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MELCOR 1.8.2 ASSESSMENT: THE MP-1 AND MP-2 LATE PHASE MELT PROGRESSION EXPERIMENTS

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Abstract

MELCOR is a fully integrated, engineering-level computer code being developed at Sandia National Laboratories for the USNRC, that models the entire spectrum of severe accident phenomena in a unified framework for both BWRs and PWRs. As a part of an ongoing assessment program, MELCOR has been used to model the MP-1 and MP-2 experiments, which provided data for late-phase melt progression in PWR geometries.

Core temperatures predicted by MELCOR were within 250-500K of measured data in both MP-1 and MP-2. Relocation in the debris bed and metallic crust regions of MP-2 was predicted accurately compared to PIE data. Temperature gradients in lower portions of the test bundle were not predicted well in both MP-1 and MP-2, due to the lack of modeling of the heat transfer path to the cooling jacket in those portions of the test bundles.

Fifteen sensitivity studies were run on various core (COR), control volume hydrodynamics (CVH) and heat structures (HS) package parameters. No unexpected sensitivities were found, and in particular there were no sensitivities to reduced time step, finer nodalization or to computer platform.

Calculations performed by the DEBRIS and TAC2D codes for MP-1 and MP-2 showed better agreement with measured data than those performed by MELCOR. This was expected, though, due to the fully 2-dimensional modeling used in the other codes.

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Chapter 1

Introduction

MELCOR is a fully integrated, engineering-level computer code being developed at Sandia National Laboratories for the U. S. Nuclear Regulatory Commission (US-NRC), that models the progression of severe accidents in light water reactor nuclear power plants [1]. The entire spectrum of severe accident phenomena, including reactor coolant system and containment thermal/hydraulic response, core heatup, degradation and relocation, and fission product release and transport, is treated in MELCOR in a unified framework for both boiling water reactors (BWRs) and pressurized water reactors (PWRs).

The purpose of the Melt Progression, or MP, series of experiments was to investigate late phase core melt progression and to benchmark severe accident codes. There were two experiments in the MP series. The MP-1 experiment, carried out at Sandia National Laboratories in the Annular Core Research Reactor (ACRR) in 1989, began with an initial configuration representing a degraded core [2]. The test bundle consisted of three regions: a fuel rod region, consisting of 32 PWR-size fuel rods; a crust region, containing the 32 fuel rods surrounded by a Zr-UO₂ crust; and a debris region, consisting of a ZrO₂-UO₂ rubblized debris bed. The MP-1 experiment used nuclear heating and progressed to partial melting and settling of the debris bed region. No material was melted in the crust and stub regions during the MP-1 experiment. The MP-2 experiment used a test bundle that was quite similar to that of MP-1, with a taller stub region and decreased insulation in the radial direction. The MP-2 experiment was conducted in November 1992 [3]; it progressed to partial melting of the crust and debris regions, and resulted in more relocation than had taken place in MP-1.

For this task, an assessment of the MELCOR code was performed using the MP-1 and MP-2 experiments. These calculations were performed as post-test analyses, with both test data and the results of other code analyses available for comparison. Sensitivity studies were performed on the MELCOR core (COR) package, control volume hydrodynamics (CVH) package and heat structures (HS) package parameters, and the results of the base case calculation are compared with results from other codes modeling MP-1 and MP-2. The version of MELCOR used to model these experiments was version 1.8OF of the code. All modifications resulting from this assessment task have been implemented in the production version of the code.

One of the few modifications made to model these experiments was the addition of the capability to input core materials in a degraded state. This allowed the modeling of the debris region as particulate debris and the crust region as conglomerate debris refrozen onto the cladding component (see Appendix A for a discussion of conglomerate versus particulate debris in MELCOR). This modification was not part of MELCOR 1.8.2, released in April 1993. However, it will be included in future releases of MELCOR.

Temperatures were predicted to within 500K in all regions and within 250K in many regions, while the calculated melting and relocation in MP-2 agreed quite well with PIE data. This level of agreement with experimental data was considered good, given the complicated arrangement of the MP-1 and MP-2 experimental test packages, and the fact that MELCOR is designed to model large-scale reactor plants rather than small-scale experiments like MP-1 and MP-2. No unexpected sensitivities in MELCOR input were found. Temperatures predicted by two other codes, DEBRIS and TAC2D were closer to measured data, but this was also expected due to the two-dimensional modeling in these codes. This task added a new feature to MELCOR, namely the capability to initialize the core in a degraded state.

The remainder of this report is structured as follows. The experimental setup of MP-1 and MP-2 is described in Chapter 2. The base case MELCOR models for MP-1 and MP-2, which represent the best approximation of experimental conditions, are described in Chapter 3. The results calculated with MELCOR using the base case input models are discussed in Chapter 4. A number of sensitivity studies were done on MELCOR parameters in the COR, CVH and HS packages, on the input problem nodalization, on the time steps used to model MP-1 and MP-2, and on machine dependency. These studies are described in Chapter 5. The MELCOR base case results are compared with results from the DEBRIS and TAC2D codes in Chapter 6. The modifications to MELCOR required to model these experiments are described in Chapter 7. This work is summarized and final conclusions are given in Chapter 8. A discussion of conglomerate versus particulate debris in the COR package of MELCOR appears in Appendix A, while the MELCOR input decks used for the MP-1 and MP-2 base case calculations are given in Appendix B.

Chapter 2

Facility and Test Description

The MP series of experiments was designed to complement the DF experimental series. While the DF series represented the early phases of core damage [4, 5, 6, 7], the MP series tested the behavior of a degraded core after the postulated formation of a metallic blockage upon which a rubblized debris bed rested. The test bundles in both MP-1 and MP-2 consisted of three regions: a rubblized debris bed (the debris region), resting on a metallic crust surrounding 32 fuel rods (the crust region), below which there were the 32 bare fuel rods (the stub region). While the MP-1 experiment progressed until partial melting of the debris bed, the MP-2 experiment was taken further and resulted in partial melting and relocation of the metallic blockage to the bottom of the test section.

The geometry and initial conditions of both experiments are described below. Differences between MP-1 and MP-2 are described when appropriate; otherwise, the information given applies to both tests. More detailed descriptions of the MP-1 and MP-2 test scenarios are given later in this chapter.

2.1 Facility Description

The MP experiments were completely self-contained in their own sealed packages, which were inserted into the ACRF facility at Sandia National Laboratories. Diagrams of the MP-1 and MP-2 test sections are shown in Figures 2.1.1 and 2.1.2. There were three active regions of the experimental packages: the stub, crust, and debris regions. These regions are described separately in the following sections. Dimensions for the various regions for MP-1 and MP-2 are given in Table 2.1.1, and material masses for the two experiments are given in Table 2.1.2. More details about the MP-1 and MP-2 experiments can be found in [2, 3].

Figure 2.1.1. Diagram of the MP-1 test bundle (from [2]).

Figure 2.1.2. Diagram of the MP-2 test bundle (from [3]).

Table 2.1.1. Test section component dimensions for the MP-1 and MP-2 experiments.

Dimension	MP-1	MP-2
Test Bundle		
Bundle height	25.3 cm	30.0 cm
Bundle radius	4.36 cm	4.36 cm
Region heights		
Stub Region	5.4 cm	10.0 cm
Crust Region	3.5 cm	3.5 cm
Debris Region	16.4 cm	16.5 cm
Radial insulation dimensions		
W outer radius		4.38 cm
ThO ₂ outer radius	5.07 cm	5.72 cm
Ta outer radius	5.16 cm	5.84 cm
ZrO ₂ fiber outer radius	7.62 cm	6.78 cm
Al outer radius		7.78
Stainless steel outer radius	8.40 cm	8.41 cm
Axial insulation dimensions		
ThO ₂ thickness	2.0 cm	2.0 cm
ZrO ₂ thickness	6.3 cm	6.3 cm

Table 2.1.2. Material masses for the MP-1 and MP-2 experiments.

MP-1:

Material	Masses (kg)		
	Stub Region	Crust Region	Debris Region
UO ₂ (fuel)	1.077	0.595	
Zr (clad)	0.215	0.119	
UO ₂ (debris)		0.274	3.698
Zr (debris)		0.427	
ZrO ₂ (debris)		0.154	0.578

MP-2:

Material	Masses (kg)		
	Stub Region	Crust Region	Debris Region
UO ₂ (fuel)	1.912	0.613	
Zr (clad)	0.415	0.122	
UO ₂ (debris)		0.065	3.859
Zr (debris)		0.296	
ZrO ₂ (debris)		0.109	0.802
Sn (debris)		0.033	
Ag (debris)		0.092	
In (debris)		0.023	
Fe (debris)		0.094	
Cr (debris)		0.017	
Ni (debris)		0.059	
Mo (debris)		0.005	

2.1.1 Stub Region

The stub region is the lowermost region containing active fuel in Figures 2.1.1 and 2.1.2. This region consisted of 32 PWR-type fuel rods arranged in a 1.27 cm (0.5 in.) square pitch. The lattice was 6x6, with the 4 corner rods removed because of space considerations. The bottoms of the fuel rods were held in place by a steel "grid spacer", while the tops of the fuel rods extended into and were held in place by the crust above the stub region. The fuel rods used were of typical PWR fuel rod dimensions, with a pellet OD of 0.826 cm, a clad OD of 0.963 cm and a clad thickness of 0.122 cm. The stub region was 5.4 cm tall in the MP-1 experiment and 10.0 cm tall in the MP-2 test.

2.1.2 Crust Region

The crust region resides directly above the stub region in Figures 2.1.1 and 2.1.2. The crust region consisted primarily of metallic material and was designed to represent a blockage formed from lower melting point reactor materials. Such materials are postulated to candle down the fuel rods during a severe accident, refreezing in cooler parts of the core to form a metallic blockage. In both experiments, the crust region consisted of the ends of the 32 fuel rods, surrounded by a metallic blockage. In MP-1, the metallic blockage consisted of a UO_2 , ZrO_2 , and Zr mixture in weight ratios of 32%, 18% and 50%, respectively. The metallic blockage region in MP-2 consisted of cladding material (Zr, Sn), PWR control rod materials (Ag, In) and stainless steel (elements Fe, Cr, Ni and Mo). The crust material in MP-2 was designed to represent the lower crust composition of TMI-2. In both MP-1 and MP-2 the crust region was 3.5 cm tall. The material masses in this region are given in Table 2.1.2.

2.1.3 Debris Region

The debris region, which rested on the crust region in both experiments, consisted of UO_2 and ZrO_2 particulate debris. In both experiments the debris bed was approximately 16.4 cm tall. The material masses in the debris region are given in Table 2.1.2. The particle diameters in the debris bed varied between 1 and 5 mm, with a mean of approximately 2 mm.

2.1.4 Test Section Radial Barriers and Insulation

The test sections in both MP-1 and MP-2 were insulated so that the debris and crust regions would reach temperatures sufficient for partial material melting. Other materials surrounding the test section served as melt barriers. Because of the high temperatures and material melting expected, several layers of melt barrier and insulation were used in the radial and axial directions. For the MP-1 experiments, the barrier and insulating layers in the radial direction, from the test section outward, were: ThO_2 , tantalum, ZrO_2 fiber, and stainless steel. For MP-2, the layers were tungsten, ThO_2 , ZrO_2 , aluminum and stainless steel. On top, both test sections were

provided with layers of ThO_2 , ZrO_2 and stainless steel, while on the bottom a stainless steel “grid spacer” was used. The radial barrier and insulation dimensions are given in Table 2.1.1, and the layers are shown in Figures 2.1.1 and 2.1.2. Heat was removed from the test bundle by a cooling jacket directly outside the primary containment in both experiments.

The thicknesses of the ThO_2 layer was greater in the MP-2 experiment than in MP-1 in order to retain the greater amount of molten material expected in MP-2. This allowed the MP-2 experiment to progress to a more advanced damage state than that attained in MP-1.

2.1.5 Instrumentation

All regions of the test section, including the layers of insulation, were fully instrumented with thermocouples in both experiments. In the debris and crust regions, where higher temperatures were expected, type C (W/Re) thermocouples were used. These thermocouples are considered reliable up to a temperature of 2600K, about 300K below the expected melting temperature of the debris. Type S (Pt/Rh) and type K (chomel/alumel) thermocouples were used in the stub region and in the outer insulation layers, where lower temperatures were expected. Diagrams of the thermocouple placement and name designation are shown for the MP-1 and MP-2 experiments in Figures 2.1.3 and 2.1.4, respectively.

2.2 Test Descriptions

The MP-1 and MP-2 experiments were both driven using nuclear heating from the ACRR at Sandia National Laboratory. The ACRR power histories for the MP-1 and MP-2 experiments are shown in Figures 2.2.1 and 2.2.2, respectively. In each experiment, the fission power was increased in a stepwise fashion. The plateaus between power increases were used to determine bundle heat loss rates, which facilitated control of the experiments.

Nuclear heating in the MP-1 experiment was sustained for approximately 9500 seconds. During that time, melting of approximately 50% of the debris bed materials occurred [2]. These materials relocated through the debris pore space towards the crust blockage. The MP-1 experiment was terminated due to a high temperature limit in the radial insulating layers at the ThO_2 -Ta interface.

Nuclear heating in the MP-2 experiment occurred over the course of approximately 19800 seconds. The initial stages of the experiment were very similar to MP-1 behavior. After 13500 seconds, however, a molten pool of material in the debris region began attacking the crust region materials. The post-test examination of the MP-2 experiment indicated that some crust materials had slumped to the bottom of the stub region. It was also indicated that molten debris material had relocated into the former crust region, where they solidified to form a higher density crust around the embedded fuel rods.

Figure 2.1.3. Thermocouple names and locations in the MP-1 experiment (from [2]).

Figure 2.1.4. Thermocouple names and locations in the MP-2 experiment (from [3]).

More details about MP-1 and MP-2 experiment progression are given in Chapter 4, when MELCOR base case results are discussed, and in the experimental reports [2, 3].

Figure 2.2.1. ACRR console reactor power during the MP-1 experiment.

Figure 2.2.2. ACRR console reactor power during the MP-2 experiment.

Chapter 3

MELCOR Input Model

The input models used to represent the MP-1 and MP-2 experiments for the base case calculations are described in this chapter. The base case models did not use all the MELCOR default input options; however, the non-default input parameters used in these models were reasonably justifiable from an engineering perspective, and were the result of sensitivity studies which showed better agreement with experimental data. The sensitivity studies used to refine the base case input models are described in Chapter 5.

The parts of the MELCOR base case models describing geometric and mass inputs are described first. Initial and boundary conditions used in the base case calculations are given as well. The base case models for MP-1 and MP-2 were quite similar, and are discussed together. The differences between the models are also highlighted. Listings of the two base case models are included in Appendix B, for reference. The final section gives information about the MELCOR input used for time step and model control.

3.1 Geometry

The MP-1 and MP-2 base case input models represented only those parts of the MP experiments that were considered significant. The parts of the experiment modeled included everything inside the steel containment boundary radially, and between the zirconia insulator on top and the bottom grid spacer axially. Any experimental conditions outside these boundaries were modeled in MELCOR as boundary conditions.

3.1.1 CVH/FL Package Models

In the base case models, each region (stub, crust, debris) was modeled with its own control volume, and the three control volumes were connected in series using flow paths. A sensitivity study on the MP-1 CVH and COR nodalization is described in Section 5.3.

Since the MP experiments were closed systems, there were no flow paths into or out of the test bundle. All control volumes were initialized with helium at a pressure of 68.9 kPa (10 psia) and a temperature of 300K.

3.1.2 COR Package Model

The core package input for the MP-1 base case model consisted of three radial rings and thirteen axial levels, for a total of 39 core cells. The axial nodalization in the MP-1 base case model is shown in Figure 3.1.1. The stub and crust regions were each divided axially into three levels, while the debris region was divided into six levels. There was also one level at the bottom of the bundle. The MP-2 base case model contained five stub region levels instead of three, for a total of 15 levels, to account for the increased height of this region in MP-2. The starting elevations for axial levels in the MP-1 and MP-2 base case models are given in Table 3.1.1. The radial nodalization in both MP-1 and MP-2 consisted of three radial rings with outer radii of 1.4 cm, 2.7 cm and 4.36 cm; the number of fuel rods contained in the inner, middle and outer rings were 4, 10 and 18, respectively. It was necessary to split four fuel rods equally between the middle and outer rings, because the circular ring boundary passed through four rods in the square lattice.

The component material masses in the MP-1 and MP-2 base case input models are given in the input listings in Appendix B, from region-wise masses given in Table 2.1.2. In all cases, intact fuel rod material masses were apportioned according to the number of fuel rods in each radial ring, while the debris masses in the debris and crust regions were apportioned based on flow area (i.e. the cross-sectional area not occupied by fuel rods). The particulate and conglomerate debris masses in the debris and crust regions, respectively, were initialized using new MELCOR input developed specifically for this modeling task (see Appendix A for a discussion of conglomerate versus particulate debris in MELCOR). The new input capabilities are available in the default MELCOR code starting with version 1.80D (i.e. they are not available in MELCOR version 1.8.2), and are described in detail in Chapter 7.

The first axial level in the MP-1 and MP-2 base case models contained much of the mass of the lower grid spacers (see Figures 2.1.1 and 2.1.2). In addition, the core boundary conduction option on input record COR00011 was used to link the "other structure" (OS) component in the first axial level and outer-most ring (modeling part of the grid spacer) directly to the radial heat structure at that level. This modeling strategy was chosen in order to enhance heat losses through the lower part of the core; modeling the grid spacer as part of the lower head would not have been appropriate since an adiabatic boundary condition on the bottom surface of the lower head is assumed by the COR package. Although this modeling strategy was the most appropriate given MELCOR's capabilities, it still did not represent the real situation in the grid spacer. MELCOR does not model conduction from inner ring OS components to the outer ring OS component, and so radial heat loss from the grid spacer was under-predicted.

The total fission power used in the MP-1 base case model was calculated from region-wise coupling factors (given in the experimental report [2]) and the ACRR

power. Briefly, the calculation procedure was as follows. A coupling factor was given for each region in units of $W/kg(UO_2)\text{-kW(ACRR)}$. To get the total fission power deposited in the test bundle per kW of ACRR power, the product of coupling factor and the UO_2 mass in each region was summed over the three regions. This sum was used as a multiplier to a control function whose value contained the ACRR power in kW, which resulted in the total bundle fission power. In MP-2, the calculations described above were performed in control functions that used the actual region-wise UO_2 masses, to account for the relocation of UO_2 during the experiment.

The axial peaking factors used in the MP-1 and MP-2 base case models were calculated using shape factors and region-wise coupling factors given in the MP experimental reports [2, 3]. For each region, an axial shape factor curve was given. These curves were integrated, and the integrated contribution over each axial level was calculated. These integrated shape factor contributions were normalized and multiplied by the normalized region coupling factors to get the cell-wise peaking factors. Average axial peaking factors used in the MP-1 and MP-2 base case input models are given in Table 3.1.2. In this table, the axial peaking factors for both MP-1 and MP-2 are separated for all regions by ascending axial level. Axial peaking factors are set on record CORZjj03.

Radial shape factor curves were given in the MP experiment reports for each axial region. It was necessary to average these curves because MELCOR does not allow axial level-specific radial peaking factors. The radial shape factor curves in each region were integrated, and the normalized contribution for each radial ring was computed. These normalized, region-wise shape factors were averaged using a region-wise UO_2 mass weighting to arrive at the average radial peaking factors. Average radial peaking factors used in the MP-1 and MP-2 base case models are given in Table 3.1.3. Radial peaking factors are set on record CORRjj03.

The radiation view factors used in the base case MELCOR model, set on record COR00003, were equal to the MELCOR default values of 0.25. A sensitivity study on radiation view factors is reported in section 5.1.5.

The materials interactions (eutectics) model was not used in the MP-1 and MP-2 base case models. This was done because it was observed that the crust region materials acted independently rather than interacting at temperatures lower than their respective melting points in MP-1 and MP-2 [2, 3]. A sensitivity study on the use of this model is described in Section 5.1.6.

