  0.0 * Top nozzle
*
*        XMNSSS XMNSCP   XMNSZR   XMNSSX XMNSZX
COR117KNS  0.0   0.0  0.418585561  0.0    0.0
*
*         DHYCL    DHYOS    DHYPD DHYCNC    DHYCNB   DHYSS     DHYRK   DHYPB
COR11704 0.011296 0.011296  0.01  0.011296 0.011296 0.011296 0.011296 0.011296
*         DHYRK
COR11704C 0.011296
*
*         ASCELR     AFLOWC AFLOWB
COR11705  0.126083  0.027489  0.0
*
*          ASFU        ASCL   ASOS ASCN ASSS ASNS
COR11706  1.055201  1.122650  0.0  0.0  0.1  0.136283134
*           ASRK
COR11706C 0.252165
*
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
*
* Baseplate and below ...................................................
*
*  0.50" SS based plate with 5" OD hole
*
* Ring 1 ............................................................
* Level 2 ...........................................................
*     0.126083
*   5" inlet hole
*   AFLOWC = pi/4 * (5")^2 = 0.012668 m^2
*   AFLOWR = 0.5" * 9.04"  = 0.00292 m^2
*   ASSS = 2 sides x (9.04")^2 - AFLOWC = 0.1055 m^2 - 0.012668 m^2 = 0.092779m^2
*   Baseplate mass = ASSS/2 * 0.5" * 7930 kg/m^3 = 4.672 kg
*
COR102KFU 0.000000 0.0
COR102KCL 0.000000 0.0 0.0
COR102KRK 0.000000 0.0 0.0 0.0 0.0
*            SS    Zr SSOX ZrO2
COR102KSS 4.671949 0.0 0.0 0.0
*
*          DHYCL  DHYOS DHYPD DHYCNC DHYCNB   DHYSS   DHYRK DHYPB
COR10204 0.011296  0.1  0.01  0.1  0.011296  0.011296  0.1  0.011296
*          ASCELR  AFLOWC AFLOWB
COR10205 0.002916  0.012668  0.0
*        ASFU  ASCL ASOS ASCN ASSS         ASRK
COR10206  0.0  0.0  0.0  0.0  0.092779328  0.0
```

```
*
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-
*
* Ring 1 ....................................................................
* Level 1 ...................................................................
*
*   No materials,  from CORRjj01 discussion above,
*
*   Ring 1 = 6" ID = 0.01824 m2
*
*   ASCELR = pi D (0.1524 m) = 0.072966 m2
*
COR101KFU 0.000000 0.0
COR101KCL 0.000000 0.0 0.0
COR101KSS 0.000000 0.0 0.0 0.0
COR101KRK 0.000000 0.0 0.0 0.0 0.0
*
*       DHYCL DHYOS DHYPD DHYCNC DHYCNB DHYSS DHYRK DHYPB
COR10104  0.1  0.1  0.01  0.1     0.1    0.1  0.1     0.1
*            ASCELR   AFLOWC   AFLOWB
COR10105  0.072966  0.018241469  0.0
*        ASFU ASCL  ASOS  ASCN   ASSS ASRK
COR10106 0.0   0.0   0.0   0.0   0.0   0.0
*
******************************************************************************
*      SFP FLOOR INPUT
******************************************************************************
*
*   Pitch  = [9.04"]^2 = 0.05272 m^2
*
*        IS   TLH    RADLH    ICVCAV
CORLHD01  1   301.0  0.129547  900
CORLHD02  2   301.0  0.129547  900
*
CORLHN01 'STAINLESS STEEL'    0.006350  'STAINLESS STEEL'    0.006350
CORLHN02 'CONCRETE'           0.016350  'CONCRETE'           0.016350
CORLHN03 'CONCRETE'           0.056350  'CONCRETE'           0.056350
CORLHN04 'CONCRETE'           0.106350  'CONCRETE'           0.106350
CORLHN05 'CONCRETE'           0.256350  'CONCRETE'           0.256350
CORLHN06 'CONCRETE'           0.506350  'CONCRETE'           0.506350
CORLHN07 'CONCRETE'           0.756350  'CONCRETE'           0.756350
CORLHN08 'CONCRETE'           1.006350  'CONCRETE'           1.006350
CORLHN09 'CONCRETE'           1.506350  'CONCRETE'           1.506350
CORLHN10 'CONCRETE'           2.006350  'CONCRETE'           2.006350
******************************************************************************
*
*  Other sensitivity coefficients
*
*             UO2 relocation with no Zr (only ZrO2)
SC11321   1132   2575.0   1
*             Enhance conduction of debris as it becomes molten
SC12501   1250   2700.0   1
*
* Sensitivity Coefficients for Zircaloy air oxidation
*
SC10041  1004  600.0  1   * Set minimum temperature for oxidation to 600 K
*
.
```

A.3 Hydrodynamic Input – cvh.gen

```
******************************************************************************
* SFP CVH and FL input
******************************************************************************
*
* CVH input ******************************************************************
*
* Under the racks (Core Levels 1 and 2)---------------------------------------
*
*  H     = 6"   (0.1524 m)
*  Pitch = 9.04"
*
*  Per CORRii01 -  Ring 1 = 0.05272 m^2
*                  Volume = 0.05272 m^2 x 6" = 0.00804 m^2
*
*  Core plate = pi/4 x (6")^2 x 0.5" = 14.1 in^3
*             = 0.000232 m^3
*
*
* \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
* CV volumes/altitudes, and FL flow areas, altitudes,
*  hyrdaulic diameters, and K flow coefficient have changed
* ////////////////////////////////////////////////////////////
*
*
* \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
* \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
* old Flow Area           = 0.0287m^2 (or 0.029 m^2 in some places)
* old active fuel length  = 144" = 12 nodes at 12" (0.3048m) each
* old hydraulic diameter  = 0.0118 m
* old K total             = 28.0
* ------------------------------------------------------------
* new Flow Area           = 0.027489 m^2
* new active fuel length  = 142.25" = 12 nodes at 11.854" (0.3011m) each
* new hydraulic diameter  = 0.011296 m
* new K total             = 27.7
* //////////////////////////////////////////////////////////////////
* //////////////////////////////////////////////////////////////////
*
*
CV01000 'POOL BOTTOM' 2 2 1
CV010B1 0.0 0.0
CV010B2 0.1524 -0.002800    * 5" OD tube
CV010B3 0.1651 -0.000349
*
* Storage cells===============================================================
*
* 1st lvl (inlet) ------------------------------------------------------------
*
*  Flow Area = 0.0274885200154511 m^2
*
CV10100 'Inlet R1' 2 2 1
CV101B1 0.1651 0.0
CV101B2 0.3214 -0.004300
*
* 2nd lvl (active fuel) ------------------------------------------------------
*
CV10200 'R1 Lev 4-5' 2 2 1
CV102B1 0.3214 0.0
CV102B2 0.6225 -0.008277
CV102B3 0.9236 -0.008277
*
* 3rd lvl (active fuel) ------------------------------------------------------
*
CV10300 'R1 Lev 6-7' 2 2 1
CV103B3 0.9236 0.0
CV103B4 1.2247 -0.008277
```