The intact material porosities at all axial levels were set to 0.750. This artificially high value forced the fuel rods in the crust and stub regions to support particulate debris (see [8] for details). Thus, the only material allowed to relocate into the crust and stub regions was molten material. The debris porosities were set to 0.513, corresponding to the porosities reported in [2, 3]. Porosities are set on input records CORZjj01. (See [8] for an explanation of intact versus debris porosities in MELCOR.)

The core component initial temperatures (input record CORijj03) were set to the best estimated temperatures in each region, derived from thermocouple data. See the input decks in Appendix B for the actual temperatures used.

The critical minimum thickness for zircaloy, set on record COR00008, was set to 10^{-5} m, compared to the MELCOR default value of 10^{-4} m. The base case value was

chosen to allow the cladding to support conglomerate debris in the crust region.

The minimum component mass and the minimum mass used for temperature control in sensitivity coefficient array 1502 were set to 10^{-7} and 10^{-6} kg, respectively, compared to their default values of 10^{-3} kg and 10.0 kg. These are the component masses below which component mass and energy are discarded and below which a component is not subject to maximum temperature change criteria, respectively. These parameters were reduced to take into account the reduced component masses in this experiment compared to those found in full-scale reactor core models. A sensitivity study on these parameters is described in Section 5.1.7.

Parameters in sensitivity coefficient array 1302 were set to allow UO_2 appearing in the cladding and particulate debris components to absorb fission power. By default, only UO_2 in the fuel component is allowed to absorb fission power.

The properties of zircaloy were changed to the values given by the MATPRO material properties package [9]. In particular, the melting temperature of zircaloy was changed from 2098K to 2200K. Other MELCOR assessments have shown the MATPRO value to be superior [10, 11, 12].

The densities of UO_2 , ZrO_2 and stainless steel and the thermal conductivities for these materials were changed to the values described in the MP-1 experimental report [2].

Table 3.1.1. Radial and axial nodalization dimensions for the MP-1 and MP-2 base case MELCOR input problems.

MP-1		MP-2	
Level	Starting elevation (cm)	Level	Starting elevation (cm)
1	-12.60	1	-12.60
2	0.00	2	0.00
3	1.80	3	2.00
4	3.60	4	4.00
5	5.40	5	6.00
6	6.57	6	8.00
7	7.73	7	10.00
8	8.90	8	11.67
9	11.63	9	12.33
10	14.37	10	13.50
11	17.10	11	16.25
12	19.83	12	19.00
13	22.57	13	21.75
		14	24.50
		15	27.25

Figure 3.1.1. Core and heat structures nodalization in the MP-1 base case model. MP-2 dimensions were slightly different in the stub region and in the radial heat structures.

Table 3.1.2. Average axial power peaking factors used in the MP-1 and MP-2 base case input models.

MP-1		MP-2	
Level	Peaking factor	Level	Peaking factor
1	0.000	1	0.000
2	0.634	2	0.315
3	0.519	3	0.345
4	0.293	4	0.352
5	0.890	5	0.371
6	0.601	6	0.487
7	0.429	7	0.183
8	2.025	8	0.157
9	1.825	9	0.164
10	1.785	10	2.397
11	1.785	11	2.433
12	1.760	12	2.470
13	1.725	13	2.325
		14	2.362
		15	2.760

Table 3.1.3. Average radial power peaking factors used in the MP-1 and MP-2 base case input models.

Ring	Peaking factor	
	MP-1	MP-2
1	0.818	0.638
2	0.620	0.758
3	1.562	1.604

3.1.3 Heat Structures Model

The base case models for MP-1 and MP-2 contained fourteen and sixteen heat structures, respectively. All but one of these were radial boundary heat structures, one for each core axial level, as required by the COR package. The remaining heat structure was the upper axial boundary heat structure.

For MP-1, the radial heat structures from core level two upward consisted of four material layers; from the inside out, they were: ThO_2 , tantalum, ZrO_2 fiber, and stainless steel. For MP-2, the layers were tantalum, ThO_2 , tantalum, ZrO_2 fiber, aluminum and stainless steel. Tantalum was used instead of tungsten for the inner-most heat structure layer because tungsten properties were not readily available and because both metals had little effect on overall temperature drop in the radial insulation. These heat structures modeled the radial thermal insulation and melt barriers. The thickness of these layers in MP-1 and MP-2 are given in Table 3.1.4. The materials that made up the radial heat structures in the MP-1 base case model are shown in Figure 3.1.1 (dimensions for MP-2 were slightly different). There were 31 temperature nodes in the MP-1 radial heat structures, and 46 nodes in the MP-2 radial heat structures; these nodes were approximately evenly spaced throughout the heat structures. The heat structures at level one in both base case models were identical in dimension to those above, but consisted entirely of stainless steel. This was done to model the outer portions of the grid spacer and its conduction to the test section containment boundary.

The ThO_2 , Ta and ZrO_2 used in the radial boundary heat structures were input to the MP package as new materials. Their densities, thermal conductivities, and specific heat capacities were given in the MP-1 experimental report [2]. The specific enthalpies were derived by integrating the specific heat capacity relations.

All heat structures in the MP-1 and MP-2 base case models used the default radiation model (equivalent band), with emissivities of 0.7. This parameter was probably unnecessary; the lack of steam or CO_2 in the MP-1 and MP-2 test bundles precluded HS package radiation calculations, since radiation is calculated only with these gases in control volume atmospheres. The COR radiation heat transfer model uses black body emissivities.

The outer boundaries of the radial and axial heat structures used temperature-specified boundary conditions. The instrumented temperature on the outside of the steel containment layer (the "cooling jacket" temperature) was used on all outer boundaries.

3.2 MELCOR Input

The MELCOR input files are also listed in Appendix B. The maximum time steps used in the MELCOR input for MP-1 and MP-2 were 0.1 and 0.5 seconds, respectively. In the case of MP-2, the time step that was chosen was a tradeoff between CPU time and CVH subcycling frequency.

In both the MP-1 and MP-2 input problems, the COR dT/dz model was turned off, using the CORTST01 record. This was done because there was no gas flow

Table 3.1.4. Radial boundary heat structures parameters for the MP-1 and MP-2 base case input models.

Layer	Material	Thickness	
		MP-1	MP-2
1	Ta	–	0.01 cm
2	ThO ₂	0.71 cm	1.35 cm
3	Ta	0.09 cm	0.09 cm
4	ZrO ₂ fiber	2.46 cm	1.73 cm
5	Al	–	1.00 cm
6	Stainless steel	1.43 cm	0.63 cm

through the MP-1 and MP-2 test bundles (both experiments were closed systems). In addition, the MP-2 base case model used a value of 2 for the candling model option on record CORTST01, which enabled individual materials to candle out of conglomerate debris (see Section 7.2 and Appendix A for an explanation of conglomerate versus particulate debris in MELCOR).

Chapter 4

MELCOR Base Case Calculation Results

The results of the MELCOR base case calculations for MP-1 and MP-2 are discussed in this chapter. Note that the base case input models did not use all default MELCOR input options and sensitivity coefficients, but rather used those that either resulted in better agreement with experimental data or that reflected the state of knowledge about either experimental conditions or model accuracy. The base case model was the result of several MELCOR sensitivity studies, some of which are described in the next chapter.

The results of the MP-1 and MP-2 base case models are discussed separately. For each experiment, the component temperature results are discussed first, since these quantities were measured directly by the experiment instrumentation. Failure and relocation phenomena are then discussed, and the final core state is analyzed and compared with PIE (Post Irradiation Examination) data.

Temperature and relocation phenomena are discussed starting with the debris region, since this is the part of the experiment of most interest and most representative of postulated accident conditions. Discussion then proceeds to the crust and rod stub regions.

4.1 MP-1

4.1.1 Debris Region Temperatures

The debris region in MP-1 was instrumented at four axial levels (see Figure 2.1.3); each of these levels had corresponding levels in the MELCOR base case core model. The temperatures at each of these levels are discussed in succession.

The particulate debris temperatures calculated by MELCOR at axial levels 8, 9, 10 and 11 are compared with the measured temperatures in Figures 4.1.1 and 4.1.2 (see Figure 2.1.3 for thermocouple locations and identifiers). Peak debris temperatures calculated for levels 9 and 10 corresponded closely to measured peak temperatures at those levels, while at levels 8 and 11 calculated temperatures were approximately 250K below measured temperatures. In all cases, calculated temperatures rose more

quickly than measured temperatures during the first 1000 seconds of the experiment, and then increased at a slower rate than measured, until the power increase at 9000 seconds. MELCOR-calculated temperatures showed very little radial variation in the debris region.

Temperatures at all axial levels for each ring in the debris region are compared with measured temperatures in Figures 4.1.3, 4.1.4 and 4.1.5. Most ring one debris temperatures were bounded by peak centerline temperatures measured by thermocouples towards the end of the experiment, with the maximum peak calculated temperature about 200K below the measured value. The temperatures in rings two and three were also quite close to measured temperatures in those rings. In all rings, debris temperatures between 6500 seconds and 9000 seconds were 250–500K below measured temperatures. There are two possible sources of temperature discrepancies in the debris region: either the heat losses to the radial heat structures were not predicted correctly, or the power peaking factors were incorrect. The temperature data in Figures 4.1.3–4.1.5 suggest that the power peaking factors might have been the cause of the discrepancies. Radial heat loss errors would have affected outer rings more than inner rings, while MELCOR results were closer to measured data for outer rings than for inner rings.

4.1.2 Crust Region Temperatures

The crust region in MP-1 consisted of a U-Zr-O metallic crust formed around 32 fuel rods. This crust was radially adjacent to the ThO_2 melt barrier, and was modeled in MELCOR as conglomerate debris frozen onto the cladding component. Thus, cladding temperatures are reported in this section and represent the temperatures of both cladding and the metallic crust material.

Calculated crust region temperatures for all axial levels in the crust region are compared with measured temperatures in Figures 4.1.6– 4.1.8 for the three core rings, respectively. Note that there was almost no axial variation in cladding temperature in all three rings. This was due to axial heat conduction in the cladding component.

The trend in time of calculated temperatures compared to measured temperatures was just opposite the calculated temperature trends in the debris region. Temperatures in the crust region started lower then increased at a greater rate than the measured temperatures, resulting in slight overprediction of temperatures in later parts of the experiment. Calculated temperatures were within 200K of measured temperatures at all times. The over-prediction of crust temperatures could be caused by inaccuracies in the peaking factors in the MP-1 base case model; skewing of the power to the crust region would also explain the under-prediction of the debris region temperatures.

Measured peak crust temperatures ranged from a low of 1850K in ring one to a high of 1950K in ring two, while calculated peak crust temperatures were around 2000K for the inner two rings and 1850K for the outer ring.

4.1.3 Stub Region Temperatures

Thermocouples in the stub region of MP-1 were attached to the fuel rod cladding. Therefore, measured temperatures for this region are compared to cladding temperatures calculated by MELCOR.

The cladding temperatures at levels one through four for all rings are compared to measured temperatures in Figures 4.1.9– 4.1.11. The calculated temperatures at all levels in the stub region were higher than measured temperatures, with the greatest discrepancy appearing during the final power increase between 8500 and 9500 seconds. The temperature disagreement grew smaller towards the top of the stub region. This indicates that MELCOR did not calculate as steep a temperature gradient going down the stub region as existed in the experiment. This was due to the grid spacer at the bottom of the bundle, which served as a large heat sink at the bottom of the test bundle and which was connected directly to the cooling jacket. This heat sink was unrepresentative of what would probably appear in a typical severe accident, and so these temperature discrepancies are not considered very significant to this assessment.

Also shown in Figure 4.1.9 are "other structure" component temperatures in axial level one compared to measured grid spacer temperatures. The outer-most ring was much closer to the measured grid spacer temperature over the entire problem. There were two reasons for this agreement. First, the boundary conduction model in the COR package kept the OS temperature in ring three close to the heat structure temperature at that level, and second, the heat structure at that level was all steel whose outer surface was maintained at a fixed temperature around 300K. Radial heat conduction from the OS components in the two inner rings to the OS component in the outer ring is not modeled by MELCOR, and therefore the temperatures of these components more closely followed the stub region temperatures. This phenomenon is also discussed in Section 4.1.4.

The calculated stub temperatures for rings one, two and three are given in Figures 4.1.12–4.1.14, respectively. These figures show that cladding temperatures were over-estimated in all rings. Note also that there was little axial variation in calculated clad temperatures. Both of these effects were due to axial heat conduction and radiation calculated by MELCOR. A sensitivity study on the axial conduction model is described in Section 5.1.1.

Figure 4.1.1. MP-1 base case: particulate debris temperatures versus measured temperatures at axial levels 8 (top) and 9 (bottom) for all rings.

Figure 4.1.2. MP-1 base case: particulate debris temperatures versus measured temperatures at axial levels 10 (top) and 11 (bottom) for all rings.

Figure 4.1.3. MP-1 base case: particulate debris temperatures versus measured temperatures in ring one for all axial levels in the debris region.

Figure 4.1.4. MP-1 base case: particulate debris temperatures versus measured temperatures in ring two for all axial levels in the debris region.

Figure 4.1.5. MP-1 base case: particulate debris temperatures versus measured temperatures in ring three for all axial levels in the debris region.

Figure 4.1.6. MP-1 base case: cladding temperatures versus measured temperatures in ring one for all axial levels in the crust region.

Figure 4.1.7. MP-1 base case: cladding temperatures versus measured temperatures in ring two for all axial levels in the crust region.

Figure 4.1.8. MP-1 base case: cladding temperatures in ring three for all axial levels in the crust region.

Figure 4.1.9. MP-1 base case: stub region cladding temperatures compared to measured temperatures at axial level two.

Figure 4.1.10. MP-1 base case: stub region cladding temperatures compared to measured temperatures at axial level three.

Figure 4.1.11. MP-1 base case: stub region cladding temperatures compared to measured temperatures at axial level four.

Figure 4.1.12. MP-1 base case: stub region cladding temperatures compared to measured temperatures in ring one.

Figure 4.1.13. MP-1 base case: stub region cladding temperatures compared to measured temperatures in ring two.

Figure 4.1.14. MP-1 base case: stub region cladding temperatures compared to measured temperatures in ring three.

4.1.4 Axial and Radial Temperature Profiles

Many of the thermocouples placed in the MP-1 test bundle were aligned along the centerline, allowing the measurement of axial temperature profiles through time. There were also three locations axially where the radial temperature profile was measured (see Figure 2.1.3). The calculated radial and axial temperature profiles are compared to measured results in this section.

The calculated axial temperature profiles in the test bundle for all rings are compared to the measured centerline axial temperature profiles at 4800, 8400 and 9400 seconds in Figures 4.1.15, 4.1.16 and 4.1.17, respectively. At 4800 seconds, there were no steep temperature gradients within any of the three regions, with the debris region being much hotter than the other two regions. The situation was much different at 8400 seconds, where measured temperatures showed steep gradients in all regions, especially in the stub region. The gradients calculated by MELCOR were not as steep. In the debris region, the smaller temperature gradient could have been due to the peaking factor input. MELCOR calculated more of an axial temperature gradient in the debris region, both at 8400 and 9400 seconds, because axial heat conduction in the particulate debris component is not considered in MELCOR. In the stub region, MELCOR calculated almost no temperature gradient, due to axial conduction in the cladding component. The measured temperatures showed a steep gradient, due to the large grid spacer mass at the bottom of the bundle, which provided a very effective heat sink for the bundle, as well as the ceramic content of the crust material. The calculated crust region temperatures also showed little gradient, again because of axial conduction. The largest temperature discrepancy at 8400 seconds was in the center of the debris region, and was close to 500K. This discrepancy might be reduced if there were more axial peaking of the fission power in the base case model. At 9400 seconds, the peak debris temperature climbed to almost 3000K, which was approximately 100K below the peak measured temperature in the debris. The steep temperature gradients in the stub and crust regions still existed in the measured data at this time.

Temperatures measured by thermocouples in the centerline of the debris region became unreliable after approximately 2600K, due to thermal and electrical shunting in the thermocouple wires. Therefore, temperatures measured just outside the tantalum liner (see Figure 2.1.3) have been used to investigate the agreement of other codes with measured data later in the experiment (see Chapter 6). However, the bottom of the tantalum liner was in direct contact with the grid spacer, and therefore the liner represented a very effective heat transfer path to the cooling jacket (see Figure 2.1.1). The measured Ta liner temperatures clearly reflected this heat transfer, having a linear temperature gradient going down the liner. Since the MELCOR HS package could not model this heat transfer path, the Ta liner temperatures calculated by MELCOR did not compare well at all with measured quantities, except at the axial position of peak liner temperature. For example, Figure 4.1.18 shows these temperatures at 9400 seconds. Ta liner temperatures calculated by MELCOR did not show the linear temperature gradient along the liner that is shown by the data. The centerline Ta liner temperature calculated by MELCOR was in good agreement with the measured

temperature at that point, however.

The radial temperature profiles in the debris and crust regions are shown for 4800 and 9400 seconds in Figures 4.1.19 and 4.1.20, respectively. Crust and debris region temperatures were close to measured data at both times in the center and at the outside of the bundle. In the ZrO_2 insulation layer, measured temperatures were shown in [2] to be biased lower due to thermal shunting in the thermocouple wires. MELCOR results for this layer of insulation compared favorably with those of the DEBRIS code (see Chapter 6). Assuming the DEBRIS-calculated temperatures were more representative of actual temperatures than the temperatures indicated by the thermocouples in this region, MELCOR-calculated temperatures here were accurate.

4.1.5 Final Material Configurations

Melting and relocation in MP-1 was restricted to the debris region. Data from the experimental report [2] indicate that there was a surface of a formerly molten pool at an elevation of approximately 14.9 cm (6 cm above the crust surface in the debris region). Below this surface, the porosity was very small, indicating that the debris in this area was filled in with molten material that relocated from above. Above 14.9 cm, the average porosity was approximately 70%, compared to an original porosity of 51% at the start of the experiment (the final porosities varied radially and axially between 50% and 100%). This voided region was left by the melting and relocating debris. Below the debris region, there was no melting indicated by the final material configurations.

The MELCOR calculation for MP-1 showed virtually no melting in the debris region. The reason for this was that calculated temperatures in the debris region never reached the ZrO_2 melting point of 2990K. They did come quite close, however. Figures 4.1.1- 4.1.14 show that the debris region temperatures as a whole were lower than measured temperatures, while the crust and stub region temperatures as a whole were higher than measured temperatures. This, along with the lack of any calculated melting and relocation in the debris region, suggest that the peaking factors were skewed away from the debris region in the MP-1 base case model.

Figure 4.1.15. MP-1 base case: axial temperature profiles in all rings at 4800 seconds, compared to measured temperatures.

Figure 4.1.16. MP-1 base case: axial temperature profiles in all rings at 8400 seconds, compared to measured temperatures.

Figure 4.1.17. MP-1 base case: axial temperature profiles in all rings at 9400 seconds, compared to measured temperatures.

Figure 4.1.18. MP-1 base case: centerline and tantalum liner axial temperature profiles at 9400 seconds, compared to measured temperatures.

Figure 4.1.19. MP-1 base case: debris and crust region radial temperature profiles at 4800 seconds, compared to measured temperatures.

Figure 4.1.20. MP-1 base case: debris and crust region radial temperature profiles at 9400 seconds, compared to measured temperatures.

4.2 MP-2

The MP-2 experiment was carried further in time than MP-1, and therefore resulted in more melting and relocation (see Section 2.2 for a more thorough discussion of accident progression in the MP-2 experiment). In addition, there were slight differences in test bundle geometry between MP-1 and MP-2 (see Section 2.1) that resulted in higher debris region temperatures in MP-2.

In the following sections, component temperatures are discussed first, starting with the debris region and proceeding downward in the test bundle. Axial and radial temperature profiles throughout the bundle are discussed next, followed by a discussion of melting and relocation behavior and a description of the final material configurations in MP-2.