```
CV103B5 1.5258 -0.008277
*
* 4th lvl (active fuel) -------------------------------------------------------
*
CV10400 'R1 Lev 8-9' 2 2 1
CV104B1 1.5258 0.0
CV104B2 1.8269 -0.008277
CV104B3 2.1280 -0.008277
*
* 5th lvl (active fuel) -------------------------------------------------------
*
CV10500 'R1 Lev 10-11' 2 2 1
CV105B3 2.1280 0.0
CV105B4 2.4291 -0.008277
CV105B5 2.7302 -0.008277
*
* 6th lvl (active fuel) -------------------------------------------------------
*
CV10600 'R1 Lev 12-13' 2 2 1
CV106B1 2.7302 0.0
CV106B2 3.0313 -0.008277
CV106B3 3.3324 -0.008277
*
* 7th lvl (active fuel) -------------------------------------------------------
*
CV10700 'R1 Lev 14-15' 2 2 1
CV107B3 3.3324 0.0
CV107B4 3.6335 -0.008277
CV107B5 3.9346 -0.008277
*
* 8th lvl (above active fuel) -------------------------------------------------
*
CV10800 'R1 Lev 16-17' 2 2 2
CV108B1 3.9346 0.0
CV108B2 4.0463 -0.003071
CV108B3 4.1884 -0.003907
*  -0.0034545 *** unkown VOLUME
* Upper pool ==================================================================
*
* Open region above the racks
*
* - Fixed properties imposed here
*
CV02000 'UPPER POOL' 2 2 2
CV02001 0 -1 * time independent
CV020B1 4.1884 0.0
CV020B2 5.0000 1.0000000
*
*
* Pool periphery ==============================================================
*
CV03000 'PERIPHERY' 2 2 1
CV030B1 0.0    0.
CV030B2 5.0    1.0
*
*
* FL input ********************************************************************
*
* Storage cell flow paths =====================================================
*
*   New experimental analysis = 27.7
*
* Ring 1 ----------------------------------------------------------------------
* k_total = 27.7
* 1 storage cell, 1 fuel assembly
*
FL10100 'CORE R1 IN' 10 101 0.1651 0.1651
FL10101 0.027489 0.1563 1.0
FL10103 3.150000 3.1500
FL101S1 0.027489 0.1563 0.011296 1.50E-06 * Inlet nozzle
FL101S2 0.012668 0.1524 0.127000 5.00E-06 * Flow to assembly HD = 5", L ~ 0.1524 m
```

```
*
FL10200 'CORE R1 2' 101 102 0.3214 0.3214
FL10201 0.027489 0.3011 1.0 * Use full channel area and appropriate K's
FL10203 3.350000 3.3500  * 1/6th spacer loss
FL102S1 0.027489 0.3011 0.011296 1.50E-06 27.475
*
FL10300 'CORE R1 3' 102 103 0.9236 0.9236
FL10301 0.027489 0.6022 1.0 * Use full channel area and appropriate K's
FL10303 3.350000 3.3500  * 1/6th spacer loss
FL103S1 0.027489 0.6022 0.011296 1.50E-06 27.475
*
FL10400 'CORE R1 4' 103 104 1.5258 1.5258
FL10401 0.027489 0.6022 1.0 * Use full channel area and appropriate K's
FL10403 3.350000 3.3500  * 2/6th spacer loss
FL104S1 0.027489 0.6022 0.011296 1.50E-06 27.475
*
FL10500 'CORE R1 5' 104 105 2.1280 2.1280
FL10501 0.027489 0.6022 1.0 * Use full channel area and appropriate K's
FL10503 3.350000 3.3500  * 2/6th spacer loss
FL105S1 0.027489 0.6022 0.011296 1.50E-06 27.475
*
FL10600 'CORE R1 6' 105 106 2.7302 2.7302
FL10601 0.027489 0.6022 1.0 * Use full channel area and appropriate K's
FL10603 3.350000 3.3500  * 2/6th spacer loss
FL106S1 0.027489 0.6022 0.011296 1.50E-06 27.475
*
FL10700 'CORE R1 7' 106 107 3.3324 3.3324
FL10701 0.027489 0.6022 1.0 * Use full channel area and appropriate K's
FL10703 3.350000 3.3500  * 2/6th spacer loss
FL107S1 0.027489 0.6022 0.011296 1.50E-06 27.475
*
FL10800 'CORE R1 8' 107 108 3.9346 3.9346
FL10801 0.027489 0.6022 1.0 * Use full channel area and appropriate K's
FL10803 3.350000 3.3500  * 1/6th spacer loss
FL108S1 0.027489 0.6022 0.011296 1.50E-06 27.475
*
FL10900 'CORE R1 9' 108 20 4.1884 4.1884
FL10901 0.027489 0.2000 1.0 * Use full channel area and appropriate K's
FL10903 1.100000 1.1000
FL109S1 0.027489 0.1117 0.011296 1.50E-06 27.475
FL109S2 0.027489 0.0883 0.011296 1.50E-06 27.475
*  *** unkown flow path length
* Upper pool to peripheral region =============================================
*
FL00200 'PERIPH TO BOT' 30 10 0.1651 0.1651
FL00201 0.115440 2.153 1.0 0.1 0.1
FL00202 3
FL00203 1.000000 1.0
FL002S1 0.012668 0.3476 0.127000 5.00E-06 *  Assume 0.5" tube inlet
*
FL00500 'CrossFlow' 20 30 5.00 5.00
FL00501 10.000000 1.0 1.0
FL00502 3
FL00503 0.000000 0.0
FL005S1 10.000000 1.0 100.0 1.50E-06
*
CV90000 'Environment' 2 2 99
CV90001 0 -1   *  TIME-INDEPENDENT CV
CV900A0 3
CV900A1 PVOL 8.38E+04 PH2O 0.00 TATM 300.00 MLFR.5 0.80 MLFR.4 0.20
*
*** ELEV VOL
CV900B1 0.000000 0.0
CV900B2 5.000000 10.0
*
*
.
```

A.4 Heat Structure, Rack, and Insulation Input – hs.gen

```
********************************************************************************
* SFP HS input
********************************************************************************
*
* Radial boundary heat structure specification ================================
*         ihsa
*         ----
corz1702 11700
corz1602 11600
corz1502 11500
corz1402 11400
corz1302 11300
corz1202 11200
corz1102 11100
corz1002 11000
corz0902 10900
corz0802 10800
corz0702 10700
corz0602 10600
corz0502 10500
corz0402 10400
corz0302 10300
corz0202 10200
corz0102 0
*
* Boundary heat structure dt/dz input ----------------------------------------
*
hs11700004 117
hs11600004 116
hs11500004 115
hs11400004 114
hs11300004 113
hs11200004 112
hs11100004 111
hs11000004 110
hs10900004 109
hs10800004 108
hs10700004 107
hs10600004 106
hs10500004 105
hs10400004 104
hs10300004 103
hs10200004 102
*hs10100004 101
*
* Level core radial boundary heat structures ==================================
*
*   - Enclosed section inner dimension   = 8.73"
*   - Rack wall thickness (SS)           = 0.075"
*   - SS Wrapper thickness               = 0.036"
*   - Boraflex thickness                 = 0.082"
*   - Boraflex width                     = 7.5"
*   - Boraflex height                    = 150"
*
*  6" Insulation
*  Boral layer (not used)
*  Stainless steel wrapper (not used)
*
*                   np       igeom         iss
hs10200000           2           2           0
*               hsname
hs10200001    'Level 2'
*                hsalt       alpha
hs10200002         0.1524      1.0. * vert
*               hsmult
```

```
hs10200003          1.0
*               nodloc      ifmmat          xi
hs10200100          -1           1     0.06350  * 5" OD tube into assembly
*               xvalue      nxvalu
hs10200104     0.06450           2    * 0.001
*               matnam      mshnum
hs10200201    'stainless steel'  1
*                 isrc      nsdloc      vsmult
hs10200300          -1
*                 ibcl        ibvl      iflowl       cpfpl       cpfal
hs10200400           1         010       'INT'         0.5         0.5
*               asuffl        clnl       bndzl
hs10200500        0.0029     0.0113     0.0127
*                 ibcl        ibvl      iflowl       cpfpl       cpfal
hs10200600           1         030       'EXT'         0.5         0.5
*               asuffl        clnl       bndzl
hs10200700       0.0029      0.1        0.0127
*
*                   np       igeom         iss
hs11700000           8           2           0
hs11600000           8           2           0
hs11500000           8           2           0
hs11400000           8           2           0
hs11300000           8           2           0
hs11200000           8           2           0
hs11100000           8           2           0
hs11000000           8           2           0
hs10900000           8           2           0
hs10800000           8           2           0
hs10700000           8           2           0
hs10600000           8           2           0
hs10500000           8           2           0
hs10400000           8           2           0
hs10300000           8           2           0
hs10200000           8           2           0
*
* hsname
hs11700001 'Level 17'
hs11600001 'Level 16'
hs11500001 'Level 15'
hs11400001 'Level 14'
hs11300001 'Level 13'
hs11200001 'Level 12'
hs11100001 'Level 11'
hs11000001 'Level 10'
hs10900001 'Level 9'
hs10800001 'Level 8'
hs10700001 'Level 7'
hs10600001 'Level 6'
hs10500001 'Level 5'
hs10400001 'Level 4'
hs10300001 'Level 3'
hs10200001 'Level 2'
*
* Z Vert
hs11700002 4.0463 1.0 * dz = 0.1421
hs11600002 3.9346 1.0 * dz = 0.1117
hs11500002 3.6335 1.0 * dz = 0.3011
hs11400002 3.3324 1.0 * dz = 0.3011
hs11300002 3.0313 1.0 * dz = 0.3011
hs11200002 2.7302 1.0 * dz = 0.3011
hs11100002 2.4291 1.0 * dz = 0.3011
hs11000002 2.1280 1.0 * dz = 0.3011
hs10900002 1.8269 1.0 * dz = 0.3011
hs10800002 1.5258 1.0 * dz = 0.3011
hs10700002 1.2247 1.0 * dz = 0.3011
hs10600002 0.9236 1.0 * dz = 0.3011
hs10500002 0.6225 1.0 * dz = 0.3011
hs10400002 0.3214 1.0 * dz = 0.3011
hs10300002 0.1651 1.0 * dz = 0.1563
hs10200002 0.1524 1.0 * dz = 0.0127
```

```
*
* xi
*   A_rect = 4 x 8.8386" x DZ
*   A_cyl  = 2 x pi x r_eq x DZ
*   r_eq   = 5.6268" (0.1429 m)
*
* nodloc ifmmat xi
hs11701100 -1 1 0.1429
hs11700100 -1 1 0.1429
hs11600100 -1 1 0.1429
hs11500100 -1 1 0.1429
hs11400100 -1 1 0.1429
hs11300100 -1 1 0.1429
hs11200100 -1 1 0.1429
hs11100100 -1 1 0.1429
hs11000100 -1 1 0.1429
hs10900100 -1 1 0.1429
hs10800100 -1 1 0.1429
hs10700100 -1 1 0.1429
hs10600100 -1 1 0.1429
hs10500100 -1 1 0.1429
hs10400100 -1 1 0.1429
hs10300100 -1 1 0.1429
hs10200100 -1 1 0.1429
*
*    Vol_rect = 4 x 8.8386" x 0.075" x DZ
*    Vol_cyl  = pi x (r_o^2 - r_i^2) x DZ
*    r_o      = sqrt ( Vol_rect / pi + r_i^2 ) = 5.7013" (0.1448 m)
*
hs11700102 0.1448 2 * rack wall
hs11600102 0.1448 2 * rack wall
hs11500102 0.1448 2 * rack wall
hs11400102 0.1448 2 * rack wall
hs11300102 0.1448 2 * rack wall
hs11200102 0.1448 2 * rack wall  8.993
hs11100102 0.1448 2 * rack wall
hs11000102 0.1448 2 * rack wall
hs10900102 0.1448 2 * rack wall  0.0386 0.00965
hs10800102 0.1448 2 * rack wall  0.0772 0.0193
hs10700102 0.1448 2 * rack wall  8.8375
hs10600102 0.1448 2 * rack wall
hs10500102 0.1448 2 * rack wall
hs10400102 0.1448 2 * rack wall
hs10300102 0.1448 2 * rack wall
hs10200102 0.1448 2 * rack wall
*
* 6" of kaowool = 11.7013" (0.2972 m)
*
hs11700103 0.2972 8 * kaowool
hs11600103 0.2972 8 * kaowool
hs11500103 0.2972 8 * kaowool
hs11400103 0.2972 8 * kaowool
hs11300103 0.2972 8 * kaowool
hs11200103 0.2972 8 * kaowool
hs11100103 0.2972 8 * kaowool
hs11000103 0.2972 8 * kaowool
hs10900103 0.2972 8 * kaowool
hs10800103 0.2972 8 * kaowool
hs10700103 0.2972 8 * kaowool
hs10600103 0.2972 8 * kaowool
hs10500103 0.2972 8 * kaowool
hs10400103 0.2972 8 * kaowool
hs10300103 0.2972 8 * kaowool
hs10200103 0.2972 8 * kaowool
*
hs11700201 'stainless steel' 1 * rack wall
hs11600201 'stainless steel' 1 * rack wall
hs11500201 'stainless steel' 1 * rack wall
hs11400201 'stainless steel' 1 * rack wall
hs11300201 'stainless steel' 1 * rack wall
hs11200201 'stainless steel' 1 * rack wall
```