4.2.1 Debris Region Temperatures

The debris region temperatures at levels 10 and 11 are shown in Figure 4.2.1 (see Table 3.1.1 for a description of axial levels versus test section elevations). The calculated temperatures at level 10 were in between those measured by the three thermocouples at that level until approximately 14000 seconds, after which the calculated temperatures were lower than expected by as much as 500K. Calculated debris temperatures in level 11 were also below measured values. Note however that these thermocouples experience electrical shunting effects above 2600K that make their readings somewhat unreliable. These temperature profiles are similar to those for the MP-1 experiment (see Figures 4.1.1– 4.1.2), where the calculated temperatures rose quickly in the beginning and tailed off towards the end of the experiment, compared to measured data.

The calculated versus measured temperatures in levels 12 and 13 are shown in Figure 4.2.2, and in levels 14 and 15 in Figure 4.2.3. The same trends are seen in these upper levels that were evident in the lower levels of the debris region, although the temperature discrepancies were smaller. The measured temperature for level 15 was lower than calculated debris temperatures because that thermocouple was in contact with the insulation at the top of the bundle.

The particulate debris component at axial levels 14 and 15 failed at approximately 19600 seconds, shortly after the final fission power increase (see Figure 2.2.2). This relocation was consistent with the final bundle state of MP-2, and is discussed in more detail in Section 4.2.5.

The calculated debris temperatures for all axial levels in the debris region in ring one are shown in Figure 4.2.4. This figure shows that the peak calculated debris temperature was approximately 3100K, in axial levels 11 and above; this temperature corresponds with the UO_2 melting temperature in MELCOR of 3113K. The calculated temperature difference through the debris region was 500K, compared to a measured value of almost 900K. The calculated debris temperatures were bounded by measured temperatures in ring one as a whole, at least until thermocouple measurements became unreliable above 2600K. The smaller amount of peaking in the MELCOR-calculated temperatures may have been due to the axial peaking factors.

A similar effect was noted in the MP-1 base case results (see Section 4.1.4).

The calculated debris temperatures for all axial levels in the debris region in rings two and three are shown in Figures 4.2.5 and 4.2.6. The peak temperatures and temperature gradients in these rings were similar to those in ring one.

4.2.2 Crust Region Temperatures

The thermocouple instrumentation in the crust region of MP-2 was quite similar to that of MP-1 (see Figure 2.1.4). There were five thermocouples distributed in three different axial locations. Note that the MELCOR base case model represented the crust material (that material not included in the embedded fuel rods) as conglomerate debris that was refrozen onto the cladding component. Therefore, the cladding component temperature represented both intact and crust material in the crust region. Cladding temperatures are used to compare MELCOR calculations in the crust region with measured results in the following discussion. (See Appendix A for a discussion of conglomerate versus particulate debris in MELCOR.)

The cladding temperatures calculated for level 7 (the lowest crust region axial level) for all radial rings are compared to measured temperatures for this level in Figure 4.2.7. During most of the experiment, calculated temperatures were quite close to and were bounded by measured temperatures at this axial level. The calculated and measured temperatures diverged a bit between 15000 and 17000 seconds, with the peak temperatures differing by approximately 250K at the time of thermocouple failure.

Calculated temperatures for levels 8 and 9 are compared with measured temperatures in Figures 4.2.8 and 4.2.9, respectively. The agreement between calculated and measured temperatures at these levels was similar to that at axial level 7, with calculated temperatures below measured temperatures by less than 250K, mostly later in the experiment.

The temperatures for all crust region levels in rings one, two and three are compared to measured results in Figures 4.2.10– 4.2.12, respectively. These figures show that the largest temperature discrepancy was in ring one, where calculated temperatures lagged measured temperatures by as much as 200K, mostly later in the experiment. For the outer two rings, calculated temperatures were within 100K of measured values. These figures also show that there was very little axial variation in temperature. This was due to the axial heat conduction for the cladding component, and is discussed in more detail in Section 4.2.4.

4.2.3 Stub and Grid Spacer Region Temperatures

There were only two thermocouples located in the stub region (see Figure 2.1.4), at approximately the mid-point axially. The remaining thermocouples were located on the lower boundary of the crust region (FRS1000 and FRK1044) and at the grid spacer (GSK0013 and GSK0018).

The cladding temperatures for levels 2 and 3 and the “other structure” component temperatures for level 1 for all rings are compared with measured data in

Figure 4.2.13. Since the lower thermocouples at this level (GSK0013 and GSK0018) were fastened to the grid spacer, the temperatures indicated by them were more representative of the heat sink at the bottom of the test section than of the cladding temperatures further up in the stub region. This is shown by the large differences in temperature measured between thermocouple GSK0013 and thermocouples FRK0514 and FRS1000 in Figure 4.2.16. The OS temperatures in the inside two rings increased with time, while the ring three OS temperatures remained low. These effects were due to the COR boundary conduction model, as discussed in detail in Section 4.1.3.

The calculated temperatures at level 4 for all rings are compared with measured temperatures in Figure 4.2.14. Calculated temperatures here were approximately 500K higher than measured data. This was approximately the same temperature difference seen in the stub region for the MP-1 assessment (see Section 4.1.3), and shows the lack of an axial temperature gradient in the stub region calculated temperatures.

The calculated temperatures at levels 5 and 6 for all rings are compared with measured temperatures in Figure 4.2.15. The thermocouples used for comparison at this level were located on the bottom surface of the crust region. Therefore, although the calculated temperatures matched the data quite well at this level, it is believed that they are actually high, since the measured temperatures were probably higher than those experienced in the cladding slightly below the bottom surface of the crust. However, the temperature discrepancy was probably not great, due to axial heat conduction through the cladding.

The temperatures for all axial levels in ring one of the stub region are shown in Figure 4.2.16. Again, there was very little axial temperature gradient in this region, due to axial conduction in the cladding component. Stub region temperatures in rings two and three (see Figures 4.2.17 and 4.2.18, respectively) were similar to those in ring one.

Figure 4.2.1. MP-2 base case: particulate debris temperatures versus measured temperatures at axial levels 10 (top) and 11 (bottom) for all rings.

Figure 4.2.2. MP-2 base case: particulate debris temperatures versus measured temperatures at axial levels 12 (top) and 13 (bottom) for all rings.

Figure 4.2.3. MP-2 base case: particulate debris temperatures versus measured temperatures at axial levels 14 (top) and 15 (bottom) for all rings.

Figure 4.2.4. MP-2 base case: debris region particulate debris temperatures compared to measured temperatures in ring one.

Figure 4.2.5. MP-2 base case: debris region particulate debris temperatures compared to measured temperatures in ring two.

Figure 4.2.6. MP-2 base case: debris region particulate debris temperatures compared to measured temperatures in ring three.

Figure 4.2.7. MP-2 base case: crust temperatures versus measured temperatures at axial level 7 for all rings.

Figure 4.2.8. MP-2 base case: crust temperatures versus measured temperatures at axial level 8 for all rings.

Figure 4.2.9. MP-2 base case: crust temperatures versus measured temperatures at axial level 9 for all rings.

Figure 4.2.10. MP-2 base case: crust region cladding temperatures compared to measured temperatures in ring one.

Figure 4.2.11. MP-2 base case: crust region cladding temperatures compared to measured temperatures in ring two.

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Figure 4.2.12. MP-2 base case: crust region cladding temperatures compared to measured temperatures in ring three.

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Figure 4.2.13. MP-2 base case: stub region temperatures versus measured temperatures at axial levels 1, 2 and 3 for all rings. "Other structure" component temperatures given for level 1, cladding component temperatures for levels 2 and 3.

Figure 4.2.14. MP-2 base case: stub region cladding temperatures versus measured temperatures at axial level 4 for all rings.

Figure 4.2.15. MP-2 base case: stub region cladding temperatures versus measured temperatures at axial levels 5 and 6 for all rings.

Figure 4.2.16. MP-2 base case: stub region cladding temperatures compared to measured temperatures in ring one.

Figure 4.2.17. MP-2 base case: stub region cladding temperatures compared to measured temperatures in ring two.

Figure 4.2.18. MP-2 base case: stub region cladding temperatures compared to measured temperatures in ring three.

4.2.4 Axial and Radial Temperature Profiles

Many of the thermocouples placed in the MP-2 test bundle were aligned along the centerline, allowing the measurement of axial temperature profiles through time. There were also two locations axially where the radial temperature profile was measured (see Figure 2.1.4). The radial and axial temperature profiles are compared to MELCOR results in this section.

The calculated centerline axial temperature profiles in the test bundle are compared to the measured temperature profiles for 11000 and 16000 seconds in Figure 4.2.19. At 11000 seconds, the MELCOR-calculated debris region temperatures were approximately 500K below measured temperatures (this was discussed in Section 4.2.1). The temperature gradients in the crust and debris regions at 11000 seconds were close to the measured temperature gradients in those regions. These gradients were relatively flat within each region, with large temperature differences between regions. The large differences were due to the power deposition, which depended on the region-wise UO_2 masses. The stub region calculated temperature gradient was relatively flat, while the measured gradient was much steeper. This steep gradient was due to the large grid spacer at the bottom of the test bundle, and was discussed in Section 4.1.3. By 16000 seconds, the temperature profile in the debris region had become more peaked. The measured temperature data was unreliable above 2600K, due to electrical and thermal conductivity effects in the thermocouple wire. The crust and stub region calculated temperature profiles were still relatively flat, due to axial heat conduction calculated for the cladding component.

The calculated and measured centerline axial temperature profiles for 18000 and 19500 seconds are shown in Figure 4.2.20. By 18000 seconds, the thermocouples in the debris and crust regions had all failed or become unreliable because of melting and/or conductivity effects. The calculated temperature profiles at that time were slightly more peaked in the debris region and between the crust and stub regions. At 19500 seconds, the debris region temperature profile was even more peaked, with the temperature profile in the crust and stub regions unchanged from 18000 seconds. It was shortly after 19500 seconds that the upper two axial levels in the debris region completely melted.

Measured temperature profiles along the outside surface of the tantalum liner have been used to verify temperatures calculated by the DEBRIS code for the debris region after the thermocouple readings became unreliable [3]. This was not possible for the MELCOR code, for the following reasons. In the MP-2 test bundle, the bottom edge of the tantalum liner was in direct contact with the steel grid spacer, which was itself in direct contact with the cooling jacket (see Figure 2.1.2). This provided a very effective heat transfer path axially through the tantalum liner and grid spacer out of the test bundle. Figure 4.2.21 shows the axial temperature profile along the tantalum liner at 16000 seconds. Rather than showing a large temperature difference between the debris and crust regions, as is shown in the centerline temperature profiles in Figure 4.2.19, there was a constant temperature drop going down the liner towards the grid spacer. The heat conduction along the liner raised liner temperatures in all but the hottest axial location. By not modeling axial heat conduction in the

tantalum liner, MELCOR temperature predictions for this heat structure were not very accurate. Note that the inability of MELCOR to calculate two-dimensional heat transfer in heat structures limits its effectiveness in modeling experiments with significant two-dimensional heat structure heat transfer effects.

The calculated and measured radial temperature profiles (in the center of the debris bed axially) at 11000 and 16000 seconds are shown in Figure 4.2.22. At 11000 seconds, the calculated radial temperature profile in the debris bed was slightly less peaked than the measured profile. The calculated temperature drop in the three outer heat structure layers was very close to the measured temperature drop there. By 16000 seconds, the measured debris bed temperatures were unreliable (due to thermocouple conductivity effects above 2600K); the debris temperature profile was still relatively flat, but had increased to almost 2700K. The heat structure radial temperature profile at this time was predicted correctly.

The calculated and measured radial temperature profile (in the center of the debris bed axially) at 19500 seconds is shown in Figure 4.2.23. At this time, the debris bed had reached the UO_2 melting temperature of 3113K. Since the eutectics model was deactivated in the base case model, this means that the ZrO_2 in that part of the debris bed had completely melted by 19500 seconds (the melting temperature of ZrO_2 in MELCOR is 2990K). The radial temperature profile in the heat structures at this time was predicted accurately in the outer three layers. The calculated tantalum liner temperature at this time was probably not accurate, since the peak in the axial temperature profile had probably moved lower than the debris region mid-point by that time.

The radial temperature profile in the middle of the crust region is compared to the measured radial profile at 11000 seconds in Figure 4.2.24. The measured temperature profile was quite flat in the crust region, due to radial heat conduction through the crust material. In MELCOR, conduction between radial rings is not modeled. However, the radial power peaking factors for the entire test bundle were biased towards the outer ring, due to the influence of debris region radial peaking factors (see the discussion of peaking factor input in Section 3.1.2). These two effects probably offset each other and resulted in the relatively flat calculated radial temperature profile in the crust region. Note that the measured tantalum liner temperature is much higher than the calculated temperature at that position, due to axial heat conduction down the liner (which was not modeled in MELCOR).

The crust region radial temperature profile is compared to the measured radial profile at 19500 seconds in Figure 4.2.25. At this time, most of the thermocouples in this region had failed due to large scale melting of the crust material at approximately 2200K, the melting temperature of zircaloy. The calculated temperatures show that the inner ring was melting while the outer rings were not (with the exception of the Ag and In, which had melted and candled out at a much lower temperature). However, the radial temperature profile was still relatively flat across the crust region. In the heat structures, the temperature profile was predicted accurately outside the Ta liner.

Figure 4.2.19. MP-2 base case: centerline axial temperature profiles at 11000 and 16000 seconds.

Figure 4.2.20. MP-2 base case: centerline axial temperature profiles at 18000 and 19500 seconds.

Figure 4.2.21. MP-2 base case: axial temperature profiles of the outer surface of the tantalum liner at 16000 seconds.

Figure 4.2.22. MP-2 base case: radial temperature profiles at 11000 and 16000 seconds in the midpoint of the debris region.

Figure 4.2.23. MP-2 base case: radial temperature profiles at 19500 seconds in the midpoint of the debris region.

Figure 4.2.24. MP-2 base case: radial temperature profiles at 11000 seconds in the midpoint of the crust region.

Figure 4.2.25. MP-2 base case: radial temperature profiles at 19500 seconds in the midpoint of the crust region.

4.2.5 Final Material Configurations

In comparison to MP-1, there was more melting and relocation in the MP-2 experiment. Post-test radiographs of the test bundle showed a flat surface at an elevation of approximately 21 cm, about halfway up in the debris region [3]. This was the surface of a formerly molten pool of ceramic material that relocated to the bottom of the debris region. The radiograph also showed a semi-circular region where the molten ceramic pool had eroded into the crust region. This region extended to an elevation of approximately 12 cm, or about halfway into the crust (from the top). Finally, an agglomeration of material was observed at the bottom of the stub region; this material extended up to an elevation of about 3 cm.

The initial material configuration in the MP-2 MELCOR model is shown in Figure 4.2.26. This figure shows configurations for all rings summed together at each axial level. The materials in the particulate debris component are shown in the upper half, while the fuel and cladding components are shown in the lower half. Most of the core materials input in the MP-2 MELCOR model are shown in this figure, with the exception of the steel in the other structure component, which was used to model the grid spacer at the bottom of the test bundle.

The final material configuration calculated by MELCOR for MP-2 summed over all rings is shown in Figure 4.2.27 (this figure can be compared to the original material locations in Figure 4.2.26). The final material configurations for rings one, two and three are shown in Figures 4.2.28– 4.2.30, respectively.

In the debris region (starting at 13.5 cm elevation), the ZrO_2 was calculated to have melted and relocated first, ending up in the lower two levels of this region and partially in the crust and stub regions. This was due to the default melting point of ZrO_2 (2990K) being lower than that of UO_2 (3113K). Figure 4.2.27 shows that the upper surface of the debris in the debris region was at the top of level 12, at an elevation of 21.75 cm. This is slightly higher than the debris surface elevation of 21 cm that was indicated in the post-test radiograph. There was no information given in the radiograph concerning the material compositions in various parts of the molten pool at this elevation. The relocation of ZrO_2 was calculated by MELCOR using logical and refreezing considerations; surface tension effects which may have been important in MP-2 were not considered. The material composition in various regions will not be known until a PIE report has been published.

Figure 4.2.27 shows that a substantial amount of crust material relocated from the crust region, which was originally fully blocked. The average “upper surface” of the crust is difficult to pinpoint from the results in Figure 4.2.27. However, a corresponding plot made for the inner ring (see Figure 4.2.28) shows that only 50% of the material in level 9 remained at the end of the problem, while the two lower crust levels were fully blocked. This indicates that the crust surface in the inner ring was located at the top of level 8, at approximately 12.3 cm. This is close to the upper crust surface elevation of 12 cm indicated by the radiograph. It is interesting that the uppermost crust level was not fully blocked at the end of the problem. Particulate debris was prevented from relocating there by the artificially high intact porosities used in the crust region (see Section 3.1.2). However, much of the molten ZrO_2 was

also prevented from relocating into the crust region by the blockage of the lower-most debris region level (level 10). Inspection of the masses residing in each region at the end of the problem indicates that about 11% of the debris region ZrO_2 relocated to other regions, while virtually none of the UO_2 relocated out of the debris region. The relocation of ZrO_2 into lower regions had to have occurred between the time the control poison in the crust melted (freeing some space in the crust region) and the time the lower-most debris region level was blocked with refrozen ZrO_2 .

Figure 4.2.27 shows that all of the control poison and some Zr and ZrO_2 relocated to the bottom of the test bundle. In addition, some of the Zr and ZrO_2 was refrozen onto fuel rods in the stub region. Since the eutectic model was not enabled in the base case input (see Section 3.1.2), the crust region materials melted and relocated individually. Of all the materials in the crust region blockage, the control poison material had the lowest default melting point in MELCOR (1075K), and so it was the first material to melt and relocate from the crust region. It relocated all the way to the bottom of the test bundle because the cladding components at all levels had already heated up to the control poison melting temperature (probably because of axial heat conduction). Since the crust region temperatures never exceeded 2500K (see Figures 4.2.10– 4.2.12), the ZrO_2 refrozen onto the cladding in the stub region had to have come from the debris region. Had this material come from the crust region, it probably would have ended up at the bottom of the bundle, for the same reason the control poison ended up there. Qualitatively, the material at the bottom of the test bundle was calculated to be made up mostly of control poison and zircaloy, with small portions of ZrO_2 and UO_2 (the UO_2 relocated from the crust region, not from the debris region). This compares well with the PIE, which reported the agglomeration at the bottom of the test bundle to be made up of “metallic” material.

The calculated volume fraction at level 2 occupied by relocated material (in contrast to fuel and clad that was there initially) was close to 20% summed over all rings. This material was spread over all three rings (see Figures 4.2.28– 4.2.30), with slightly more relocated material in ring two than in the other rings. This puts the calculated height of the debris pile in the bottom of the test bundle at the top of level 2, at 2.0 cm. This compares with a height of 3 cm shown in the radiograph. Note that the height of the debris pile is highly dependent on its shape, and that MELCOR fills cells with debris from the bottom up. If MELCOR allowed debris to fall into a “pile”, it could be possible that the height of this pile would be taller than 2.0 cm.

Figure 4.2.26. MP-2 base case: initial material distribution (at 0.0 seconds) in the MELCOR model in the particulate debris (top) and the fuel and clad (bottom) components.

Figure 4.2.27. MP-2 base case: final material distribution calculated by MELCOR at 20000 seconds in the particulate debris (top) and the fuel and clad (bottom) components.

Figure 4.2.28. MP-2 base case: final material distribution in ring one calculated by MELCOR at 20000 seconds in the particulate debris (top) and the fuel and clad (bottom) components.

Figure 4.2.29. MP-2 base case: final material distribution in ring two calculated by MELCOR at 20000 seconds in the particulate debris (top) and the fuel and clad (bottom) components.

Figure 4.2.30. MP-2 base case: final material distribution in ring three calculated by MELCOR at 20000 seconds in the particulate debris (top) and the fuel and clad (bottom) components.

Chapter 5

Sensitivity Studies

A number of sensitivity studies were done to investigate the influence on results of varying all of the non-default options and some of the other input options that were used in the MP-1 base case model. Many of the non-default options used in the model were the result of preliminary versions of these sensitivity studies. The focus of most of the sensitivity studies was the core package in MELCOR, because of the emphasis the MP assessment placed on this package.

The studies reported in this chapter are grouped into four main areas. These areas are: general core package input options, heat structures package studies, COR and CVH nodalization for MP-1, and time step and machine dependency studies. Some of the sensitivity studies were performed with the MP-1 experiment model, while some were performed with MP-2.