```
hs11100201 'stainless steel' 1 * rack wall
hs11000201 'stainless steel' 1 * rack wall
hs10900201 'stainless steel' 1 * rack wall
hs10800201 'stainless steel' 1 * rack wall
hs10700201 'stainless steel' 1 * rack wall
hs10600201 'stainless steel' 1 * rack wall
hs10500201 'stainless steel' 1 * rack wall
hs10400201 'stainless steel' 1 * rack wall
hs10300201 'stainless steel' 1 * rack wall
hs10200201 'stainless steel' 1 * rack wall
*
hs11700202 'kaowool' 7 * kaowool
hs11600202 'kaowool' 7 * kaowool
hs11500202 'kaowool' 7 * kaowool
hs11400202 'kaowool' 7 * kaowool
hs11300202 'kaowool' 7 * kaowool
hs11200202 'kaowool' 7 * kaowool
hs11100202 'kaowool' 7 * kaowool
hs11000202 'kaowool' 7 * kaowool
hs10900202 'kaowool' 7 * kaowool
hs10800202 'kaowool' 7 * kaowool
hs10700202 'kaowool' 7 * kaowool
hs10600202 'kaowool' 7 * kaowool
hs10500202 'kaowool' 7 * kaowool
hs10400202 'kaowool' 7 * kaowool
hs10300202 'kaowool' 7 * kaowool
hs10200202 'kaowool' 7 * kaowool
*
hs11700300 -1
hs11600300 -1
hs11500300 -1
hs11400300 -1
hs11300300 -1
hs11200300 -1
hs11100300 -1
hs11000300 -1
hs10900300 -1
hs10800300 -1
hs10700300 -1
hs10600300 -1
hs10500300 -1
hs10400300 -1
hs10300300 -1
hs10200300 -1
*
hs11700400 1 108 'INT' 0.5 0.5
hs11600400 1 108 'INT' 0.5 0.5
hs11500400 1 107 'INT' 0.5 0.5
hs11400400 1 107 'INT' 0.5 0.5
hs11300400 1 106 'INT' 0.5 0.5
hs11200400 1 106 'INT' 0.5 0.5
hs11100400 1 105 'INT' 0.5 0.5
hs11000400 1 105 'INT' 0.5 0.5
hs10900400 1 104 'INT' 0.5 0.5
hs10800400 1 104 'INT' 0.5 0.5
hs10700400 1 103 'INT' 0.5 0.5
hs10600400 1 103 'INT' 0.5 0.5
hs10500400 1 102 'INT' 0.5 0.5
hs10400400 1 102 'INT' 0.5 0.5
hs10300400 1 101 'INT' 0.5 0.5
hs10200400 1 10 'INT' 0.5 0.5
*
hs11700500 0.1261 0.0113 0.1421
hs11600500 0.0991 0.0113 0.1117
hs11500500 0.2671 0.0113 0.3011
hs11400500 0.2671 0.0113 0.3011
hs11300500 0.2671 0.0113 0.3011
hs11200500 0.2671 0.0113 0.3011
hs11100500 0.2671 0.0113 0.3011
hs11000500 0.2671 0.0113 0.3011
hs10900500 0.2671 0.0113 0.3011
```

```
hs10800500 0.2671 0.0113 0.3011
hs10700500 0.2671 0.0113 0.3011
hs10600500 0.2671 0.0113 0.3011
hs10500500 0.2671 0.0113 0.3011
hs10400500 0.2671 0.0113 0.3011
hs10300500 0.1386 0.0113 0.1563
hs10200500 0.0029 0.0113 0.0127
*
hs11700600 1 900 'EXT' 0.5 0.5
hs11600600 1 900 'EXT' 0.5 0.5
hs11500600 1 900 'EXT' 0.5 0.5
hs11400600 1 900 'EXT' 0.5 0.5
hs11300600 1 900 'EXT' 0.5 0.5
hs11200600 1 900 'EXT' 0.5 0.5
hs11100600 1 900 'EXT' 0.5 0.5
hs11000600 1 900 'EXT' 0.5 0.5
hs10900600 1 900 'EXT' 0.5 0.5
hs10800600 1 900 'EXT' 0.5 0.5
hs10700600 1 900 'EXT' 0.5 0.5
hs10600600 1 900 'EXT' 0.5 0.5
hs10500600 1 900 'EXT' 0.5 0.5
hs10400600 1 900 'EXT' 0.5 0.5
hs10300600 1 900 'EXT' 0.5 0.5
hs10200600 1 900 'EXT' 0.5 0.5
*
hs11700700 0.1261 0.1 0.1421
hs11600700 0.0991 0.1 0.1117
hs11500700 0.2671 0.1 0.3011
hs11400700 0.2671 0.1 0.3011
hs11300700 0.2671 0.1 0.3011
hs11200700 0.2671 0.1 0.3011
hs11100700 0.2671 0.1 0.3011
hs11000700 0.2671 0.1 0.3011
hs10900700 0.2671 0.1 0.3011
hs10800700 0.2671 0.1 0.3011
hs10700700 0.2671 0.1 0.3011
hs10600700 0.2671 0.1 0.3011
hs10500700 0.2671 0.1 0.3011
hs10400700 0.2671 0.1 0.3011
hs10300700 0.1386 0.1 0.1563
hs10200700 0.0029 0.1 0.0127
*
* Core outlet upper boundary heat structures ==================================
*                   np       igeom         iss
hs11701000           2           1           0
*               hsname
hs11701001   'Level r1'
*                 hsalt       alpha
hs11701002      4.1884          0.
*               hsmult
hs11701003         1.0
*               nodloc      ifmmat          xi
hs11701100          -1           1         0.0
*               xvalue      nxvalu
hs11701101      0.0001           2
*               matnam      mshnum
hs11701201 'STAINLESS STEEL 304' 1
*                 isrc      nsdloc      vsmult
hs11701300          -1
*                 ibcl        ibvl      iflowl       cpfpl       cpfal
hs11701400           1         108       'INT'         0.5         0.5
*               asuffl        clnl       bndzl
hs11701500    4.996e-2      0.0113     0.0113
*                 ibcl        ibvl      iflowl       cpfpl       cpfal
hs11701600           1         020       'EXT'         0.5         0.5
*                 emis       rmodl       pathl
hs11701601         0.3 'equiv-band'     0.1468
*               asuffl        clnl       bndzl
hs11701700    4.996e-2      0.0113     0.0113
*
*               ihsrd1      ihsrd2        View      icfrd1      icfrd2
```

```
hsrd000010       11701      -30000         0.5           0           0
*
*                   np       igeom         iss
hs30000000           2           2           0
*               hsname
hs30000001       'CYBL'
*                hsalt       alpha
hs30000002      0.0000          1.     * vert
*               hsmult
hs30000003         1.0
*               nodloc      ifmmat          xi
hs30000100          -1           1         5.0
*               xvalue      nxvalu
hs30000101      5.2000           2    * Stainless steel
*               matnam      mshnum
hs30000201    'stainless steel'  1
*                 isrc      nsdloc      vsmult
hs30000300          -1
*                 ibcl        ibvl      iflowl       cpfpl       cpfal
hs30000400           1         900       'INT'         0.5         0.5
*               asuffl        clnl       bndzl
hs30000500       100.0         5.0         5.0
*                 ibcl        ibvl      iflowl       cpfpl       cpfal
hs30000600           0
.
```

A.5 Material Input – mp.gen and mp_mgo.gen

mp.gen Input File:

```
***********************************************************************
***
***          MATERIAL PROPERTIES
***********************************************************************
***            Property              Units
***            Temperature          K
***            density               kg/m*3
***            heat capacity         J/kg-K
***            thermal conductivity  W/m-K
***
*------------------------------------
***          Material 1 is concrete
*------------------------------------
mpmat00100   CONCRETE
***
***          PROPERTY   TAB FUNC
***
mpmat00101     RHO         1
mpmat00102     ENH         2
mpmat00103     TMP         3
mpmat00104     CPS         4
mpmat00105     THC         5
mpmat00151     DEN    2533.2
mpmat00152     MLT    5000.0
mpmat00153     LHF       1.0
***
***          Density of concrete
***
tf00100     'RHO CONCRETE'   2   1.0    0.0
***
***          TEMPERATURE     RHO
***
tf00112         200.0      2533.2       *157.5 LB/FT^3 'DEN(NM) SLAB
tf00113        5000.0      2533.2
***
***          Enthalpy of concrete
***
tf00200     'ENH CONCRETE'   2   1.0    0.0
***
***          TEMPERATURE     CPS
***
tf00212         200.0        0.0
tf00213        5000.0  4224000.0
***
***          Enthalpy of concrete
***
tf00300     'TMP CONCRETE'   2   1.0    0.0
***
***          TEMPERATURE     CPS
***
tf00312            0.0      200.0
tf00313      4224000.0     5000.0
***
***          Heat capacity of concrete
***
tf00400     'CPS CONCRETE'   2   1.0    0.0
***
***          TEMPERATURE     CPS
***
tf00412         200.0      880.0
tf00413        5000.0      880.0
***
```

```
***          Thermal conductivity of concrete
***
tf00500     'THC CONCRETE'   2   1.0    0.0
***
***          TEMPERATURE     THC
***
tf00512         200.0         1.524     *0.800 BTU/HR/FT/F 'TC(NM)' SLAB
tf00513        5000.0         1.524
***
***          Material 3 is carbon steel    ***** MODEL LEGACY *****
***
mpmat00300  'CARBON STEEL'
***
***          PROPERTY   TAB FUNC
***
mpmat00301     RHO         21
mpmat00302     CPS         22
mpmat00303     THC         23
***
***          Density of carbon steel
***
tf02100     'RHO CARBON STEEL'   2   1.00   0.0
***
***          TEMPERATURE     RHO
tf02112         273.15     7833.0
tf02113        5000.00     7833.0
***
***          Heat capacity of carbon steel
***
tf02200     'CPS CARBON STEEL'   2   1.00   0.0
***
***          TEMPERATURE     CPS
tf02212         273.15      465.0
tf02213        5000.00      465.0
***
***          Thermal conductivity of carbon steel
***
tf02300     'THC CARBON STEEL'  10   1.00   0.0
***
***          TEMPERATURE     THC
tf02310         273.15       55.0
tf02311         373.15       52.0
tf02312         473.15       48.0
tf02313         573.15       45.0
tf02314         673.15       42.0
tf02315         873.15       35.0
tf02316        1073.15       31.0
tf02317        1273.15       29.0
tf02318        1473.15       31.0
tf02319        9973.15       31.0
*******************************************************************************
***          Material 4 is insulation (Asbestos)
***
mpmat00400  'INSULATION'
***
***          PROPERTY   TAB FUNC
***
mpmat00401     RHO         31
mpmat00402     CPS         32
mpmat00403     THC         33
mpmat00451     DEN      400.0
***
***          Density of Asbestos
***
tf03100     'RHO Insulation'     2   1.0   0.0
***
***          TEMPERATURE     RHO
tf03112         273.15      400.0
tf03113        5000.0       400.0
***
***          Heat capacity of Asbestos
```

```
***
tf03200     'CPS Insulation'     2   1.0   0.0
***
***          TEMPERATURE     CPS
tf03212         273.15     4188.0
tf03213        5000.0      4188.0
***
***          Thermal conductivty of Asbestos
***
tf03300     'THC Insulation'     2   1.0   0.0
***
***          TEMPERATURE     THC
tf03310         273.15       0.15
tf03311        5000.0        0.15
********************************************************************************
***          Material 5 is Quartz
***
mpmat00500  'QUARTZ'
***
***          PROPERTY   TAB FUNC
**
mpmat00501     RHO         41
mpmat00502     CPS         42
mpmat00503     THC         43
mpmat00551     DEN     2226.0
***
***          Density of glass
***
tf04100     'RHO Glass'      2   1.0   0.0
***
***          TEMPERATURE     RHO
tf04112         273.15     2226.0
tf04113        5000.0      2226.0
***
***          Heat capacity of quartz
***
tf04200     'CPS Quartz'     2   1.0   0.0
***
***          TEMPERATURE     CPS
tf04212         273.15      712.0
tf04213        5000.0       712.0
***
***          Thermal conductivty of quartz
***
tf04300     'THC Quartz'     3   1.0   0.0
***
***          TEMPERATURE     THC
tf04310         273.15       14.0
tf04311         422.15        7.2
tf04312        5000.0         7.2  * Assumed constant
********************************************************************************
********************************************************************************
***          Material 6 is Zirconia
***
mpmat00600  'zirconia'
***
***          PROPERTY   TAB FUNC
**
mpmat00601     RHO         51
mpmat00602     CPS         52
mpmat00603     THC         53
mpmat00651     DEN      480.0
***
***          Density of Zirconia
***
tf05100     'RHO Zirconia'      2   1.0   0.0
***
***          TEMPERATURE     RHO
tf05112         273.15      480.0
tf05113        5000.0       480.0
***
```

```
***          Heat capacity of zirconia felt
***
tf05200     'CPS zirconia'     4   1.0   0.0
***
***          TEMPERATURE     CPS
tf05211         273.15      544.0
tf05212         367.15      544.0
tf05213        2645.15      733.0
tf05214        5000.0       753.0
***
***          Thermal conductivity of zirconia
***
tf05300     'THC zirconia'     7   1.0   0.0
***
***          TEMPERATURE     THC
tf05311         273.15      0.08
tf05312         673.00      0.08
tf05313         1073.0      0.11
tf05314         1373.0      0.14
tf05315         1673.0      0.19
tf05316         1923.0      0.23
tf05317         5000.0      0.23       * Assumed constant
*******************************************************************************
*******************************************************************************
***          Material 7 is Kaowool
***
mpmat00700  'Kaowool'
***
***          PROPERTY   TAB FUNC
**
mpmat00701     RHO         61
mpmat00702     CPS         62
mpmat00703     THC         63
mpmat00751     DEN       96.0
***
***          Density of Kaowool
***
tf06100     'RHO Kaowool'      2   1.0   0.0
***
***          TEMPERATURE     RHO
tf06112         273.15       96.0
tf06113        5000.0        96.0
***
***          Heat capacity of Kaowool
***
tf06200     'CPS Kaowool'     14 1.0   0.0
***
***          TEMPERATURE     CPS
tf06211         273.15      7.88e02
tf06212         373.15      8.26e02
tf06213         473.15      8.62e02
tf06214         573.15      8.96e02
tf06215         673.15      9.28e02
tf06216         773.15      9.57e02
tf06217         873.15      9.85e02
tf06218         973.15      1.01e03
tf06219         1073.15     1.03e03
tf06220         1173.15     1.05e03
tf06221         1273.15     1.07e03
tf06222         1373.15     1.09e03
tf06223         1473.15     1.10e03
tf06224         5000.00     1.10e03
***
***          Thermal conductivity of Kaowool
***
tf06300     'THC Kaowool'     14  1.0   0.0
***
***          TEMPERATURE     THC
tf06311         273.15      2.08e-02
tf06312         373.15      3.45e-02
tf06313         473.15      5.02e-02
```