5.1 General COR Package Sensitivity Studies

5.1.1 Axial Conduction

In the MELCOR COR package, axial conduction is calculated between *like components* in axially adjacent cells, except for the particulate debris component. Axial heat conduction was a very important heat loss mechanism in MP-1 and MP-2 because of the steel grid spacer at the bottom of the test bundle, which provided a large heat sink and a direct heat loss path to the cooling jacket (see discussion in Section 4.2.4). Although the full heat transfer path through the grid spacer to the cooling jacket was not modeled in MELCOR, axial conduction still influenced component temperatures in hot regions of the bundle. For this sensitivity study, the axial conduction model was deactivated using the CORTST01 record in MELCOR input. This study was run with the MP-2 input problem.

Disabling axial conduction resulted in much higher temperatures in the debris and crust regions, as shown in Figures 5.1.1 and 5.1.2, respectively. Debris region temperatures were almost 400K higher, while crust region temperatures were up to 750K higher than measured values. The elevated temperatures in these regions were caused by the lack of heat conduction down through the fuel and cladding components into the stub region. This also lowered stub region temperatures by approximately

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450K (see Figure 5.1.3). The debris region temperatures were elevated not because of the lack of axial heat conduction directly between debris and crust region components (there is no axial heat conduction in the particulate debris component), but because the crust region temperatures were much higher, thereby decreasing the radiation heat transfer between the debris and crust regions. This effect was much more prominent in the lower portions of the debris region.

The MELCOR calculation for this sensitivity study did not run to completion. The calculation died when large-scale component failure occurred. This caused calculational difficulties in the CVH package. This problem is described more fully in Section 7.3.

5.1.2 Candling Model Options

In previous versions of MELCOR, molten conglomerate debris was held up by a minimum intact or oxidized mass (input on records COR00008 and SC1131) in that component. One of the modifications made as part of this assessment task was to allow individual materials to candle out of the conglomerate debris residing on a particular component. Both options are now available in MELCOR, and are adjusted using the IDRP element (element number 5) on the CORTST01 record. In the base case model for MP-2, IDRP=2 was used to allow individual materials to candle from the conglomerate debris (the default value of this parameter in MELCOR is unchanged, which results in molten material holdup in some cases). For this sensitivity study, two cases were performed. In the first case (candling-off), the candling model was disabled entirely by setting IDRP=1 on record CORTST01. For the second case in this study (candling-default), the default candling model activation option (IDRP=0) was used. For a more detailed discussion of the various candling model options, see Section 7.2 and [8].

The final material locations for the candling-off case and for the candling-default case are shown in Figures 5.1.4 and 5.1.5, respectively. Using the default candling model and disabling the candling model altogether both resulted in more material being held in the cladding component in the crust region. In addition, turning off the candling model held all molten debris material in the debris region.

Both cases showed small component temperature decreases in the crust and stub regions. For example, temperatures in level 8 of the crust region are shown in Figure 5.1.6. The temperature differences were due to the increased thermal mass present in the crust (due to the absence of candling), which held the crust temperatures down.

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Figure 5.1.1. MP-2 axial conduction sensitivity study: debris region temperatures at axial level 10 with and without axial heat conduction in the COR package.

Figure 5.1.2. MP-2 axial conduction sensitivity study: crust region temperatures at axial level 9 with and without axial heat conduction in the COR package.

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Figure 5.1.3. MP-2 axial conduction sensitivity study: stub region temperatures at axial level 4 with and without axial heat conduction in the COR package.

Figure 5.1.4. MP-2 candling model sensitivity study: final material configurations with the candling model disabled. Particulate debris and fuel and cladding components are shown in the upper and lower portions of the figure, respectively.

Figure 5.1.5. MP-2 candling model sensitivity study: final material configurations using the default candling model option. Particulate debris and fuel and cladding components are shown in the upper and lower portions of the figure, respectively.

Figure 5.1.6. MP-2 candling model sensitivity study: level 8 (crust region) cladding temperatures compared to base case and measured values.

5.1.3 Candling Model Refreezing Heat Transfer Coefficient

Material refreezing did not play a very major role in the MP experiment MELCOR models. There was almost no material relocation in the MP-1 experiment. In MP-2 the only significant material candling was done by control poison materials, and by the time they candled the underlying material was at a high enough temperature where little refreezing took place. The only materials affected by the candling refreezing heat transfer coefficients, therefore, were ZrO_2 and Zr. For this sensitivity study, the refreezing heat transfer coefficients on input record COR00005 were set to 50% and 150% of their default values of 1000 W/mK. The MP-2 experiment model was used for this study.

There were no discernable differences in component temperatures in any region for both cases of this study, and there were only slight differences in final material configurations. Figure 5.1.7 shows the material configurations at 20000 seconds for the 150% case (this figure can be compared with the corresponding base case material configurations in Figure 4.2.27). The only significant differences were in ZrO_2 and Zr. There was slightly more ZrO_2 left in the debris and crust regions, due to the enhanced refreezing caused by an increased heat transfer coefficient. Likewise, less Zr candled into the stub region from the crust region.

Although the particular refreezing heat transfer coefficients used in the candling model did not affect results very much, the candling model itself did have an effect; this is discussed in Section 5.1.2.

5.1.4 Convection Heat Transfer Coefficient

For this sensitivity study, the forced and free convection heat transfer coefficients calculated by the COR package were varied by $\pm 50\%$. This was done by modifying the multipliers used in convection heat transfer correlations in sensitivity coefficients 1212, 1214, 1221, 1222, 1231 and 1232.

Varying the convection heat transfer coefficients had no effect on the calculated temperatures in MP-1. This was probably due to the closed system, where radiation heat transfer dominates over convection heat transfer.

Figure 5.1.7. MP-2 candling refreezing heat transfer coefficient sensitivity study: final material configurations for the 150% case. Particulate debris and fuel and cladding components are shown in the upper and lower portions of the figure, respectively.

5.1.5 Core Component View Factors

The view factors used to calculate radiation heat transfer between core package components were left at their default values of 0.25 in the MP-1 and MP-2 MELCOR base case models. These parameters can be important if radiation heat transfer is a significant contributor to heat loss from the test bundle. In the two MP-2 cases run for this sensitivity study, the view factors were set to 0.1 and 0.5. View factors are set using input record COR00003.

Adjusting the view factors had a significant effect on calculated component temperatures. Generally, increasing the view factors in heated components caused those components' temperatures to decrease, due to enhanced radiation heat transfer, and vice versa for decreasing component view factors. For example, Figures 5.1.8 and 5.1.9 show particulate debris at level 12 and cladding temperatures at level 8, respectively. In the particulate debris, decreasing the view factors to 0.1 increased temperatures by approximately 300K, while increasing the view factors to 0.5 decreased temperatures by about 200K. In the crust, temperatures were increased by 200K for decreased view factors, and were decreased by 50K for increased view factors. In both regions, the effect of decreasing the view factors by 60% (from 0.25 to 0.1) had a larger effect on temperatures than raising the view factors by 100% did. This shows that radiation heat losses from heated components were already close to their maximum. Stub region temperatures for both cases were much like those in the crust region, and are not shown here.

The case with decreased radiation view factors did not run to completion, but rather died just before 18000 seconds. This was caused by a control volume filling up with core debris. This situation is not allowed by the CVH package, and results in the termination of a MELCOR calculation.

The final material configurations for the 0.5 view factors case are shown in Figure 5.1.10. This figure shows that there was much less melting and relocation in this case than there was in the base case problem (see Figure 4.2.27.) Most of the crust region material was in place (except for the control poison material), and only some of the ZrO_2 in the upper-most debris region cells relocated.

Figure 5.1.8. MP-2 view factors sensitivity study: level 12 (debris region) cladding temperatures compared to base case and measured values.

Figure 5.1.9. MP-2 view factors sensitivity study: level 8 (crust region) cladding temperatures compared to base case and measured values.

Figure 5.1.10. MP-2 view factors sensitivity study: final material configurations for the 0.5 view factors case. Particulate debris and fuel and cladding components are shown in the upper and lower portions of the figure, respectively.

5.1.6 Eutectics Model

In the MP-1 and MP-2 base case input models, the eutectics model was not activated. This was done because large-scale eutectics effects were not observed in either experiment [2, 3]. In this sensitivity study, the MP-2 model was rerun with the eutectics model activated. The eutectics model is activated on input record COR00006.

The eutectics model in MELCOR models the behavior of material residing in the conglomerate debris on any component (see Appendix A for a discussion of conglomerate versus particulate debris in MELCOR). When the eutectics model is activated, the conglomerate debris is modeled as a single material with a single melting point. The eutectic melting point (corresponding to the solidus temperature in a true eutectic mixture) is calculated as a mass-weighted average of the melting points of individual materials residing in the mixture. The eutectic mixture melts and relocates as a single material, rather than behaving as individual materials.

Eutectic interactions did not dominate material behavior in the MP experiments [2, 3]. In the debris region, significant ZrO_2 melting occurred before any attack of the UO_2 , and such attack was limited. In the crust region, materials melted and relocated individually at their respective melting points, rather than relocating after the eutectic temperature was reached.

Activating the eutectics model lowered temperatures by approximately 75K in the crust region (see Figure 5.1.11). Enabling the eutectics model raised the effective melting point of the conglomerate debris mixture, which prevented the relocation of control poison material at its relatively low melting point (1075K). Retaining all the material in the crust region increased the thermal inertia of the crust, slowing its temperature rise. Temperatures in the stub and debris regions were also decreased, in response to the crust temperatures.

The final material locations for this sensitivity study are shown in Figure 5.1.12. Enabling the eutectics model prevented large-scale melting in the crust region, resulting in no material candling into the stub region. Debris region temperatures were high enough to melt the ZrO_2 , which settled to the bottom of the debris region. Since the crust region remained unmolten, the molten debris region material could not get past the crust blockage, and therefore remained in the debris region. Using the eutectics model resulted in poorer agreement in final material configurations because the materials in the crust region of MP-2 acted as independent materials. This was because the crust was formed by pressing together a mixture of component powders rather than melting these materials into a mixture which then solidified.

Note that the ZrO_2 melted as an individual material because it resided in the particulate debris component, which is considered an *intact* material for eutectic formation purposes; that is, when the eutectics model is active, materials in particulate debris melt individually, while materials in the conglomerate debris melt as eutectic mixtures (again, see Appendix A for a discussion of conglomerate versus particulate debris in MELCOR).

mp2
mp20C

11/04/93 15:46:09 MELCOR IBM-RISC

Figure 5.1.11. MP-2 eutectics model sensitivity study: level 8 (crust region) cladding temperatures compared to base case and measured values.

Figure 5.1.12. MP-2 eutectics model sensitivity study: final material configurations with the eutectics model activated. Particulate debris and fuel and cladding components are shown in the upper and lower portions of the figure, respectively.

5.1.7 Minimum Component Mass

The minimum component mass and minimum component mass for temperature control are set in sensitivity coefficient array 1502. These parameters are the minimum component mass below which mass can be discarded and the minimum mass used to limit temperature changes in any particular time step. The default values of these parameters (10^{-3} and 10.0 kg, respectively) are meant for modeling full-size reactor cores, and were adjusted (to 10^{-7} and 10^{-6} kg, respectively) in the MP-1 and MP-2 base case models to account for the smaller component masses in those models. In this study, default values for these parameters were used with the MP-1 input model.

The debris region temperatures were not affected by this change, and are therefore not shown here. The crust and stub region temperatures were affected, however. The crust and stub region temperatures for ring one are shown in Figures 5.1.13 and 5.1.14, respectively. The crust region peak temperatures in this study were approximately 125K above base case values, while the stub region peak temperatures were approximately 75K below base case values. Inspection of the output file for this study showed that no mass was discarded from the problem, because none of the component masses were below 10^{-3} kg. All of the component masses were below 10.0 kg, however, and so the differences in crust and stub temperatures can be attributed to the temperature control done in the COR package. Allowing components to undergo large temperature changes during a MELCOR calculation can lead to inaccuracies in heat transfer, which can show up in component temperatures as they did in this study. Note that because the COR package explicitly balances the actual energy transferred between components, these differences did not show up as energy errors.

5.1.8 Particulate Debris Diameter

The diameter of particulate debris determines the debris surface areas used for heat transfer and oxidation (this parameter is input on record CORijj04). In the MELCOR base case models for MP-1 and MP-2, the debris diameter was set to 2.0 mm, which was reported as the mean diameter in a range of 1–5mm in [2]. In this sensitivity study, the MP-1 problem was rerun with the debris diameter increased and decreased by a factor of two.

The component temperatures for both cases of this sensitivity study and in all regions of the test bundle were all identical to the base case results, and therefore are not shown here. Debris diameters did not influence results probably because there was little convection heat transfer (due to the lack of flow through the MP-1 test bundle) and no oxidation of debris (due to the lack of steam or oxygen).

Figure 5.1.13. MP-1 minimum component mass sensitivity study: level 5 crust region temperatures.

Figure 5.1.14. MP-1 minimum component mass sensitivity study: level 2 stub region temperatures.

5.2 Heat Structure Package Studies

5.2.1 Gamma Heating

In addition to the fission power heating taking place during the MP-1 and MP-2 experiments, there was also a small amount of gamma heating. This heat was deposited in all structures, but was neglected in the base case models because the heating rates were considered low enough to be insignificant. In this sensitivity study, gamma heating input was implemented in the MP-2 model according to heating rates obtained from the personnel performing the MP experiments¹. These heating rates are summarized in Table 5.2.1. For reference, MP-2 fission heating rates for UO₂ for each of the three regions are also given in the bottom portion of the table.

There were slight changes in component temperatures due to gamma heating in the heat structure materials, but these changes were insignificant. This can be attributed to the small magnitude of the gamma heating rates, compared to the fission heating rates for the MP-2 experiment.

Table 5.2.1. MP-2 gamma heating sensitivity study: gamma heating rates in heat structure materials.

Material	Heating rate (W/MW/kg)
W	.1419
ThO ₂	.1658
Ta	.1486
ZrO ₂	.1072
Al	.1093
SS	.1072
Debris UO ₂	4590
Crust UO ₂	1790
Stub UO ₂	1410

¹Personal communication with Ronald Gasser, Sandia National Laboratories, October 1993.

5.2.2 Helium Gap Between Heat Structure Layers

The individual layers of insulation between the fuel regions and cooling jackets in the MP-1 and MP-2 test bundles did not fit together without gaps. Some space was left in these layers to allow fitting the experimental packages together. The gaps that were left were filled with helium, along with the open regions in the test bundle. These gaps were neglected in the MP-1 and MP-2 base case input models. In this sensitivity study, helium gaps were input to the MP-2 model to investigate their influence on bundle temperatures.

In this study, helium gaps were inserted between all heat structure layer interfaces inside of the ZrO_2 layer in the MP-2 input model (see Table 3.1.4 for a description of heat structure layers used in the MP-1 and MP-2 base case input models). In addition, the ThO_2 layer in the debris region was split into two layers, between which another helium gap was modeled. The total thicknesses of the helium gaps in the debris region and in the crust and stub regions were 0.138 cm and 0.133 cm, respectively. These gaps compare to the total heat structure thickness of 4.8 cm, for a maximum of 3% helium gap.

As expected, inserting helium gaps in the heat structure layers increased component temperatures inside the test bundle. Temperatures in most regions were raised by about 150K; for example, Figures 5.2.1 and 5.2.2 show temperatures at levels 12 (debris region) and 8 (crust region), respectively. This problem did not run to completion, however, because massive relocation resulted in the CVH problem described in Section 7.3.

5.2.3 Heat Structure Outer Boundary Temperature

The MP-1 and MP-2 test bundles were both surrounded by cooling jackets, through which water was circulated to cool the experiments. The inside surface of the cooling jacket was instrumented with thermocouples, and it was the data from those thermocouples which were used as an outer boundary temperature in the MELCOR base case models. For this sensitivity study, the heat structure outer boundary temperatures in the MP-1 base case model were increased and decreased by 50K. For the 50K decrease case, the maximum of 300K and the instrumented boundary temperature minus 50K was used, to avoid a temperature below freezing in the heat structure. A value of 50K was used because the uncertainty in outer boundary temperatures in MP-1 and MP-2 was relatively low.

Both cases of this study had very little influence on core component temperatures. The radial temperature profiles at 9400 seconds at the debris and crust region mid-points, in Figures 5.2.3 and 5.2.4, show that the 50K differences on the outer heat structure boundaries became insignificant towards the inside surfaces of the heat structures. The small differences had little effect on temperatures inside the bundle.

Figure 5.2.1. MP-2 helium gap sensitivity study: level 12 (debris region) particulate debris temperatures compared to base case and measured values.

Figure 5.2.2. MP-2 helium gap sensitivity study: level 8 (crust region) cladding temperatures compared to base case and measured values.

Figure 5.2.3. MP-1 HS outer boundary temperature sensitivity study: level 12 (debris region) radial temperature profile.

Figure 5.2.4. MP-1 HS outer boundary temperature sensitivity study: level 6 (crust region) radial temperature profile.

5.3 COR and CVH Nodalization

The COR nodalization in the MP-1 base case input model used 3 rings and 13 axial levels (6 in the debris region, 3 each in the crust and stub regions, and 1 for the lower plenum), and the CVH nodalization used 3 control volumes and 2 flow paths (see Section 3.1 for a more detailed description of the base case model nodalization). The nodalization chosen for the base case model was a compromise between accuracy and problem run time. A sensitivity study was done where coarse and fine nodalizations of the MP-1 test section were used instead.

The fine nodalization study used 3 core rings and 25 axial levels (12 in the debris region, 6 each in the crust and stub region, and 1 for the lower plenum), and 9 control volumes (3 in each region). The ring nodalization was not changed because of the difficulty of splitting individual fuel rods in the crust and stub regions between multiple core rings. The number of radial boundary heat structures was also increased, as required by the core package, to match the number of core axial levels. The finer nodalization resulted in an increase in execution time of approximately a factor of seven.

The coarse nodalization study used one core ring and just 4 axial levels (one each for the debris, crust and stub regions and one for the lower plenum), and just one CVH control volume. The number of heat structures was also reduced appropriately. The reduced nodalization resulted in a decrease in execution time of approximately a factor of 5.

The CVH atmosphere temperatures in all regions for both studies are compared to base case results in Figure 5.3.1. Note that a single control volume was used for the entire test section in the coarse nodalization study. Figure 5.3.1 shows that the fine nodalization CVH temperatures for all regions were close to and surrounded the base case results, as expected. The atmosphere temperature for the coarse nodalization study (for the entire test bundle) was between the debris and crust region CVH temperatures, and was approximately 250K below the base case debris region CVH temperature. The elevated CVH temperatures in the crust and stub regions of the coarse nodalization study affected the heat transfer in these regions, as will be shown later.

The debris region temperatures for the fine nodalization study were slightly elevated in lower portions of the region. For example, Figure 5.3.2 shows that debris temperatures at level 10 were approximately 100K above base case temperatures. In lower and upper portions of the debris region, fine nodalization temperatures were closer to base case values. These variations correspond fairly closely to the CVH temperature variations shown in Figure 5.3.1; CVH temperatures for the fine nodalization case are almost 200K above base case temperatures in the middle of the bundle, and are closer to base case temperatures in the upper and lower portions of the debris region. The debris region temperatures for the coarse nodalization case, also shown in Figure 5.3.2, were lower than base case temperatures by approximately 150K. This is also consistent with differences in CVH temperatures between the coarse nodalization and base cases for the debris region.

The crust region temperatures in ring one for both nodalization studies are com-

pared to base case and measured temperatures in Figure 5.3.3. As expected, the coarse nodalization crust temperatures were higher than the base case temperatures, again because of the control volume consolidation. In fact, the higher temperatures in the coarse nodalization study caused melting and failure of the cladding material in the crust region. The crust temperatures in ring one for the finer nodalization study were approximately 100K below the base case temperatures, but the trends followed the base case data. The decreased temperatures were the result of the lower control volume temperatures in this region for the fine nodalization study.