```
tf06314         573.15      6.81e-02
tf06315         673.15      8.80e-02
tf06316         773.15      1.10e-01
tf06317         873.15      1.34e-01
tf06318         973.15      1.60e-01
tf06319         1073.15     1.88e-01
tf06320         1173.15     2.19e-01
tf06321         1273.15     2.51e-01
tf06322         1373.15     2.86e-01
tf06323         1473.15     3.22e-01
tf06324         5000.00     3.22e-01       * Assumed constant
*******************************************************************************
*******************************************************************************
***          Material 8 is Quartz2
***
mpmat00800  'Quartz2'
***
***          PROPERTY   TAB FUNC
**
mpmat00801     RHO         71
mpmat00802     CPS         72
mpmat00803     THC         73
mpmat00851     DEN      2200.0
***
***          Density of Quartz2
***
tf07100     'RHO Quartz2'      2   1.0   0.0
***
***          TEMPERATURE     RHO
tf07112         273.15      2200.0
tf07113        5000.0       2200.0
***
***          Heat capacity of Quartz2
***
tf07200     'CPS Quartz2'     8 1.0   0.0
***
***          TEMPERATURE     CPS
tf07211         273.15      600.0
tf07213         473.15      900.0
tf07215         673.15      1000.0
tf07217         873.15      1075.0
tf07219         1073.15     1100.0
tf07221         1273.15     1190.0
tf07224         1673.15     1380.0
tf07225         5000.0      1380.0
**
***          Thermal conductivity of Quartz2
***
tf07300     'THC Quartz2'     6  1.0   0.0
***
***          TEMPERATURE     THC
tf07311         273.15      1.4
tf07316         773.15      1.9
tf07321         1273.15     1.75
tf07323         1473.15     1.85
tf07324         1773.15     2.4
tf07325         5000.15     2.5       * Assumed constant
*******************************************************************************
.
```

mp_mgo.gen Input File:

```
*
*    rho(mgo) / rho(UO2) = 2950.1 kg/m^3 / 10960.0 kg/m^3
*
MPMAT50100 'URANIUM DIOXIDE'
MPMAT50101  ENH     501
MPMAT50102  TMP     502
MPMAT50103  THC     503
MPMAT50104  CPS     504
MPMAT50105  RHO     505
MPMAT50151  MLT  3113.0
MPMAT50152  DEN  2950.1
*
TF50100 'MgO h vs t'  25 1. 0.
*
*        Temp, K  Enthalpy    *     Cp
*                   J/kg      *   J/Kg K
TF50111     273.0       0.0   *     930.1
TF50112     300.0   25112.2   *     930.1
TF50113     350.0   73623.6   *    1010.4
TF50114     400.0  125491.6   *    1064.3
TF50115     450.0  179673.3   *    1102.9
TF50116     500.0  235546.5   *    1132.0
TF50117     550.0  292715.6   *    1154.8
TF50118     600.0  350919.2   *    1173.4
TF50119     650.0  409976.4   *    1188.9
TF50120     700.0  469757.4   *    1202.3
TF50121     750.0  530169.1   *    1214.2
TF50122     800.0  591140.4   *    1224.7
TF50123     850.0  652617.0   *    1234.4
TF50124     900.0  714558.0   *    1243.3
TF50125     950.0  776928.9   *    1251.6
TF50126    1000.0  839703.5   *    1259.4
TF50127    1050.0  902861.0   *    1266.9
TF50128    1100.0  966383.5   *    1274.0
TF50129    1150.0 1030256.5   *    1280.9
TF50130    1200.0 1094468.3   *    1287.6
TF50131    1250.0 1159008.6   *    1294.0
TF50132    1300.0 1223867.9   *    1300.3
TF50133    1350.0 1288885.2   *    1300.3
TF50134    2200.0 2394140.2   *    1300.3
TF50135    5000.0 6034980.2   *    1300.3
*
TF50200 'MgO t vs h'  25 1. 0.
*
*        Enthalpy  Temp, K    *     Cp
*          J/kg               *   J/Kg K
TF50211        0.0    273.0   *     930.1
TF50212    25112.2    300.0   *     930.1
TF50213    73623.6    350.0   *    1010.4
TF50214   125491.6    400.0   *    1064.3
TF50215   179673.3    450.0   *    1102.9
TF50216   235546.5    500.0   *    1132.0
TF50217   292715.6    550.0   *    1154.8
TF50218   350919.2    600.0   *    1173.4
TF50219   409976.4    650.0   *    1188.9
TF50220   469757.4    700.0   *    1202.3
TF50221   530169.1    750.0   *    1214.2
TF50222   591140.4    800.0   *    1224.7
TF50223   652617.0    850.0   *    1234.4
TF50224   714558.0    900.0   *    1243.3
TF50225   776928.9    950.0   *    1251.6
TF50226   839703.5   1000.0   *    1259.4
TF50227   902861.0   1050.0   *    1266.9
TF50228   966383.5   1100.0   *    1274.0
TF50229  1030256.5   1150.0   *    1280.9
TF50230  1094468.3   1200.0   *    1287.6
TF50231  1159008.6   1250.0   *    1294.0
TF50232  1223867.9   1300.0   *    1300.3
```

```
TF50233  1288885.2   1350.0   *    1300.3
TF50234  2394140.2   2200.0   *    1300.3
TF50235  6034980.2   5000.0   *    1300.3
*
TF50300 'MgO k vs t'  28 1. 0.
*          Temp, K     MgO heater
*    k, W/m/K
TF50311     273.0        2.052
TF50312     300.0        2.085
TF50313     350.0        2.144
TF50314     366.3        2.162
TF50315     400.0        2.199
TF50316     450.0        2.251
TF50317     500.0        2.300
TF50318     539.0        2.336
TF50319     550.0        2.345
TF50320     600.0        2.387
TF50321     650.0        2.426
TF50322     700.0        2.461
TF50323     750.0        2.492
TF50324     757.0        2.497
TF50325     800.0        2.521
TF50326     850.0        2.546
TF50327     900.0        2.568
TF50328     950.0        2.586
TF50329     995.0        2.599
TF50330    1000.0        2.601
TF50331    1050.0        2.612
TF50332    1100.0        2.620
TF50333    1150.0        2.625
TF50334    1182.0        2.627
TF50335    1200.0        2.627
TF50336    1250.0        2.625
TF50337    1300.0        2.619
TF50338    5000.0        2.619
*
TF50400 'MgO Cp vs t'  24 1. 0.
*
*          Temp, K    Cp
*             K     J/kg-K
TF50411     273.0    930.1
TF50412     300.0    930.1
TF50413     350.0   1010.4
TF50414     400.0   1064.3
TF50415     450.0   1102.9
TF50416     500.0   1132.0
TF50417     550.0   1154.8
TF50418     600.0   1173.4
TF50419     650.0   1188.9
TF50420     700.0   1202.3
TF50421     750.0   1214.2
TF50422     800.0   1224.7
TF50423     850.0   1234.4
TF50424     900.0   1243.3
TF50425     950.0   1251.6
TF50426    1000.0   1259.4
TF50427    1050.0   1266.9
TF50428    1100.0   1274.0
TF50429    1150.0   1280.9
TF50430    1200.0   1287.6
TF50431    1250.0   1294.0
TF50432    1300.0   1300.3
TF50433    1350.0   1300.3
TF50434    5000.0   1300.3
*
TF50500 'MgO rho vs t'   2 1. 0.
*          Temp, K     MgO heater
*     kg/m3
TF50511     273.0       2950.1
TF50512    5000.0       2950.1
*
```

.

A.6 Radionuclide Input – rn.gen

```
********************************
*  RADIONUCLIDE PACKAGE INPUT  *
********************************
*
*     IACTV
RN1000  0   * ACTIVATE RN PACKAGE
*
*        ICRLSE
RNFP000  -2    * CORSOR RELEASE MODEL WITH S/V RATIO
*
*        NUMSEC NUMCMP NUMCLS NCLSW NCLSBX NUMSRA NUMSRV NCLCSI NUMCA
RN1001   10     2      16     14    13     0      0      16     6
*
RNSET001 101 010 0.1651 0.009675
RNSET002 102 101 0.3214 0.038700
RNSET003 103 102 0.9236 0.009675
RNSET004 104 103 1.5258 0.038700
RNSET005 105 104 2.1280 0.009675
RNSET006 106 105 2.7302 0.038700
RNSET007 107 106 3.3324 0.009675
RNSET008 108 107 3.9346 0.038700
*
RNSET009 010 030 0.00 1.00
RNSET010 020 020 4.1884 1.00
RNSET011 030 030 0.00 1.00
RNSET012 900 900 0.00 1.00
*
RNACOEF  1
*
*      *** FUEL INVENTORIES ***
*
*   RING 1: 100.0%
*
*     R L NINP  RINP1   RINP2
*           *** RING 1 ***
RNFPN11501  0  0.083333 1.000
RNFPN11401  0  0.083333 1.000
RNFPN11301  0  0.083333 1.000
RNFPN11201  0  0.083333 1.000
RNFPN11101  0  0.083333 1.000
RNFPN11001  0  0.083333 1.000
RNFPN10901  0  0.083333 1.000
RNFPN10801  0  0.083333 1.000
RNFPN10701  0  0.083333 1.000
RNFPN10601  0  0.083333 1.000
RNFPN10501  0  0.083333 1.000
RNFPN10401  0  0.083333 1.000
*
*      *** GAP RADIONUCLIDES ***
*    R L      CLFAIL (1173=DEFAULT CLADDING FAILURE TEMPERATURE)
*           *** RING 1 ***
RNGAP10300  1701.
RNGAP10400  1701.
RNGAP10500  1701.
RNGAP10600  1701.
RNGAP10700  1701.
RNGAP10800  1701.
RNGAP10900  1701.
RNGAP11000  1701.
RNGAP11100  1701.
RNGAP11200  1701.
RNGAP11300  1701.
RNGAP11400  1701.
*
*           *** RING 1 ***
*     R L  NINP  RINP1  RINP2
RNGAP10301  1     0.0    1.0   * XE
```

```
RNGAP10302  2     0.0    1.0   * CS
RNGAP10303  3     0.0    1.0   * BA, SR
RNGAP10304  4     0.0    1.0   * I
RNGAP10305  5     0.0    1.0   * TE
*
RNGAP10401  -104  1.0    1.0
RNGAP10501  -104  1.0    1.0
RNGAP10601  -104  1.0    1.0
RNGAP10701  -104  1.0    1.0
RNGAP10801  -104  1.0    1.0
RNGAP10901  -104  1.0    1.0
RNGAP11001  -104  1.0    1.0
RNGAP11101  -104  1.0    1.0
RNGAP11201  -104  1.0    1.0
RNGAP11301  -104  1.0    1.0
RNGAP11401  -104  1.0    1.0
*
*******************************************************************************
*
*  Sensitivity coefficients to specify all decay power into the UO2
*
sc13211   1321  1.0   1    * UO2
sc13212   1321  0.0   2    *
sc13213   1321  0.0   3    *
sc13214   1321  0.0   4    *
sc13215   1321  0.0   5    *
sc13216   1321  0.0   6    *
sc13217   1321  0.0   7    *
*
sc13221   1322  1.0   1    * UO2
sc13222   1322  1.0   2    *
sc13223   1322  1.0   3    *
sc13224   1322  1.0   4    *
sc13225   1322  1.0   5    *
sc13226   1322  1.0   6    *
sc13227   1322  1.0   7    *
sc13228   1322  1.0   8    *
sc13229   1322  1.0   9    *
*
*******************************************************************************
.
```

A.7 Core Sensitivity Coefficients Input – core-sc.gen

```
********1*********2*********3*********4*********5*********6*********7*********8
*           COR Sensitivity Coefficients
*
*     From [NUREG/CR-6846], the rate equations for air oxidation of steam-preoxidized
*     zirconium alloys.
*     All rate constants are based on mass of Zr consumed (i.e., modified for MELCOR input
*     from NUREG/CR-6846).
*
*      Rate constant (in kg^2/m^4-s) = A * exp( -B / T )
*
*                   Pre-breakaway       Post-breakaway
*     Material      A         B         A          B
*     Zr-4          2.67e1    17490     2.97e3     19680        Eqns.  6.6  and 6.7
*     Zirlo         6.95e0    16100     1.39e5     22865        Eqns.  6.27 and 6.28
*     M5            2.83e1    22660     4.69e4     22600        Eqns.  6.37 and 6.38
*
* turn on lifetime model
*
*           IOXB
COROXB         1
*
* Set up for lifetime model - pre-breakaway in SC-1001
*
SC10011     1001      26.7      1         2
* ANL Zr-4 "bare" pre-breakaway temperature coefficient, Eq. 6.6
SC10012     1001      17490.    2         2
* ANL Zr-4 "bare" pre-breakaway temperature exponent, Eq. 6.6
SC10013     1001      26.7      3         2
* ANL Zr-4 "bare" pre-breakaway temperature coefficient, Eq. 6.6
SC10014     1001      17490.    4         2
* ANL Zr-4 "bare" pre-breakaway temperature exponent, Eq. 6.6
SC10015     1001      9998.0    5         2     * Start of transition
SC10016     1001      9999.0    6         2     * End of transition
*
SC10041     1004      600.0     1               * Set minimum temperature for oxidation to 600 K
*
* Enter ANL post-breakaway for Zr-2 in 1016
*
SC10161     1016      2970.0    1         2
* ANL Zr-4 post-breakaway temperature coefficient, Eq. 6.7
SC10162     1016     19680.0    2         2
* ANL Zr-4 post-breakaway temperature exponent, Eq. 6.7
*
* Transition coefficient for pre- to post-breakaway
*
SC10181     1018      1.25      1         *  Breakaway SC
*
*           UO2 RELOCATION WITH NO ZR (ONLY ZRO2)
*
SC11321     1132      2800.0    1
*
*           ENHANCE CONDUCTION OF DEBRIS AS IT BECOMES MOLTEN
*
SC12501     1250      2800.0    1
*
*           MINIMUM POROSITY FOR FLOW RESISTANCE
*
SC15051     1505      0.05      1
*
*           MINIMUM POROSITY FOR CALCULATING HEAT TRANSFER TO FLUID
*
SC15052     1505      0.05      2
*
*           USE 0-D LOWER HEAD STRESS/STRAIN DISTRIBUTION
*
SC16001     1600      0.0       1
```

```
*
*           TEMPERATURE WHEN LOWER HEAD YIELD STRESS VANISHES
*
SC16031     1603      9999.0    2
*
*           ERGUN EQUATION, MINIMUM POROSITY (CVH Package)
*
SC44131     4413      0.05      5
*
*           MINIMUM HYDRO VOLUME FRACTION
*
SC44141     4414      0.01      1
.
```

A.8 Zircaloy Air Oxidation Breakaway Input – core-lifetime.gen