The stub region temperatures for the fine nodalization case were slightly above base case temperatures, again because of the slightly higher CVH temperatures in that region in the fine nodalization case. The stub region temperatures for the coarse nodalization case were substantially higher, due to the control volume consolidation.

5.4 Machine Dependency and Time Step Studies

MELCOR is a very portable code, running on many different computer platforms of both 32-bit and 64-bit architectures. Comparing code results across these platforms can reveal both machine dependencies and general coding problems [11]. Also, the MELCOR code contains both global time step control and package-specific time step subcycling. The effectiveness of that time step control is sometimes suspect, and it is always a good idea to investigate a range of time steps for any particular input model. In this section, studies that were performed to investigate the dependency of MP results on computer platform and the time step control in MELCOR are discussed.

5.4.1 Machine Dependency Study

MELCOR 1.8 version OF was installed on six different computer platforms, where the MP-2 base case input model was run. These computer platforms and the acronyms used to refer to them in the plot legends are: DECstation 5000/240 (utx), Hewlett Packard 755 (hpw), IBM RS/6000 Model 550 (i60), SUN Sparcstation 2 (sun), Cray-YMP8/864 (ucs), and Gateway 486/DX2-50 (lah). The first four machines are 32-bit UNIX workstations, the fifth a 64-bit supercomputer, and the sixth an IBM PC compatible. The base case results for each of these machines were translated to one machine and cross-plotted to compare results. Note that the MP-2 base case and other sensitivity study calculations were performed on the IBM RS/6000 Model 550.

The core material temperature data for most components in all rings and axial levels were virtually identical over all computer platforms. For example, particulate debris component temperatures in ring one level 12 are shown in Figure 5.4.1, and cladding component temperatures in ring one at levels 8 (crust region) and 4 (stub region) are shown in Figures 5.4.2 and 5.4.3, respectively. The only discrepancy between machines was in the crust and stub regions at approximately 10000 seconds, where the cladding temperatures calculated by the IBM RS/6000 were slightly below the temperatures calculated on other platforms.

Figure 5.3.1. MP-1 nodalization sensitivity study: control volume temperatures compared to base case values.

Figure 5.3.2. MP-1 nodalization sensitivity study: particulate debris temperatures at axial level 10 (using the base case nodalization as a reference) in the debris region compared to base case and measured values.

Figure 5.3.3. MP-1 nodalization sensitivity study: ring one cladding temperatures in the crust region compared to base case and measured values.

There were very slight differences in final material configurations for most machines, but these differences exceeded 1% of total cell volume in only one case, that of the Cray run. The final material configurations for the Cray run are shown in Figure 5.4.4 (these can be compared to the base case final material configurations in Figure 4.2.27). The most noticeable difference was in the lower two axial levels of the crust region, where the Cray run showed the levels being closer in blocked volume fraction. There were also slight differences in the upper portion of the debris region, where there was slightly less UO_2 left in axial level 12 (starting at 19.0 cm) in the Cray run. These differences were all less than 5% of the total cell volumes, and they did not affect the blockage state (fully or partially blocked) in either case.

The cpu times required for the entire base case calculation on these machines are plotted in Figure 5.4.5. This figure shows that the SUN Sparc2 used the most cpu time, followed closely by the Gateway 486. The fastest platform in this case was the Cray YMP.

Table 5.4.1 shows the COR and CVH subcycle ratios on each platform and the execution time ratios. Note that the HP run time results were closer to the IBM results than in previous reports [10], due to a reduction in optimization chosen for the MELCOR code.

Table 5.4.1. CVH and COR subcycle ratios used by the six computers in the machine dependency sensitivity study. Also shown are the total execution times and the total execution times normalized to that of the Hewlett Packard 755.

Machine	Avg. No. of CVH Sub- cycles per Cycle	Avg. No. of COR Sub- cycles per Cycle	Total Execution Time (s)	Normalized Execution Time
Cray YMP8/864	1.026	3.135	11932.0	1.00
DECStation 5000/240	1.024	3.249	22865.4	1.92
Gateway 486/DX2-50	1.023	3.260	75849.0	6.36
HP 755	1.025	3.242	18608.7	1.56
IBM RS/6000 Model 550	1.060	2.914	16518.5	1.38
SUN Sparc 2	1.028	3.993	87199.4	7.31

Figure 5.4.1. MP-2 machine sensitivity study: particulate debris temperatures in axial level 12 (debris region).

Figure 5.4.2. MP-2 machine sensitivity study: cladding temperatures in axial level 8 (crust region).

Figure 5.4.3. MP-2 machine sensitivity study: cladding temperatures in axial level 4 (stub region).

Figure 5.4.4. MP-2 machine sensitivity study: final material configurations for the Cray case. Particulate debris and fuel and cladding components are shown in the upper and lower portions of the figure, respectively.

Figure 5.4.5. MP-2 machine sensitivity study: MELCOR execution times on all computer platforms.

5.4.2 Time Step Study

The maximum time step specified in the MP-2 base case input was 0.5 seconds. This produced a CVH subcycle ratio of 1.060 (little subcycling) and a COR package subcycle ratio of 2.914 (lots of subcycling). For this study, the MP-2 problem was run with maximum time steps of 0.1, 0.25, and 1.0 seconds.

Core component temperatures were generally insensitive to time step variations. There was a slight sensitivity in the upper-most debris region level (level 15), where the failure timing varied by several hundred seconds (see Figure 5.4.6). The crust region temperatures also varied slightly for the different time steps; for example, temperatures in level 8 for the 0.1 second and 1.0 second cases are shown in Figure 5.4.7. However, both the timing and temperature sensitivities were very slight, and had little effect on overall calculation results.

The subcycle ratios for each of the cases of this study are given in Table 5.4.2, compared to ratios from the base case calculation. The subcycle ratios show clear trends, generally increasing with increasing time steps. This data shows that the base case maximum time step was a reasonable choice, with an acceptably low CVH subcycle ratio. The COR package subcycle ratios were substantially lower with the reduced time steps, but this was not considered a problem since core component temperatures showed so little time step sensitivity.

Table 5.4.2. MP-2 timestep sensitivity study: CVH and COR package subcycle ratios.

Max time step	CVH subcycle ratio	COR subcycle ratio
0.1	1.002	1.049
0.25	1.032	1.695
0.5 (base case)	1.060	2.914
1.0	1.229	3.127

Figure 5.4.6. MP-2 time step sensitivity study: level 15 (debris region) particulate debris temperatures for the 0.1 second and 1.0 second cases, compared to base case (0.5 second) and measured values.

Figure 5.4.7. MP-2 time step sensitivity study: level 8 (crust region) cladding temperatures for the 0.1 second and 1.0 second cases, compared to base case (0.5 second) and measured values.

Chapter 6

Comparison With Other Codes

The only other codes to model the MP experiments so far have been DEBRIS for the MP-1 and MP-2 experiments and TAC2D for the MP-1 experiment [2, 3]. These modeling efforts were performed as both scoping and post-test calculations and were done by the same group performing the experiments.

TAC2D [13] is a standard two-dimensional heat transfer code used to model experiments at Sandia National Laboratories. It has models specific to the analysis of experiments, but has no models for material relocation.

The DEBRIS code [14] is designed to analyze late phase heat and mass transfer phenomena within a rubblized debris bed. The code solves mass, momentum and energy conservation equations in a two dimensional geometry to describe material melting and relocation in a debris environment. Some of the models in this code were specifically tailored to the geometry and phenomena in the MP experiments.

6.1 MP-1

The debris and crust region temperatures calculated by MELCOR for levels 11 and 6 are compared to the corresponding temperatures calculated by DEBRIS and measured temperatures in Figure 6.1.1. The DEBRIS-calculated temperatures for the debris region were below the measured temperatures between 7500 and 9000 seconds, as were the MELCOR-calculated temperatures for this region, although the discrepancy was smaller. In the crust region, the temperatures calculated by DEBRIS were very close to the measured values, while the MELCOR-calculated temperatures were slightly high later in the experiment. Peak temperatures calculated by the two codes at these levels were within 150K of each other.

Axial temperatures profiles for DEBRIS and MELCOR at 4800 and 9200 seconds are shown in Figures 6.1.2 and 6.1.3, compared to measured data. The MELCOR temperature profile was fairly close to the DEBRIS results and measured data at both times. However, these figures clearly show that DEBRIS was much better suited for calculating the axial temperature profile in the stub region. This was due to the true two-dimensional heat transfer modeling used in the DEBRIS code, compared to the quasi-two-dimensional modeling used in MELCOR. Note also that, at 9200 seconds,

DEBRIS calculated a higher temperature in the lower portions of the debris region which MELCOR did not calculate. This was due to the increased power density due to the melting and settling of UO_2 .

The radial temperature profiles calculated by MELCOR, DEBRIS and TAC2D are compared to measured profiles in Figures 6.1.4, 6.1.5, and 6.1.6, for 4200, 4800 and 9200 seconds, respectively. Figure 6.1.4 shows that temperatures calculated by MELCOR compared well with TAC2D calculations at 4200 seconds. MELCOR temperatures were also close to DEBRIS temperatures early in the experiment, as shown in Figure 6.1.5 for 4800 seconds. Note that all three codes calculated temperatures in the ZrO_2 liner that were much higher than measured temperatures there. This reinforces the assertion that measured temperatures were low here due to heat conduction through the thermocouple wires. The temperatures measured by all three codes are compared to measured temperatures for 9200 seconds in Figure 6.1.6. MELCOR-calculated temperatures were close to TAC2D and DEBRIS temperatures in the outer portions of the bundle, and were close to DEBRIS temperatures towards the bundle center. The TAC2D-calculated temperatures for inner portions of the bundle were probably in error, since TAC2D did not account for material melting.

Figures 6.1.1– 6.1.6 show that temperatures calculated by MELCOR for the MP-1 experiment are in reasonably good agreement with those calculated by TAC2D and DEBRIS, in most cases differing by less than 150K. These other codes achieved better agreement with the measured data than did MELCOR, but this was to be expected considering the two-dimensional modeling in TAC2D and DEBRIS and the relatively coarse modeling in MELCOR.

Figure 6.1.1. MP-1 code comparison study: temperatures calculated by MELCOR and DEBRIS for axial levels 11 (debris region) and 6 (crust region).

Figure 6.1.2. MP-1 code comparison study: centerline axial temperature profiles calculated by MELCOR and DEBRIS at 4800 seconds.

Figure 6.1.3. MP-1 code comparison study: centerline axial temperature profiles calculated by MELCOR and DEBRIS at 9200 seconds.

Figure 6.1.4. MP-1 code comparison study: radial temperature profiles in the debris region mid-plane calculated by MELCOR and TAC2D at 4200 seconds.

Figure 6.1.5. MP-1 code comparison study: radial temperature profiles in the debris region mid-plane calculated by MELCOR and DEBRIS at 4800 seconds.

Figure 6.1.6. MP-1 code comparison study: radial temperature profiles in the debris region mid-plane calculated by MELCOR, TAC2D and DEBRIS at 9200 seconds.

6.2 MP-2

There was much less data from other codes currently available for the MP-2 experiment than there was for MP-1. The only other code used to model MP-2 was DEBRIS; this modeling effort was performed by the same group that performed the experiment at Sandia National Labs. The data available from the DEBRIS analysis is in the form of axial temperature profiles at several times.

The axial temperature profiles calculated by MELCOR and DEBRIS at 9500 seconds are compared with measured data in Figure 6.2.1. As in the MP-1 analysis, the axial temperature gradient at the bottom of the core was captured in the DEBRIS analysis but not in the MELCOR calculations. The reason for this was the axial conduction and the lack of a heat conduction path from the OS component to the cooling jacket, as discussed in Section 4.1.4 of this report. The axial temperature profile in the crust and debris regions calculated by MELCOR had the correct shape, but the curve as a whole was below the DEBRIS-calculated temperatures as well as the measured temperatures in the debris region, by about 400K.

By 14000 seconds, the temperatures calculated by MELCOR for the crust region had also fallen below the DEBRIS-calculated values (see Figure 6.2.2), by about 200K. The temperature profile calculated by MELCOR in the debris region was less peaked than that calculated by DEBRIS as well. The peak temperature locations calculated by the two codes are close to each other, both falling close to the center of the debris region. However, centerline temperatures calculated by MELCOR were almost 500K lower than the DEBRIS temperatures; this may indicate an error in peaking factors used for the debris region in the MELCOR analysis.

Figure 6.2.3 shows the axial temperature profiles calculated by the two codes at 19000 seconds. The DEBRIS data shows a shift in peak temperature towards the bottom of the debris region. This was due to the melting and relocation of UO_2 to that location. Although in MELCOR, the distribution of fission power is based on UO_2 mass present in each core cell, the peaking factors were constant throughout this analysis. Due to the normalization procedure used in MELCOR, this resulted in a relative power shift towards the lower portions of the bundle. In particular, since the stub region peaking factors were greater than those in the crust region (see Table 3.1.2), the stub region temperatures were affected most by this relative power shift. This is shown in Figure 6.2.3, where MELCOR temperatures were higher than DEBRIS temperatures by a larger amount in the stub region than is shown in Figure 6.2.2 for 14000 seconds.

DEBRIS-calculated temperatures were also given for the Ta liner compared to measured data. However, since MELCOR did not account for the axial heat conduction from the Ta liner to the grid spacer at the bottom of the bundle, MELCOR-calculated Ta liner temperatures were nowhere near the measured data. Therefore, no comparison is made with DEBRIS temperatures in this location. Note that the modeling of two-dimensional heat transfer in heat structures is one area where codes like DEBRIS are clearly superior to MELCOR.

In summary, these analyses show that the DEBRIS and TAC2D codes were better able than MELCOR to capture the actual temperature profiles in the MP-1 and MP-

2 experiments. In most cases, though, MELCOR temperatures were within 200K of those calculated by the other codes. One of the values of more accurate codes like DEBRIS and TAC2D is to provide guidance on where MELCOR modeling could be improved, and what effects those improvements might have on MELCOR results. Possible aspects of MELCOR modeling needing improvement as indicated by these analyses include time-varying power peaking factors, two-dimensional heat conduction in heat structures and the lower head, and an option for radial heat conduction between components in inner rings. Note that some of these models would only be important when modeling small-scale experiments, and their implementation may not be important for modeling full-scale nuclear plants.

Figure 6.2.1. MP-2 code comparison study: centerline axial temperature profiles calculated by MELCOR and DEBRIS at 9500 seconds.

Figure 6.2.2. MP-2 code comparison study: centerline axial temperature profiles calculated by MELCOR and DEBRIS at 14000 seconds.

Figure 6.2.3. MP-2 code comparison study: centerline axial temperature profiles calculated by MELCOR and DEBRIS at 19000 seconds.

Chapter 7

Code Problems and Modifications

This task required modification of the COR package to allow an initial core configuration containing conglomerate and particulate debris. Also, several code problems were identified during the course of this assessment project. These modifications resulted in the submission of several MELCOR Defect Investigation Reports (DIR's). Each modification is discussed in this chapter.

7.1 Initialize COR with Debris (for MP-1 Assessment)

In previous versions of MELCOR, the initial core configuration could not contain particulate or conglomerate debris. That is, only intact components were allowed in the initial core configuration. The MP-1 and MP-2 experiments began with an initial configuration which contained rubblized debris resting upon a metallic crust. This arrangement was most logically represented in MELCOR using particulate and conglomerate debris. Therefore, modeling the MP-1 and MP-2 experiments required the ability to initialize the core in a degraded state.

Modifications were made to MELCOR to allow particulate and conglomerate debris in any core cell in the initial core configuration. In addition, components can be initialized with oxidized material as part of the intact mass. The cell component initial temperatures input record was also modified to allow the input of a particulate debris temperature. The new and modified input records are described briefly below. More detailed descriptions can be found in the COR User's Guide.

CORijjKcc - Component Masses: For component cc (FU, CL, CN, CB, OS, PD), input the mass of each allowed material in ring i, axial level jj. For example, for the cladding component, masses of zircaloy, Inconel and ZrO_2 can be input. For the particulate debris component, masses of all possible core materials (except heater element material) are allowed.

CORijjYcc - Conglomerate Debris Masses: Conglomerate debris masses associated with component cc in ring i, axial level jj. All components except FU are allowed for cc (there is no conglomerate debris associated with the fuel component).

CORijj03 - Cell Initial Temperatures: Add TDP, the particulate debris initial temperature, onto the end of this input record.

The addition of particulate and conglomerate debris in the initial core configuration does not affect the flow area input, which is calculated assuming only the presence of intact components. Therefore, when initializing a core with debris, care must be taken to allow enough free volume for the addition of the debris in each cell. The occupation of volume by conglomerate and particulate debris is done as if that debris instantaneously relocated to the cell at the initial starting time.

The initialization of conglomerate debris into the eutectic material state is performed if the eutectic model is active when MELGEN is run.

This new feature also allows the user to manually rezone a partially or completely degraded core, as long as materials in the core are either fully molten or not molten at all. This may be desirable to reduce run times for MELCOR executions after most of the core degradation has taken place. Rezoning was not used in the MP assessment input models.

This feature was implemented in DIR's 1192, 1196 and 1198, which were included in the production version of MELCOR in updates 1.80C and 1.80D. Note that these updates are later than the version of MELCOR released as MELCOR 1.8.2 in April 1993, (version 1.8NM), and so this feature is not included in MELCOR 1.8.2.

7.2 Individual Material Candling

In previous versions of MELCOR, with the eutectics model off, zircaloy and stainless steel were subject to holdup by oxide shells. Other materials, such as control poison, were not allowed to candle individually at all. When the eutectics model was on, all molten materials were part of the eutectic mixture, which was subject to oxide holdup in all components except for fuel and particulate debris. The net effect was that control poison material was not allowed to candle individually until the material onto which it was attached (as conglomerate debris) completely relocated.

In the case of the MP assessment, this resulted in the holdup of control poison material in the crust region after it had melted, for the rest of the calculation. This was not the behavior observed in MP-2, where poison material relocated from the crust region after it had formed a sufficient molten mass. Note that this was not an error in the candling model, which was designed to model candling on the inside surface of the cladding and for which the holdup of molten material by intact cladding was appropriate.

A modification was made to the candling model input which allowed individual materials to candle out of a conglomerate debris mixture *in addition to the default behavior of intact material holdup*. The new feature was implemented as an alternate

value of IDRP on the CORTST01 record in MELCOR input. If this value is set to 2, individual materials are allowed to candle out of a conglomerate debris mixture. This feature was implemented in update 1.80D as a result of DIR 1200.

7.3 CVH Volume Reduction

A problem was encountered in several of the sensitivity studies which prevented them from running to completion. The problem occurred as a result of massive relocation of core materials to lower parts of the test bundle. In several studies, as massive relocation occurred, the CVH volumes associated with the stub and crust region began to fill up with core debris, and the volume left for CVH materials became very small. This resulted in convergence difficulties in the CVH package, which drove the system time step down below the minimum value.

This problem has been encountered in MELCOR work associated with natural circulation modeling [15]. A task has been written for FY94 which will address the coupling of blockages in the core with CVH and FL modeling. It is expected that the results of this work will improve the modeling of CVH volumes that are in the process of "filling up" with core debris.

Chapter 8

Conclusions

MELCOR is a fully integrated, engineering-level computer code being developed at Sandia National Laboratories for the USNRC, that models the entire spectrum of severe accident phenomena in a unified framework for both BWRs and PWRs. As a part of an ongoing assessment program, MELCOR has been used to model the MP-1 and MP-2 Melt Progression experiments. MP-1 and MP-2 provided data for late phase melt progression in PWR geometries, particularly in the area of melting and relocation of metallic blockages and rubblized debris beds.

The MELCOR base case input model for the MP-1 experiment consisted of 3 control volumes, 2 flow paths, and 14 heat structures. A total of 39 core cells were modeled in 3 rings, with 6 axial levels in the debris region and 3 each in the crust and stub regions. The MP-2 base case model had 5 axial levels in the stub region, to account for longer rod stubs in MP-2, and less ZrO₂ fiber in the radial insulation than in MP-1, but was otherwise similar to the MP-1 base case model. In general, very few MELCOR default input parameters were changed for this assessment, the most important being the core boundary conduction model, which was used to model the lower grid spacer, and the minimum component masses on COR package sensitivity coefficient 1502, which were adjusted to accommodate the lower masses found in experiments compared to full core models. The input models for MP-1 and MP-2 were unusual in the sense that they initialized the core in a degraded state, using a new feature added as part of this assessment task (this new feature is included in MELCOR 1.8OD, and so is not included in MELCOR 1.8.2, which was released in April 1993).