```
*********1*********2*********3*********4*********5*********6*********7*********8
plot101     cor-zrox-life.116
plot102     cor-zrox-life.115
plot103     cor-zrox-life.114
plot104     cor-zrox-life.113
plot105     cor-zrox-life.112
plot106     cor-zrox-life.111
plot107     cor-zrox-life.110
plot108     cor-zrox-life.109
plot109     cor-zrox-life.108
plot110     cor-zrox-life.107
plot111     cor-zrox-life.106
plot112     cor-zrox-life.105
plot113     cor-zrox-life.104
plot114     cor-zrox-life.103
*
***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                          104
***         card number                   1000
***
cf100000    'Zr Brkawy L104'          l-gt            2         1.0         0.0
cf100001    .false.
cf100005    latch
cf100006    2  '----------  cor cell 104 oxidation breakaway'
cf100011    0.0               1.0         time
cf100010    1.0               0.0         cor-zrox-life.104                          ***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                          105
***         card number                   1001
***
cf100100    'Zr Brkawy L105'          l-gt            2         1.0         0.0
cf100101    .false.
cf100105    latch
cf100106    2  '----------  cor cell 105 oxidation breakaway'
cf100111    0.0               1.0         time
cf100110    1.0               0.0         cor-zrox-life.105                          ***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                          106
***         card number                   1002
***
cf100200    'Zr Brkawy L106'          l-gt            2         1.0         0.0
cf100201    .false.
cf100205    latch
cf100206    2  '----------  cor cell 106 oxidation breakaway'
cf100211    0.0               1.0         time
cf100210    1.0               1.0         cor-zrox-life.106                          ***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                          107
***         card number                   1003
***
cf100300    'Zr Brkawy L107'          l-gt            2         1.0         0.0
cf100301    .false.
cf100305    latch
cf100306    2  '----------  cor cell 107 oxidation breakaway'
cf100311    0.0               1.0         time
cf100310    1.0               0.0         cor-zrox-life.107                          ***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                          108
***         card number                   1004
***
cf100400    'Zr Brkawy L108'          l-gt            2         1.0         0.0
cf100401    .false.
cf100405    latch
cf100406    2  '----------  cor cell 108 oxidation breakaway'
```

```
cf100411    0.0                 1.0         time
cf100410    1.0                 0.0         cor-zrox-life.108                           ***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                            109
***         card number                     1005
***
cf100500    'Zr Brkawy L109'          l-gt            2         1.0         0.0
cf100501    .false.
cf100505    latch
cf100506    2  '----------  cor cell 109 oxidation breakaway'
cf100511    0.0                 1.0         time
cf100510    1.0                 0.0         cor-zrox-life.109                           ***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                            110
***         card number                     1006
***
cf100600    'Zr Brkawy L110'          l-gt            2         1.0         0.0
cf100601    .false.
cf100605    latch
cf100606    2  '----------  cor cell 110 oxidation breakaway'
cf100611    0.0                 1.0         time
cf100610    1.0                 0.0         cor-zrox-life.110                           ***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                            111
***         card number                     1007
***
cf100700    'Zr Brkawy L111'          l-gt            2         1.0         0.0
cf100701    .false.
cf100705    latch
cf100706    2  '----------  cor cell 111 oxidation breakaway'
cf100711    0.0                 1.0         time
cf100710    1.0                 0.0         cor-zrox-life.111                           ***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                            112
***         card number                     1008
***
cf100800    'Zr Brkawy L112'          l-gt            2         1.0         0.0
cf100801    .false.
cf100805    latch
cf100806    2  '----------  cor cell 112 oxidation breakaway'
cf100811    0.0                 1.0         time
cf100810    1.0                 0.0         cor-zrox-life.112                           ***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                            113
***         card number                     1009
***
cf100900    'Zr Brkawy L113'          l-gt            2         1.0         0.0
cf100901    .false.
cf100905    latch
cf100906    2  '----------  cor cell 113 oxidation breakaway'
cf100911    0.0                 1.0         time
cf100910    1.0                 0.0         cor-zrox-life.113                           ***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                            114
***         card number                     1010
***
cf101000    'Zr Brkawy L114'          l-gt            2         1.0         0.0
cf101001    .false.
cf101005    latch
cf101006    2  '----------  cor cell 114 oxidation breakaway'
cf101011    0.0                 1.0         time
cf101010    1.0                 0.0         cor-zrox-life.114                           ***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                            115
***         card number                     1011
***
cf101100    'Zr Brkawy L115'          l-gt            2         1.0         0.0
cf101101    .false.
cf101105    latch
cf101106    2  '----------  cor cell 115 oxidation breakaway'
```

```
cf101111    0.0                 1.0         time
cf101110    1.0                 0.0         cor-zrox-life.115                              ***
***       cor cell oxidation breakaway control functions for time at temp
***         cell                            116
***         card number                     1012
***
cf101200    'Zr Brkawy L116'          l-gt            2         1.0         0.0
cf101201    .false.
cf101205    latch
cf101206    2  '----------  cor cell 116 oxidation breakaway'
cf101211    0.0                 1.0         time
cf101210    1.0                 0.0         cor-zrox-life.116                              ***
***
***
*  Add cor-zrox-life manually until ptfread and melcor are fixed!
*
cf75000     'Life C103'         equals                1         1.0         0.0 *
cf75011     1.0                 0.0         cor-zrox-life.103
*
cf75100     'Life C104'         equals                1         1.0         0.0 *
cf75111     1.0                 0.0         cor-zrox-life.104
*
cf75200     'Life C105'         equals                1         1.0         0.0 *
cf75211     1.0                 0.0         cor-zrox-life.105
*
cf75300     'Life C106'         equals                1         1.0         0.0 *
cf75311     1.0                 0.0         cor-zrox-life.106
*
cf75400     'Life C107'         equals                1         1.0         0.0 *
cf75411     1.0                 0.0         cor-zrox-life.107
*
cf75500     'Life C108'         equals                1         1.0         0.0 *
cf75511     1.0                 0.0         cor-zrox-life.108
*
cf75600     'Life C109'         equals                1         1.0         0.0 *
cf75611     1.0                 0.0         cor-zrox-life.109
*
cf75700     'Life C110'         equals                1         1.0         0.0 *
cf75711     1.0                 0.0         cor-zrox-life.110
*
cf75800     'Life C111'         equals                1         1.0         0.0 *
cf75811     1.0                 0.0         cor-zrox-life.111
*
cf75900     'Life C112'         equals                1         1.0         0.0 *
cf75911     1.0                 0.0         cor-zrox-life.112
*
cf76000     'Life C113'         equals                1         1.0         0.0 *
cf76011     1.0                 0.0         cor-zrox-life.113
*
cf76100     'Life C114'         equals                1         1.0         0.0 *
cf76111     1.0                 0.0         cor-zrox-life.114
*
cf76200     'Life C115'         equals                1         1.0         0.0 *
cf76211     1.0                 0.0         cor-zrox-life.115
*
cf76300     'Life C116'         equals                1         1.0         0.0 *
cf76311     1.0                 0.0         cor-zrox-life.116
*
.
```

A.9 Decay Heat Input – dch.gen

```
******************************************************************************
* SFP Decay heat input
******************************************************************************
DCHREACTOR PWR
DCHDECPOW  CF-100    * Specify power from PB DKHEAT or equivalent
DCHFPOW    1.5157e7 7.2736e6 9.856e5 * Scaled to 5 of 764 total assemblies 3458 MW
DCHOPRTIME 1.8213E+8 * Peach Bottom 3, Cycles 11-13 = 2,108 days
DCHDEFCLS1 ALL
*
DCHCLS0160 CSI
DCHCLS0161 CI
*
.
```

A.10 Non-condensable Gas Input – ncg.gen

```
******************************************************************************
* SFP noncondensable gas input
******************************************************************************
NCG000     O2        4
NCG001     N2        5
NCG002     H2        6
NCG003     CO        7
NCG004     CO2       8
NCG005     CH4       9
.
```

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