For MP-1, temperatures in some parts of the debris region were under-predicted by 250–500K during part of the experiment, but peak temperatures were predicted within 250K at all debris region levels. Crust region temperatures were over-predicted by no more than 200K at all levels. Stub region temperatures were substantially over-predicted at all levels, due to downward axial heat conduction in the cladding component and the lack of radial heat losses in the grid spacer. The poor agreement with data in the stub region was not considered important, because this arrangement was not representative of a typical severe accident geometry. No melting or relocation was calculated for MP-1, compared to material melting observed in the debris region only during the experiment. This was probably due to the skewing of power

peaking factors into the crust and stub regions, and would explain the under- and over-prediction of temperatures in the debris and crust regions, respectively.

In MP-2, debris region temperatures were also under-predicted, by as much as 500K at some levels. The calculated axial temperature drop across the debris region was a maximum of 500K, compared to a measured value of approximately 900K. Temperatures in the crust region were predicted within 100K in the outer two rings and within 200K in the inner ring, while stub region temperatures were high again, because of axial conduction within core components.

Material relocation from the crust to the stub regions and within the debris region was close to the observed final material state in MP-2. MELCOR predicted a pool surface in the debris region at 21.75 cm, compared to the observed surface at about 21 cm. The calculated penetration of debris region materials into the crust region was within 0.3 cm of measured penetration, compared to a nodalization cell height of 1.17 cm in that region. MELCOR predicted the relocation of lower melting point crust materials to the bottom of the stub region, and the refreezing of material onto the rod stubs, in appropriate amounts. This was accomplished after code modifications that modified the candling model to be more representative of the MP experiment geometry (these modifications are included in version 1.8OC of MELCOR, and are part of the production version of MELCOR).

Fifteen sensitivity studies were performed on various COR, CVH and HS package input parameters. Sensitivities to minimum component mass indicated the need to use more appropriate values for experimental models (the defaults for this model were chosen based on full-plant models). Turning off axial heat conduction in COR resulted in less heat transfer from the crust region downward, raising crust and debris region temperatures substantially. The use of a new candling model option resulted in better relocation agreement. Enabling the eutectics model made relocation agreement worse, due to the retention of lower melting point materials in the crust. Inserting a helium gap in heat structures, which was more representative of the experiments, resulted in higher core temperatures, as expected. Using non-default core component view factors also affected results, due to radiation dominating the heat transfer between core components. In general, no unexpected sensitivities were found in the MP-1 and MP-2 input models.

Little or no sensitivities were found to particulate debris diameter, candling model refreezing heat transfer coefficients, convection heat transfer coefficients, gamma heating, time step and computer platform. Making the nodalization finer resulted in little change in temperature profiles, while reducing the number of core cells and control volumes smoothed out temperatures between core regions.

The results of the MP-1 and MP-2 base case calculations were compared to those from the DEBRIS and TAC2D codes. The other codes predicted temperatures much more accurately than MELCOR, particularly in the stub region, where heat transfer downward and radially outward through the grid spacer to the cooling jacket was important. Axial heat transfer down through one of the radial insulating layers and into the grid spacer was also modeled better by the other two codes. This was to be expected, due to the 2-dimensional modeling in these codes. Material relocation was not predicted much better by the DEBRIS code (TAC2D performed only heat

transfer calculations).

As part of this task, the capability to initialize the core in a degraded state was added to MELCOR and is available in versions subsequent to version 1.80D (MELCOR 1.8.2 was version 1.8NM, and therefore does not contain these modifications). Not only does this new feature allow the user to start a severe accident analysis with a degraded core, but also it adds a limited manual rezoning capability to the core package. A rezoning capability would allow the user to change the core nodalization manually after significant core degradation had taken place. The rezoning capability was not used in the MP assessment; however the capability to initialize the core in a degraded state was vital to representing the initial MP-1 and MP-2 geometries.

In conclusion, temperatures were predicted to within 500K in all regions and within 250K in many regions, while the calculated melting and relocation in MP-2 agreed quite well with PIE data. This level of agreement with experimental data was considered good, given the complicated arrangement of the MP-1 and MP-2 experimental test packages, and the fact that MELCOR is designed to model large-scale reactor plants rather than small-scale experiments like MP-1 and MP-2. No unexpected sensitivities in MELCOR input were found. Temperatures predicted by two other codes, DEBRIS and TAC2D were closer to measured data, but this was also expected due to the two-dimensional modeling in these codes. This task added a new feature to MELCOR, namely the capability to initialize the core in a degraded state.

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Appendix A

Conglomerate Versus Particulate Debris in MELCOR

This appendix gives a brief description of conglomerate and particulate debris, and how they are used in the COR package. For a more detailed description of conglomerate and particulate debris modeling, see [8].

The COR package in MELCOR models materials appearing in various *components*. A list of the components modeled in MELCOR is shown in Table A.1. *Particulate debris* is one of the components listed in the table. Particulate debris is usually formed by the conversion of another component into particulate debris after the original component's failure. Components are made up of various allowed materials. For example, the cladding component can contain zircaloy, ZrO_2 and Inconel. The particulate debris component can contain all core materials allowed in the COR package except heater element material, which does not relocate. Finally, the particulate debris component, like other components, is represented by its own unique specific internal energy (which determines component temperature), surface area and volume.

An example of the formation of particulate debris is as follows. Using the default MELCOR debris formation parameters on input record COR00008, when all the zircaloy in the cladding component melts or has been oxidized (i.e. upon cladding failure), the fuel in that cell (the fuel material in the fuel component) is added to

Table A.1. MELCOR core package component identifiers and descriptions.

Identifier	Description
FU	intact fuel component
CL	intact cladding component
CN	intact canister component (portion <u>not</u> adjacent to control blade)
CB	intact canister component (portion adjacent to control blade)
OS	"other structure" component (sometimes SS)
PD	particulate debris component (sometimes DP)

the particulate debris component in that core cell. The particulate debris in that cell is then free to relocate under the influence of gravity. Particulate debris in any cell can originate from failed components in the same cell, from materials relocated downward into the cell as particulate debris, or from radial relocation of particulate debris from adjacent rings. In any case, the particulate debris component in a core cell is modeled with a single specific internal energy and temperature.

Conglomerate debris is a term used to denote material refrozen onto another component in the MELCOR COR package. Conglomerate debris *is not* a component, but rather a material or a group of materials that has refrozen onto another component. Conglomerate debris is allowed to reside on all of the components listed in Table A.1 except the fuel component. All materials modeled in the MELCOR COR package are allowed to reside in the conglomerate debris, with the exception of heater element material, again because this material is not allowed to relocate. Conglomerate debris is not represented by its own unique specific internal energy, but rather has the same specific internal energy (and temperature) as the component on which it is refrozen.

An example of the formation of conglomerate debris is as follows. Zircaloy can melt elsewhere in the core and candle into a cell, refreezing onto the cladding in that cell. The refrozen material is designated as conglomerate debris residing on the cladding component. The cladding component in that cell consists of the zircaloy and possibly ZrO_2 and Inconel that made up the original cladding component, while the conglomerate debris residing on the cladding component is made up of the zircaloy that candled into that cell. The cladding component in that cell has a single specific internal energy (and temperature), which represents the intact component material (the zircaloy, ZrO_2 and Inconel) and the conglomerate debris refrozen onto that component (the refrozen zircaloy).

One unusual situation that can occur in MELCOR simulations is the existence of conglomerate debris refrozen onto a particulate debris component with zero mass. That is, there is zero particulate debris mass in a particular cell, but there is nevertheless conglomerate debris material residing on the particulate debris component. This can be observed in the COR package section of the edit file, on the lines labeled "PT DEBRIS" and "PTDB-DEBRIS". The former, "PT DEBRIS", lists the mass appearing in the particulate debris component. The latter, "PTDB-DEBRIS", or particulate debris debris (sic), lists conglomerate debris material residing on the particulate debris component. When material candles from a particular component downward into a different cell, there are a number of components onto which it can refreeze. The last allowed component is usually particulate debris. Generally, if none of these components is present, the molten material moves down to the next cell. However, if it cannot candle any further because it has reached a blockage (or the bottom of the core), then the molten material will "refreeze" onto the particulate debris component, even if there is no particulate debris in that cell. This is the situation in the MP-2 final material configuration (shown in Figure 4.2.27), where the only material residing in the particulate debris component at level two is "CRP Debris", which is control poison in the conglomerate debris. This material arrived in a molten state and was not able to candle further because of the grid spacer modeled at axial level one.

Appendix B

MP-1 and MP-2 Base Case Input Decks

B.1 MP-1

```
*eor* melgen
*
* 9/17 changed properties for ThO2, Ta, ZrO2(fiber), Zr, UO2, SS
*      to correspond to DEBRIS properties
* 9/20 changed initial temps for core components according to
*      initial thermocouple temp's at 1954.1 seconds; changed
*      problem start time to 1954.1 seconds.
* 9/21 changed peaking factors to correspond to shape factors from
*      DEBRIS and TWODANT code analyses
* 9/22 changed SS melting temp to 4999.OK so that it never melts
*      (for level 7 SS); changed all view factors to defaults (.25)
* 9/23 changed ss Cp and h to reflect higher melting temp due to
*      eutectic T convergence; changed Zr-SS eutectic liquifaction
*      temp to 4999.0 to prevent liquifaction of SS in level 7
* 9/27 enabled extrapolation from ends of MP enthalpy tables;
*      changed melting and failure temp's for SS to 3799.OK
* 10/6 changed debris porosities to 51.3%; increased intact porosities
*      to 75% to prevent relocation into crust and stub regions
* 10/7 corrected axial peaking factors to account for UO2 mass
* 10/19 enlarged os in level 1 to account for grid spacer mat'l, made
*      and all-stainless steel radial heat structure at level 1;
*      used core->hs heat conduction option to enhance heat xfer out
*      bottom of core
* 10/20 removed sc1131 (minimum oxide mass), sc1011 (ss-zr liquifaction
*      temp) and structure failure temp (corzjj04) input, since they
*      did not apply to this experiment
*
*****
* exec package input *
```

```

*****
*
title      'mp1'
restartf   'mp1.rst'
outputf    'mp1.gout'
diagf      'mp1.gdia'
*
tstart 1954.1 * initial problem time is 1954.1
*
*****
* cor package input *
*****
*
*-----
* general core input
*-----
*      nrad naxl ntlp ncvol nlh npntot
cor00000 3   13   1   3   10   1 *
*      rfuel  rclad  drgap  pitch  dxcan  dxss  dzlh
cor00001 4.51e-3 4.815e-3 7.6e-4 1.27e-2 1.0e0 1.0e0 1.26e-1
cor00002 pwr ag-in-cd * bwr type, b4c poison
* view factors: can-clad, sheath-can, cell-cell(rad), cell-cell(axial),
*      pool-struc (from MELPROG DF-4 report)
cor00003      0.25      0.25      0.25 0.25 0.25
*
cor00004 0 -15 0 * no TP, cf #10 for fission power, no extra gap cond
*
cor00006 1 * activate eutectic modeling
*
cor00008 1.0e-5 0.0 * critical minimum thicknesses for zr, steel
*
* increase failure temperature for lower head and penetrations
*
cor00009 1000.0 1000.0 3800.0 1.0 * htc's for pen, lh, lh failure temp
*
cor00011 5 helium 1.0e-6 2.24e-4 * gap cond from pd, helium gap,
*      * thickness, Rdif
*
*-----
* axial segment input
*-----
*
* axial geometry
corz0101 -12.6e-2 12.6e-2 0.750 0.513 * zbot, dz, porosities
corz0201 0.0 1.80e-2 0.750 0.513 * zbot, dz, porosities
corz0301 1.80e-2 1.80e-2 0.750 0.513 *
corz0401 3.60e-2 1.80e-2 0.750 0.513 *
corz0501 5.40e-2 1.167e-2 0.750 0.513 *

```

```

corz0601 6.567e-2 1.167e-2 0.750 0.513 *
* set intact porosity to almost 1 to support debris
corz0701 7.733e-2 1.167e-2 0.750 0.513 *
corz0801 8.90e-2 2.73e-2 0.750 0.513 *
corz0901 11.63e-2 2.73e-2 0.750 0.513 *
corz1001 14.37e-2 2.73e-2 0.750 0.513 *
corz1101 17.10e-2 2.73e-2 0.750 0.513 *
corz1201 19.83e-2 2.73e-2 0.750 0.513 *
corz1301 22.57e-2 2.73e-2 0.750 0.513 *
* boundary heat structures, isup
corz0102 10000 10 *
corz0202 10102 10 *
corz0302 10103 0 *
corz0402 10104 0 *
corz0502 10205 01 *
corz0602 10206 0 *
corz0702 10207 01 *
Corz0802 10308 0 *
corz0902 10309 0 *
corz1002 10310 0 *
corz1102 10311 0 *
corz1202 10312 0 *
corz1302 10313 0 *
*
* axial peaking factors
*
corz0103 0.0
corz0203 0.255
corz0303 0.209
corz0403 0.118
corz0503 0.289
corz0603 0.195
corz0703 0.139
corz0803 2.852
corz0903 2.570
corz1003 2.514
corz1103 2.514
corz1203 2.478
corz1303 2.429
*
* radial input:
corr0101 6.158e-4 * ring cross-sectional area
corr0201 1.675e-3 * ring cross-sectional area
corr0301 3.682e-3 * ring cross-sectional area
*
corr0102 10114 * upper boundary heat structure
corr0202 10114 * upper boundary heat structure
corr0302 10114 * upper boundary heat structure

```



```

*
* radial peaking factors
*
corr0103  0.818
corr0203  0.620
corr0303  1.562
*
* cell-specific input:
*
*-----
* lower plenum cells:
*-----
*
cor10101  -1  101  * no ref cell, channel, bypass cvh volumes
cor10102  0.0  0.0  6.171e-1  0.0  0.0  0.0  0.0  0.0 * fuel, clad masses
cor10103  300.0  300.0  300.0  300.0  300.0  300.0  300.0 * T(fu,cl,os,cn,cb,dp)
* Dhyd:   clad      sheath    part deb  can in    can out
cor10104  1.0e-2  1.0e-2  8.724e-2  2.0e-3  1.0e-2  1.0e-2
cor10105  1.108e-2  0.0  * radial bound area, channel, byp area
* surf area: fuel, clad, os, can in
cor10106  0.0  0.0  1.108e-2  0.0
*
cor20101  101  101  * no ref cell, channel, bypass cvh volumes
cor20102  0.0  0.0  1.678e0  0.0  0.0  0.0  0.0  0.0 * fuel, clad masses
cor20105  2.138e-2  0.0  * radial bound area, channel, byp area
* surf area: fuel, clad, os, can in
cor20106  0.0  0.0  2.138e-2  0.0
*
cor30101  101  101  * no ref cell, channel, bypass cvh volumes
cor30102  0.0  0.0  3.690e0  0.0  0.0  0.0  0.0  0.0 * fuel, clad masses
cor30105  3.452e-2  0.0  * radial bound area, channel, byp area
* surf area: fuel, clad, os, can in
cor30106  0.0  0.0  3.452e-2  0.0
*
*-----
* stub region:
*-----
*
* ring 1:
*
cor10201  -1  101  * no ref cell, channel, bypass cvh volumes
cor10202  4.488e-2  8.958e-3  0.0  0.0  0.0  0.0  0.0  0.0 * fuel, clad masses
cor10203  307.6  307.6  307.6  307.6  307.6  307.6  307.6 * T(fu,cl,os,cn,cb,dp)
* Dhyd:   clad      sheath    part deb  can in    can out
cor10204  9.630e-3  1.0e-2  2.0e-3  1.0e-2  1.0e-2
cor10205  1.583e-3  3.245e-4  * radial bound area, channel, byp area
* surf area: fuel, clad, os, can in
cor10206  2.040e-3  2.179e-3  0.0  0.0

```

```

*
cor10301 102 101 * ref cell, channel cvh volume
cor10303 322.6 322.6 322.6 322.6 322.6 322.6 * T(fu,cl,os,cn,cb,dp)
cor10401 102 101 * ref cell, channel cvh volume
cor10403 330.5 330.5 330.5 330.5 330.5 330.5 * T(fu,cl,os,cn,cb,dp)
*
* ring 2:
*
cor20201 102 101 * ref cell, channel, bypass cvh volumes
cor20202 1.122e-1 2.240e-2 0.0 0.0 0.0 0.0 0.0 0.0 * fuel, clad masses
cor20203 307.6 307.6 307.6 307.6 307.6 307.6 * T(fu,cl,os,cn,cb,dp)
cor20205 3.054e-3 9.466e-4 * radial bound area, channel, byp area
* surf area: fuel, clad, os, can in
cor20206 5.101e-3 5.448e-3 0.0 0.0
*
cor20301 202 101 * ref cell, channel cvh volume
cor20303 322.6 322.6 322.6 322.6 322.6 322.6 * T(fu,cl,os,cn,cb,dp)
cor20401 202 101 * ref cell, channel cvh volume
cor20403 330.5 330.5 330.5 330.5 330.5 330.5 * T(fu,cl,os,cn,cb,dp)
*
*
* ring 3:
*
cor30201 102 101 * ref cell, channel, bypass cvh volumes
cor30202 2.019e-1 4.031e-2 * fuel, clad masses
cor30203 307.6 307.6 307.6 307.6 307.6 307.6 * T(fu,cl,os,cn,cb,dp)
cor30205 4.931e-3 2.371e-3 * radial bound area, channel, byp area
* surf area: fuel, clad, os, can in
cor30206 9.181e-3 9.806e-3 0.0 0.0
*
cor30301 302 101 * ref cell, channel cvh volume
cor30303 322.6 322.6 322.6 322.6 322.6 322.6 * T(fu,cl,os,cn,cb,dp)
cor30401 302 101 * ref cell, channel cvh volume
cor30403 330.5 330.5 330.5 330.5 330.5 330.5 * T(fu,cl,os,cn,cb,dp)
*
*-----
* crust region:
*-----
*
* ring 1:
*
cor10501 -1 102 * ref cell, channel, bypass cvh volumes
cor10503 337.0 337.0 337.0 337.0 337.0 337.0 * T(fu,cl,os,cn,cb,dp)
cor10504 9.630e-3 1.0e-2 2.0e-3 1.0e-2 1.0e-2 * Dh:cl,os,dp,cni,cno
cor10505 1.027e-3 3.245e-4 * radial bound area, channel, byp area
cor10506 1.323e-3 1.412e-3 0.0 0.0 * surf a: fu, cl, os, cani
cor105kfu 2.479e-2 0.0 * alternate fuel mass specification
cor105kcl 4.958e-3 0.0 0.0 * alternate clad mass specification

```

```

cor105ycl 8.138e-3 1.268e-2 4.574e-3 * cong deb: UO2, Zr, ZrO2
*
cor10601 105 102 * ref cell, channel cvh volume
cor10603 334.1 334.1 334.1 334.1 334.1 334.1 * T(fu,cl,os,cn,cb,dp)
cor10701 105 102 * ref cell, channel cvh volume
cor10703 341.5 341.5 341.5 341.5 341.5 341.5 * T(fu,cl,os,cn,cb,dp)
*cor10705 1.027e-3 3.000e-4 * radial bound area, channel, byp area
cor10705 1.027e-3 3.245e-4 * radial bound area, channel, byp area
cor10706 1.323e-3 1.412e-3 0.0 0.0 * surf a: fu, cl, os, cani
*
* ring 2:
*
cor20501 105 102 * ref cell, channel, bypass cvh volumes
cor20503 337.0 337.0 337.0 337.0 337.0 337.0 * T(fu,cl,os,cn,cb,dp)
cor20506 3.306e-3 3.529e-3 0.0 0.0 * surf a: fu, cl, os, cani
cor205kfu 6.198e-2 0.0 * alternate fuel mass specification
cor205kcl 1.240e-2 0.0 0.0 * alternate clad mass specification
cor205ycl 2.374e-2 3.699e-2 1.334e-2 * cong deb: UO2, Zr, ZrO2
cor20505 1.980e-3 9.466e-4 * radial bound area, channel, byp area
*
cor20601 205 102 * ref cell, channel cvh volume
cor20603 334.1 334.1 334.1 334.1 334.1 334.1 * T(fu,cl,os,cn,cb,dp)
cor20701 205 102 * ref cell, channel cvh volume
cor20703 341.5 341.5 341.5 341.5 341.5 341.5 * T(fu,cl,os,cn,cb,dp)
*cor20705 1.980e-3 8.770e-4 * radial bound area, channel, byp area
cor20705 1.980e-3 9.466e-4 * radial bound area, channel, byp area
cor20706 3.306e-3 3.529e-3 0.0 0.0 * surf a: fu, cl, os, cani
*
*
* ring 3:
*
cor30501 105 102 * ref cell, channel, bypass cvh volumes
cor30503 337.0 337.0 337.0 337.0 337.0 337.0 * T(fu,cl,os,cn,cb,dp)
cor30505 3.197e-3 2.371e-3 * radial bound area, channel, byp area
cor30506 5.951e-3 6.353e-3 0.0 0.0 * surf a: fu, cl, os, cani
cor305kfu 1.116e-1 0.0 * alternate fuel mass specification
cor305kcl 2.231e-2 0.0 0.0 * alternate clad mass specification
cor305ycl 5.946e-2 9.266e-2 3.342e-2 * cong deb: UO2, Zr, ZrO2
*
cor30601 305 102 * ref cell, channel cvh volume
cor30603 334.1 334.1 334.1 334.1 334.1 334.1 * T(fu,cl,os,cn,cb,dp)
cor30701 305 102 * ref cell, channel cvh volume
cor30703 341.5 341.5 341.5 341.5 341.5 341.5 * T(fu,cl,os,cn,cb,dp)
*cor30705 3.197e-3 2.190e-3 * radial bound area, channel, byp area
cor30705 3.197e-3 2.371e-3 * radial bound area, channel, byp area
cor30706 5.951e-3 6.353e-3 0.0 0.0 * surf a: fu, cl, os, cani
*
*-----

```

* debris region:

*-----

*

*

* ring 1:

*

cor10801 -1 103 * ref cell, channel, bypass cvh volumes

cor10804 9.630e-3 1.0e-2 2.0e-3 1.0e-2 1.0e-2 * Dh:cl,os,dp,cni,cno

*cor10805 2.401e-3 6.158e-4 * radial bound area, channel, byp area

cor10805 2.401e-3 6.156e-4 * radial bound area, channel, byp area

cor10806 0.0 0.0 0.0 0.0 * surf area: fuel, clad, os, can in

cor108kfu 0.0 0.0 * alternate fuel mass specification

cor108kcl 0.0 0.0 0.0 * alternate clad mass specification

cor108kdp 6.348e-2 0.0 9.922e-3 * part deb masses: UO2, Zr, ZrO2

*

cor10901 108 103 * ref cell, channel cvh volume

cor11001 108 103 * ref cell, channel cvh volume

cor11101 108 103 * ref cell, channel cvh volume

cor11201 108 103 * ref cell, channel cvh volume

cor11301 108 103 * ref cell, channel cvh volume

*

* initial temps:

cor10803 377.9 377.9 377.9 377.9 377.9 377.9 * T(fu,cl,os,cn,cb,dp)

cor10903 386.4 386.4 386.4 386.4 386.4 386.4 * T(fu,cl,os,cn,cb,dp)

cor11003 396.1 396.1 396.1 396.1 396.1 396.1 * T(fu,cl,os,cn,cb,dp)

cor11103 412.7 412.7 412.7 412.7 412.7 412.7 * T(fu,cl,os,cn,cb,dp)

cor11203 386.4 386.4 386.4 386.4 386.4 386.4 * T(fu,cl,os,cn,cb,dp)

cor11303 377.9 377.9 377.9 377.9 377.9 377.9 * T(fu,cl,os,cn,cb,dp)

*

* ring 2:

*

cor20801 108 103 * ref cell, channel, bypass cvh volumes

cor20805 4.631e-3 1.675e-3 * radial bound area, channel, byp area

cor20806 0.0 0.0 0.0 0.0 * surf area: fuel, clad, os, can in

cor208kfu 0.0 0.0 * alternate fuel mass specification

cor208kcl 0.0 0.0 0.0 * alternate clad mass specification

cor208kdp 1.729e-1 0.0 2.702e-2 * part deb masses: UO2, Zr, ZrO2

*

cor20901 208 103 * ref cell, channel cvh volume

cor21001 208 103 * ref cell, channel cvh volume

cor21101 208 103 * ref cell, channel cvh volume

cor21201 208 103 * ref cell, channel cvh volume

cor21301 208 103 * ref cell, channel cvh volume

*

* initial temps:

cor20803 377.9 377.9 377.9 377.9 377.9 377.9 * T(fu,cl,os,cn,cb,dp)

```

cor20903 386.4 386.4 386.4 386.4 386.4 386.4 * T(fu,cl,os,cn,cb,dp)
cor21003 396.1 396.1 396.1 396.1 396.1 396.1 * T(fu,cl,os,cn,cb,dp)
cor21103 412.7 412.7 412.7 412.7 412.7 412.7 * T(fu,cl,os,cn,cb,dp)
cor21203 386.4 386.4 386.4 386.4 386.4 386.4 * T(fu,cl,os,cn,cb,dp)
cor21303 377.9 377.9 377.9 377.9 377.9 377.9 * T(fu,cl,os,cn,cb,dp)
*
* ring 3:
*
cor30801 108 103 * ref cell, channel, bypass cvh volumes
cor30805 7.479e-3 3.682e-3 * radial bound area, channel, byp area
cor30806 0.0 0.0 0.0 0.0 * surf area: fuel, clad, os, can in
cor308kfu 0.0 0.0 * alternate fuel mass specification
cor308kcl 0.0 0.0 0.0 * alternate clad mass specification
cor308kdp 3.800e-1 0.0 5.939e-2 * part deb masses: UO2, Zr, ZrO2
*
cor30901 308 103 * ref cell, channel cvh volume
cor31001 308 103 * ref cell, channel cvh volume
cor31101 308 103 * ref cell, channel cvh volume
cor31201 308 103 * ref cell, channel cvh volume
cor31301 308 103 * ref cell, channel cvh volume
*
* initial temps:
cor30803 377.9 377.9 377.9 377.9 377.9 377.9 * T(fu,cl,os,cn,cb,dp)
cor30903 386.4 386.4 386.4 386.4 386.4 386.4 * T(fu,cl,os,cn,cb,dp)
cor31003 396.1 396.1 396.1 396.1 396.1 396.1 * T(fu,cl,os,cn,cb,dp)
cor31103 412.7 412.7 412.7 412.7 412.7 412.7 * T(fu,cl,os,cn,cb,dp)
cor31203 386.4 386.4 386.4 386.4 386.4 386.4 * T(fu,cl,os,cn,cb,dp)
cor31303 377.9 377.9 377.9 377.9 377.9 377.9 * T(fu,cl,os,cn,cb,dp)
*
*-----
* lower head input
*-----
corlhd01 1 1 1.0e-5 300.0 1.0e-6 101 101 * rings,m,t,a,cv's
corlhd02 2 2 1.0e-5 300.0 1.0e-6 101 101 * rings,m,t,a,cv's
corlhd03 3 3 1.0e-5 300.0 1.0e-6 101 101 * rings,m,t,a,cv's
*
* penetration input
corpen01 -1 1 1.0e-5 300.0 1.0e-5 1.0e-5 1.0e-5 * try for no pen'n
* core inlet temp
cortin01 101 101 * for cv 101 (channel), use same volume (no dt/dz done)
*
*
*-----
* fission power control functions
*-----
*
* stub region power

```

```

*
*cf01100 'stub fission' add 18 1.75e3 0.0 *
* peaking factor for stub region:~~~~~
*
* add total uo2 mass in stub region:
*
*cf01111 1.0 0.0 cor-muo2-db.102 *
*cf01112 1.0 0.0 cor-muo2-db.103 *
*cf01113 1.0 0.0 cor-muo2-db.104 *
*cf01114 1.0 0.0 cor-muo2-db.202 *
*cf01115 1.0 0.0 cor-muo2-db.203 *
*cf01116 1.0 0.0 cor-muo2-db.204 *
*cf01117 1.0 0.0 cor-muo2-db.302 *
*cf01118 1.0 0.0 cor-muo2-db.303 *
*cf01119 1.0 0.0 cor-muo2-db.304 *
*cf01120 1.0 0.0 cor-muo2-fu.102 *
*cf01121 1.0 0.0 cor-muo2-fu.103 *
*cf01122 1.0 0.0 cor-muo2-fu.104 *
*cf01123 1.0 0.0 cor-muo2-fu.202 *
*cf01124 1.0 0.0 cor-muo2-fu.203 *
*cf01125 1.0 0.0 cor-muo2-fu.204 *
*cf01126 1.0 0.0 cor-muo2-fu.302 *
*cf01127 1.0 0.0 cor-muo2-fu.303 *
*cf01128 1.0 0.0 cor-muo2-fu.304 *
*
* crust region power
*
*cf01200 'crust fission' add 18 3.50e3 0.0 *
* peaking factor for crust region:~~~~~
*
* add total uo2 mass in crust region:
*
*cf01211 1.0 0.0 cor-muo2-db.105 *
*cf01212 1.0 0.0 cor-muo2-db.106 *
*cf01213 1.0 0.0 cor-muo2-db.107 *
*cf01214 1.0 0.0 cor-muo2-db.205 *
*cf01215 1.0 0.0 cor-muo2-db.206 *
*cf01216 1.0 0.0 cor-muo2-db.207 *
*cf01217 1.0 0.0 cor-muo2-db.305 *
*cf01218 1.0 0.0 cor-muo2-db.306 *
*cf01219 1.0 0.0 cor-muo2-db.307 *
*cf01220 1.0 0.0 cor-muo2-fu.105 *
*cf01221 1.0 0.0 cor-muo2-fu.106 *
*cf01222 1.0 0.0 cor-muo2-fu.107 *
*cf01223 1.0 0.0 cor-muo2-fu.205 *
*cf01224 1.0 0.0 cor-muo2-fu.206 *
*cf01225 1.0 0.0 cor-muo2-fu.207 *
*cf01226 1.0 0.0 cor-muo2-fu.305 *

```

```

*cf01227  1.0  0.0  cor-muo2-fu.306  *
*cf01228  1.0  0.0  cor-muo2-fu.307  *
*
* debris region power
*
*cf01300  'debris fission'  add 36 7.00e3  0.0  *
* peaking factor for debris region: ^^^^^^
*
* add total uo2 mass in debris region:
*
*cf01311  1.0  0.0  cor-muo2-db.108  *
*cf01312  1.0  0.0  cor-muo2-db.109  *
*cf01313  1.0  0.0  cor-muo2-db.110  *
*cf01314  1.0  0.0  cor-muo2-db.111  *
*cf01315  1.0  0.0  cor-muo2-db.112  *
*cf01316  1.0  0.0  cor-muo2-db.113  *
*cf01317  1.0  0.0  cor-muo2-db.208  *
*cf01318  1.0  0.0  cor-muo2-db.209  *
*cf01319  1.0  0.0  cor-muo2-db.210  *
*cf01320  1.0  0.0  cor-muo2-db.211  *
*cf01321  1.0  0.0  cor-muo2-db.212  *
*cf01322  1.0  0.0  cor-muo2-db.213  *
*cf01323  1.0  0.0  cor-muo2-db.308  *
*cf01324  1.0  0.0  cor-muo2-db.309  *
*cf01325  1.0  0.0  cor-muo2-db.310  *
*cf01326  1.0  0.0  cor-muo2-db.311  *
*cf01327  1.0  0.0  cor-muo2-db.312  *
*cf01328  1.0  0.0  cor-muo2-db.313  *
*
*cf01329  1.0  0.0  cor-muo2-fu.108  *
*cf01330  1.0  0.0  cor-muo2-fu.109  *
*cf01331  1.0  0.0  cor-muo2-fu.110  *
*cf01332  1.0  0.0  cor-muo2-fu.111  *
*cf01333  1.0  0.0  cor-muo2-fu.112  *
*cf01334  1.0  0.0  cor-muo2-fu.113  *
*cf01335  1.0  0.0  cor-muo2-fu.208  *
*cf01336  1.0  0.0  cor-muo2-fu.209  *
*cf01337  1.0  0.0  cor-muo2-fu.210  *
*cf01338  1.0  0.0  cor-muo2-fu.211  *
*cf01339  1.0  0.0  cor-muo2-fu.212  *
*cf01340  1.0  0.0  cor-muo2-fu.213  *
*cf01341  1.0  0.0  cor-muo2-fu.308  *
*cf01342  1.0  0.0  cor-muo2-fu.309  *
*cf01343  1.0  0.0  cor-muo2-fu.310  *
*cf01344  1.0  0.0  cor-muo2-fu.311  *
*cf01345  1.0  0.0  cor-muo2-fu.312  *
*cf01346  1.0  0.0  cor-muo2-fu.313  *
*

```

```

*cf01400  'powr (w/mwacrr)'  add  3  1.0  0.0  *
*
*cf01411  1.0  0.0  cfvalu.11  *
*cf01412  1.0  0.0  cfvalu.12  *
*cf01413  1.0  0.0  cfvalu.13  *
*
cf01500  'fission power'  equals  1  2.080e1  0.0  *
*  bundle power, W/kW(ACRR)      ~~~~~~
*
cf01511  1.0  0.0  edf.10.1  *
*
edf01000  reapow  1  read  * reactor power, 1 channels, read edf
edf01001  '/user/tjtautg/mpi/data/reapow.dat'  * data file name
edf01002  2e13.6  * format for data fields
*
cf01600  'fp integral'  integ  2  1.0  0.0  *
cf01611  1.0  0.0  cfvalu.15  *
cf01612  1.0  0.0  time
*
*
*****
* sc package input  *
*****
*
* minimum mass coeff's:
sc15021  1502  1.0e-7  1  * minimum component mass
sc15022  1502  1.0e-6  2  * minimum mass for temperature control
*
* fission power coeff's:
sc13021  1312  1.0  2  * fission power absorption in cl
sc13022  1312  1.0  6  * fission power absorption in dp
*
*****
* cvh package input  *
*****
*
*-----
* cv #101 - stub region channel volume
*-----
*
cv10100  'channel volume'  2  2  1  * non-eq thermo, vertical flow, rcs volume
cv10103  3.642e-3  * velocity area (flow area of stub region)
cv101a0  2  * option 2 for specifying properties
cv101a1  pv01 6.888e4  * volume initial conditions: atm press
cv101a2  tatm 300.0  *
cv101a3  ph2o 0.0  * no water vapor
cv101a4  mfrc.9  1.0  * atmosphere is all helium
cv101b1  -12.6000e-2  0.0

```



```

cv101b2  0.0  1.0e-6
cv101b3  5.4e-2  1.967e-4
*
*-----
* cv #102 - crust region channel volume
*-----
*
cv10200  'channel volume'  2  2  1    * non-eq thermo, vertical flow, rcs volume
cv10203  3.642e-3    * velocity area (flow area of crust region)
cv102a0  2            * option 2 for specifying properties
cv102a1  pvol 6.888e4  * volume initial conditions: atm press
cv102a2  tatm 300.0  *
cv102a3  ph2o 0.0     * no water vapor
cv102a4  mfrc.9  1.0   * atmosphere is all helium
cv102b1  5.4e-2  0.0
cv102b2  8.9e-2  1.275e-4
*
*-----
* cv #103 - crust region channel volume
*-----
*
cv10300  'channel volume'  2  2  1    * non-eq thermo, vertical flow, rcs volume
cv10303  5.972e-3    * velocity area (flow area of debris region)
cv103a0  2            * option 2 for specifying properties
cv103a1  pvol 6.888e4  * volume initial conditions: atm press
cv103a2  tatm 300.0  *
cv103a3  ph2o 0.0     * no water vapor
cv103a4  mfrc.9  1.0   * atmosphere is all helium
cv103b1  8.9e-2  0.0
cv103b2  25.3e-2  9.794e-4
*
*
*****
* fl package input *
*****
*
*-----
* fl #101 - stub to crust
*-----
*
fl10100  stub->crust  101  102  5.4e-2  5.4e-2  * from, to, inlet and outlet altitudes
fl10101  3.642e-3  4.45e-2  1.0  * area, length, fraction open
fl101s1  3.642e-3  4.45e-2  1.173e-2  * area, length, hyd diam
*
*-----
* fl #102 - crust to debris
*-----
*

```

```

fl10200 crust->debris 102 103 8.9e-2 8.9e-2 * from, to, inlet and outlet altitudes
fl10201 3.642e-3 9.95e-2 1.0 * area, length, fraction open
fl102s1 3.642e-3 9.95e-2 1.173e-2 * area, length, hyd diam
*
*
*****
* hs package input *
*****
*
*-----
* hs 10000
*-----
*
hs10000000 31 2 1 * 36 nodes, cylindrical geom, ss initialization performed
hs10000001 'lp-1' * hs name
hs10000002 -12.600e-2 1.0 * bottom elevation, vertical surface
* location data:
hs10000100 -1 1 4.362e-2 * node locations follow, ifrmt=1, inner radius
hs10000101 5.067e-2 11 * outer radius of layer 1: Thoria
hs10000102 5.156e-2 16 * outer radius of layer 2: Tantalum
hs10000103 7.620e-2 26 * outer radius of layer 3: ZrO2 (porous)
hs10000104 8.400e-2 31 * outer radius of layer 4: Stainless Steel
* composition data:
hs10000200 -1 * composition data follows
hs10000201 'stainless steel' 10 * layer 1: Thoria
hs10000202 'stainless steel' 15 * layer 2: Tantalum
hs10000203 'stainless steel' 25 * layer 3: ZrO2 (porous)
hs10000204 'stainless steel' 30 * layer 4: Stainless Steel
* internal heat source (none):
hs10000300 0 * no internal source
* inside boundary data:
hs10000400 1 101 int 1.0 1.0 * conv b.c., bound vol, int bound,
* crit. pool & atms fractions
hs10000401 0.7 equiv-band 9.63e-3 * emiss of Thoria, rad'n model,
* rad'n path length (Dfu)
hs10000500 3.452e-2 8.724e-2 12.6e-2 * area, char len (Dh used), axial len
* outside boundary data:
hs10000600 8101 -1 'ext' 1.0 1.0 * b.c. in cf101, no bv, ext surf, etc
*
*-----
* hs 10102
*-----
*
hs10102000 31 2 1 * 36 nodes, cylindrical geom, ss initialization performed
hs10102001 'stub-1' * hs name
hs10102002 0.0 1.0 * bottom elevation, vertical surface
* location data:
hs10102100 -1 1 4.362e-2 * node locations follow, ifrmt=1, inner radius

```

```

hs10102101 5.067e-2 11 * outer radius of layer 1: Thoria
hs10102102 5.156e-2 16 * outer radius of layer 2: Tantalum
hs10102103 7.620e-2 26 * outer radius of layer 3: ZrO2 (porous)
hs10102104 8.400e-2 31 * outer radius of layer 4: Stainless Steel
* composition data:
hs10102200 -1 * composition data follows
hs10102201 'thoria' 10 * layer 1: Thoria
hs10102202 'tantalum' 15 * layer 2: Tantalum
hs10102203 'zirconia (porous)' 25 * layer 3: ZrO2 (porous)
hs10102204 'stainless steel' 30 * layer 4: Stainless Steel
* internal heat source (none):
hs10102300 0 * no internal source
* inside boundary data:
hs10102400 1 101 int 1.0 1.0 * b.c., bound vol, int bound,
* crit. pool & atms fractions
hs10102401 0.7 equiv-band 9.63e-3 * emiss, rad'n model, rad'n path len (Dfu)
hs10102500 4.933e-3 1.173e-2 1.8e-2 * area, char len (Dh used), axial len
* outside boundary data:
hs10102600 8101 -1 'ext' 1.0 1.0 * b.c. in cf101, no bv, ext surf, etc
*
*-----
* hs 10103-10104
*-----
*
hs10103000 31 2 1 * 36 nodes, cylindrical geom, ss initialization performed
hs10104000 31 2 1 * 36 nodes, cylindrical geom, ss initialization performed
*
hs10103001 'stub-2' * hs name
hs10104001 'stub-3' * hs name
*
hs10103002 1.8e-2 1.0 * bottom elevation, vertical surface
hs10104002 3.6e-2 1.0 * bottom elevation, vertical surface
*
hs10103100 10102 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10104100 10102 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
*
hs10103200 10102 * composition data elsewhere
hs10104200 10102 * composition data elsewhere
*
hs10103300 0 * no internal source
hs10104300 0 * no internal source
*
hs10103400 1 101 int 1.0 1.0 * bc, bound vol, int bound, etc
hs10104400 1 101 int 1.0 1.0 * bc, bound vol, int bound, etc
*
hs10103401 0.7 equiv-band 9.63e-3 * emiss, rad'n model, path len (Dfu)
hs10104401 0.7 equiv-band 9.63e-3 * emiss, rad'n model, path len (Dfu)
*

```

```

hs10103500  4.933e-3  1.173e-2  1.8e-2  * area, char len (Dh used), axial len
hs10104500  4.933e-3  1.173e-2  1.8e-2  * area, char len (Dh used), axial len
*
hs10103600  8101  -1  'ext'  1.0  1.0  * bc in cf101, no bv, etc
hs10104600  8101  -1  'ext'  1.0  1.0  * bc in cf101, no bv, etc
*
*-----
* hs 10205
*-----
*
hs10205000  31  2  1  * 36 nodes, cylindrical geom, ss initialization performed
hs10205001  'crust-1' * hs name
hs10205002  5.40e-2  1.0 * bottom elevation, vertical surface
* location data:
hs10205100  10102  1  4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
* composition data:
hs10205200  10102  * composition data elsewhere
hs10205300  0  * no internal source
* inside boundary data:
hs10205400  1  102  int  1.0  1.0  * convective b.c., bound volume 101, int boundary,
                                     * crit. pool & atms fractions
hs10205401  0.7  equiv-band  9.63e-3 * emiss, rad'n model, path len (Dfu)
hs10205500  4.933e-3  1.173e-2  1.167e-2 * area, char len (Dh used), axial len
* outside boundary data:
hs10205600  8101  -1  'ext'  1.0  1.0  * bc in cf101, no bv, etc
                                     * exterior surface, etc
*
*-----
* hs 10206-10207
*-----
*
hs10206000  31  2  1  * 36 nodes, cylindrical geom, ss initialization performed
hs10207000  31  2  1  * 36 nodes, cylindrical geom, ss initialization performed
*
hs10206001  'crust-2' * hs name
hs10207001  'crust-3' * hs name
*
hs10206002  6.567e-2  1.0 * bottom elevation, vertical surface
hs10207002  7.733e-2  1.0 * bottom elevation, vertical surface
*
hs10206100  10102  1  4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10207100  10102  1  4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
*
hs10206200  10102  * composition data elsewhere
hs10207200  10102  * composition data elsewhere
*
hs10206300  0  * no internal source
hs10207300  0  * no internal source

```

```

*
hs10206400 1 102 int 1.0 1.0 * bc, bound vol, int bound, etc
hs10207400 1 102 int 1.0 1.0 * bc, bound vol, int bound, etc
*
hs10206401 0.7 equiv-band 9.63e-3 * emis of Thoria, rad'n model, char len (Dfu)
hs10207401 0.7 equiv-band 9.63e-3 * emis of Thoria, rad'n model, char len (Dfu)
*
hs10206500 4.933e-3 1.173e-2 1.167e-2 * area, char len (Dh used), axial len
hs10207500 4.933e-3 1.173e-2 1.167e-2 * area, char len (Dh used), axial len
*
hs10206600 8101 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
hs10207600 8101 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
*
*-----
* hs 10308
*-----
*
hs10308000 31 2 1 * 36 nodes, cylindrical geom, ss initialization performed
hs10308001 'debris-1' * hs name
hs10308002 8.90e-2 1.0 * bottom elevation, vertical surface
* location data:
hs10308100 10102 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
* composition data:
hs10308200 10102 * composition data elsewhere
hs10308300 0 * no internal source
* inside boundary data:
hs10308400 1 103 int 1.0 1.0 * convective b.c., bound volume 101, int boundary,
* crit. pool & atms fractions
hs10308401 0.7 equiv-band 9.63e-3 * emiss, rad'n model, path len (Dfu)
hs10308500 4.933e-3 8.724e-2 2.73e-2 * area, char len (Dh used), axial len
* outside boundary data:
hs10308600 8101 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
* exterior surface, etc
*
*-----
* hs 10309-10313
*-----
*
hs10309000 31 2 1 * 36 nodes, cylindrical geom, ss initialization performed
hs10310000 31 2 1 * 36 nodes, cylindrical geom, ss initialization performed
hs10311000 31 2 1 * 36 nodes, cylindrical geom, ss initialization performed
hs10312000 31 2 1 * 36 nodes, cylindrical geom, ss initialization performed
hs10313000 31 2 1 * 36 nodes, cylindrical geom, ss initialization performed
*
hs10309001 'debris-2' * hs name
hs10310001 'debris-3' * hs name
hs10311001 'debris-4' * hs name
hs10312001 'debris-5' * hs name

```

```

hs10313001  'debris-6' * hs name
*
hs10309002  11.63e-2  1.0 * bottom elevation, vertical surface
hs10310002  14.37e-2  1.0 * bottom elevation, vertical surface
hs10311002  17.10e-2  1.0 * bottom elevation, vertical surface
hs10312002  19.83e-2  1.0 * bottom elevation, vertical surface
hs10313002  22.57e-2  1.0 * bottom elevation, vertical surface
*
hs10309100  10102  1  4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10310100  10102  1  4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10311100  10102  1  4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10312100  10102  1  4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10313100  10102  1  4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
*
hs10309200  10102  * composition data elsewhere
hs10310200  10102  * composition data elsewhere
hs10311200  10102  * composition data elsewhere
hs10312200  10102  * composition data elsewhere
hs10313200  10102  * composition data elsewhere
*
hs10309300  0  * no internal source
hs10310300  0  * no internal source
hs10311300  0  * no internal source
hs10312300  0  * no internal source
hs10313300  0  * no internal source
*
hs10309400  1  103  int  1.0  1.0  * bc, bound vol, int bound, etc
hs10310400  1  103  int  1.0  1.0  * bc, bound vol, int bound, etc
hs10311400  1  103  int  1.0  1.0  * bc, bound vol, int bound, etc
hs10312400  1  103  int  1.0  1.0  * bc, bound vol, int bound, etc
hs10313400  1  103  int  1.0  1.0  * bc, bound vol, int bound, etc
*
hs10309401  0.7  equiv-band  9.63e-3  * emis of Thoria, rad'n model, char len (Dfu)
hs10310401  0.7  equiv-band  9.63e-3  * emis of Thoria, rad'n model, char len (Dfu)
hs10311401  0.7  equiv-band  9.63e-3  * emis of Thoria, rad'n model, char len (Dfu)
hs10312401  0.7  equiv-band  9.63e-3  * emis of Thoria, rad'n model, char len (Dfu)
hs10313401  0.7  equiv-band  9.63e-3  * emis of Thoria, rad'n model, char len (Dfu)
*
hs10309500  4.933e-3  8.724e-2  2.73e-2  * area, char len (Dh used), axial len
hs10310500  4.933e-3  8.724e-2  2.73e-2  * area, char len (Dh used), axial len
hs10311500  4.933e-3  8.724e-2  2.73e-2  * area, char len (Dh used), axial len
hs10312500  4.933e-3  8.724e-2  2.73e-2  * area, char len (Dh used), axial len
hs10313500  4.933e-3  8.724e-2  2.73e-2  * area, char len (Dh used), axial len
*
hs10309600  8101  -1  'ext'  1.0  1.0  * bc in cf101, no bv, etc
hs10310600  8101  -1  'ext'  1.0  1.0  * bc in cf101, no bv, etc
hs10311600  8101  -1  'ext'  1.0  1.0  * bc in cf101, no bv, etc
hs10312600  8101  -1  'ext'  1.0  1.0  * bc in cf101, no bv, etc

```

```

hs10313600 8101 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
*
*-----
* hs 10114
*-----
*
hs10114000 36 1 1 * # nodes, rectang geom, ss init'n performed
hs10114001 'upper plate' * hs name
hs10114002 25.3e-2 0.0 * bottom elevation, vertical surface
* location data:
hs10114100 -1 1 25.3e-2 * node locations follow, ifrmt=1, inner radius
hs10114101 27.3e-2 11 * layer 1: thoria
hs10114102 33.6e-2 31 * layer 2: zirconia
hs10114103 34.6e-2 36 * layer 3: stainless steel
* composition data:
hs10114200 -1 * composition data follow
hs10114201 thoria 10 * layer 1: thoria
hs10114202 'zirconia (porous)' 30 * layer 2: zirconia
hs10114203 'stainless steel' 35 * layer 3: stainless steel
*
hs10114300 0 * no internal source
* inside boundary data:
hs10114400 1 103 int 1.0 1.0 * conv b.c., bound vol 103, int bound, etc
hs10114401 0.7 equiv-band 2.0e-3 * emis of Thoria,rad model,path len (Dfu)
hs10114500 5.978e-3 8.724e-2 8.724e-2 * area, char 1 (Dh used), axial len
* outside boundary data:
hs10114600 8101 -1 'ext' 1.0 1.0 * Tc b.c. in cf101, no bv, etc
*
*-----
* cf 101 (for hs bound temps)
*-----
*
cf10100 'hs bound t' equals 1 1.0 273.15 *
cf10101 300.0
*
cf10111 1.0 0.0 edf.11.1 *
*
edf01100 hsbound 1 read * hs bound temp, 1 channels, read edf
edf01101 '/user/tjtautg/mp1/data/hsbound.dat' * data file name
edf01102 2e13.6 * format for data fields
*
*
*****
* ncg package input *
*****
*
ncg001 h2 4
ncg002 o2 5

```

```

ncg003 co 6
ncg004 co2 7
ncg005 ch4 8
ncg006 he 9
*
*
*****
* mp package input *
*****
*
***          material 5 is zircaloy
*
*   change default values for zircaloy to raise melting
*   temperature 102 k to be consistent with melprog and matpro
***
mpmat00500 zircaloy
mpmat00501 enh 220
mpmat00502 cps 221
mpmat00503 tmp 222
mpmat00504 thc 223
mpmat00550 mlt 2200.    *change melt temp to 2200 k, default=2098. k
*
tf22000 'ezirc' 16 1.0
tf22011 300.0 0.0
tf22012 400.0 21915.0
tf22013 640.0 105110.0
tf22014 1090.0 263960.0
tf22015 1093.0 265275.5
tf22016 1113.0 276195.5
tf22017 1133.0 288245.5
tf22018 1153.0 301585.5
tf22019 1173.0 316935.5
tf22020 1193.0 332795.5
tf22021 1213.0 346685.5
tf22022 1233.0 357565.5
tf22023 1248.0 363753.0
tf22024 2200.0 702665.0
tf22025 2200.01 927665.0
tf22026 3598.0 1425353.0
*
tf22100 'cpzirc' 15 1.0
tf22111 273.15 275.0
tf22112 400.0 302.0
tf22113 640.0 331.0
tf22114 1090.0 375.0
tf22115 1093.0 502.0
tf22116 1113.0 590.0
tf22117 1133.0 615.0

```


tf22118	1153.0	719.0
tf22119	1173.0	816.0
tf22120	1193.0	770.0
tf22121	1213.0	619.0
tf22122	1233.0	469.0
tf22123	1248.0	356.0
tf22124	2098.0	356.0
tf22125	5000.0	356.0

*

tf22200	'tzirc'	16	1.0
tf22211	0.0		300.0
tf22212	21915.0		400.0
tf22213	105110.0		640.0
tf22214	263960.0		1090.0
tf22215	265275.5		1093.0
tf22216	276195.5		1113.0
tf22217	288245.5		1133.0
tf22218	301585.5		1153.0
tf22219	316935.5		1173.0
tf22220	332795.5		1193.0
tf22221	346685.5		1213.0
tf22222	357565.5		1233.0
tf22223	363753.0		1248.0
tf22224	702665.0		2200.0
tf22225	927665.0		2200.01
tf22226	1425353.0		3598.0

*

tf22300	'thczr'	20	1.0
tf22311	2.73150E+02		1.23889E+01
tf22312	4.16668E+02		1.41522E+01
tf22313	5.60187E+02		1.59397E+01
tf22314	7.03705E+02		1.77515E+01
tf22315	8.47224E+02		1.95875E+01
tf22316	9.90742E+02		2.14478E+01
tf22317	1.13426E+03		2.33323E+01
tf22318	1.27778E+03		2.52410E+01
tf22319	1.42130E+03		2.71740E+01
tf22320	1.56482E+03		2.91313E+01
tf22321	1.70833E+03		3.11128E+01
tf22322	1.85185E+03		3.31185E+01
tf22323	1.99537E+03		3.51485E+01
tf22324	2.13889E+03		3.72028E+01
tf22325	2.28241E+03		3.92813E+01
tf22326	2.42593E+03		4.13840E+01
tf22327	2.56945E+03		4.35110E+01
tf22328	2.71296E+03		4.56622E+01
tf22329	2.85648E+03		4.78377E+01
tf22330	3.00000E+03		5.00374E+01

```

*
*-----
* UO2
*-----
*
*   change default thermal conductivity and density for UO2
*
***
mpmat00600  uranium-dioxide
mpmat00601  thc 224
mpmat00602  rho 225
mpmat00651  den 9850.0
*
*-----
* tf 224: thermal cond vs temp for uo2
*-----
tf22400  'thcuo2' 20 1.0
tf22411  2.73150E+02 9.75888E+02
tf22412  4.16668E+02 1.30172E+03
tf22413  5.60187E+02 1.62559E+03
tf22414  7.03705E+02 1.94518E+03
tf22415  8.47224E+02 2.25697E+03
tf22416  9.90742E+02 2.55602E+03
tf22417  1.13426E+03 2.83602E+03
tf22418  1.27778E+03 3.08952E+03
tf22419  1.42130E+03 3.30851E+03
tf22420  1.56482E+03 3.48520E+03
tf22421  1.70833E+03 3.61300E+03
tf22422  1.85185E+03 3.68760E+03
tf22423  1.99537E+03 3.70762E+03
tf22424  2.13889E+03 3.67499E+03
tf22425  2.28241E+03 3.59470E+03
tf22426  2.42593E+03 3.47412E+03
tf22427  2.56945E+03 3.32199E+03
tf22428  2.71296E+03 3.14742E+03
tf22429  2.85648E+03 2.95903E+03
tf22430  3.00000E+03 2.76435E+03
*
*-----
* tf 225: density vs. temp for UO2
*-----
*
tf22500  'UO2 d vs t' 2 1.0 0.0 * name, # data pairs, scale facts
tf22510  273.15 9850.0
tf22511  5000.0 9850.0
*
*
*-----

```

```

* SS
*-----
*
*   change default thermal conductivity, density and melting temp for SS
*
***
mpmat00700  stainless-steel
mpmat00701  thc  226
mpmat00702  rho  227
mpmat00703  cps  236
mpmat00704  enh  237
mpmat00705  tmp  238
mpmat00751  den  7954.0
mpmat00752  mlt  3799.0
mpmat00753  lhf  2.68e5
*
*-----
* tf 226: thermal cond vs temp for ss
*-----
tf22600  'thcss'  20  1.0
tf22611  2.73150E+02  1.27435E+01
tf22612  4.16668E+02  1.54560E+01
tf22613  5.60187E+02  1.81685E+01
tf22614  7.03705E+02  2.08810E+01
tf22615  8.47226E+02  2.35935E+01
tf22616  9.90742E+02  2.63060E+01
tf22617  1.13426E+03  2.90185E+01
tf22618  1.27778E+03  3.17310E+01
tf22619  1.42130E+03  3.44435E+01
tf22620  1.56482E+03  3.71560E+01
tf22621  1.70833E+03  2.63882E+01
tf22622  1.85185E+03  2.00000E+01
tf22623  1.99537E+03  2.00000E+01
tf22624  2.13889E+03  2.00000E+01
tf22625  2.28241E+03  2.00000E+01
tf22626  2.42593E+03  2.00000E+01
tf22627  2.56945E+03  2.00000E+01
tf22628  2.71296E+03  2.00000E+01
tf22629  2.85648E+03  2.00000E+01
tf22630  3.00000E+03  2.00000E+01
*
*-----
* tf 227: density vs. temp for SS
*-----
*
tf22700  'SS d vs t'  2  1.0  0.0  * name, # data pairs, scale facts
tf22710  273.15  7954.0
tf22711  5000.0  7954.0

```

```

*
*-----
* tf 236: spec heat capacity vs temp for ss
*-----
tf23600  'cpss'  16  1.0
tf23601  1  1
tf23611  273.15  475.6
tf23612  400.0  498.1
tf23613  500.0  515.8
tf23614  600.0  533.5
tf23615  700.0  551.3
tf23616  800.0  569.0
tf23617  900.0  586.7
tf23618  1000.0  604.4
tf23619  1100.0  622.1
tf23620  1200.0  639.8
tf23621  1300.0  657.5
tf23622  1400.0  675.2
tf23623  1500.0  693.0
tf23624  1600.0  710.7
tf23625  1700.0  728.4
tf23626  3800.0  728.4
*
*
*-----
* tf 237: specific enthalpy vs temp for ss
*-----
tf23700  'enhss'  18  1.0
tf23701  1  1
tf23711  300.0  0.0
tf23712  400.0  48926.0
tf23713  500.0  99624.0
tf23714  600.0  152092.0
tf23715  700.0  206332.0
tf23716  800.0  262343.0
tf23717  900.0  320125.0
tf23718  1000.0  379679.0
tf23719  1100.0  441003.0
tf23720  1200.0  504099.0
tf23721  1300.0  568966.0
tf23722  1400.0  635604.0
tf23723  1500.0  704014.0
tf23724  1600.0  774194.0
tf23725  1700.0  846146.0
tf23726  3799.0  2375058.0
tf23727  3799.01  2643058.0
tf23728  3800.0  2643786.0
*

```

```

*
*-----
* tf 238: temp vs. specific enthalpy for ss
*-----
tf23800 'tmpss' 18 1.0
tf23801 1 1
tf23811 0.0 300.0
tf23812 48926.0 400.0
tf23813 99624.0 500.0
tf23814 152092.0 600.0
tf23815 206332.0 700.0
tf23816 262343.0 800.0
tf23817 320125.0 900.0
tf23818 379679.0 1000.0
tf23819 441003.0 1100.0
tf23820 504099.0 1200.0
tf23821 568966.0 1300.0
tf23822 635604.0 1400.0
tf23823 704014.0 1500.0
tf23824 774194.0 1600.0
tf23825 846146.0 1700.0
tf23826 1114146.0 1700.01
tf23827 1186986.0 1800.0
tf23828 2643786.0 3800.0
*tf23826 2375058.0 3799.0
*tf23827 2643058.0 3799.01
*
*
*-----
* ZrO2
*-----
*
* change default thermal conductivity and density for ZrO2
*
***
mpmat00800 zirconium-oxide
mpmat00801 thc 228
mpmat00802 rho 229
mpmat00851 den 5700.0
*
*-----
* tf 228: thermal cond vs temp for ZrO2
*-----
tf22800 'thczro2' 20 1.0
tf22811 2.73150E+02 0.01
tf22812 4.16668E+02 0.01
tf22813 5.60187E+02 1.27067E-01
tf22814 7.03705E+02 4.05225E-01

```

```

tf22815  8.47228E+02  6.83382E-01
tf22816  9.90742E+02  9.61540E-01
tf22817  1.13426E+03  1.23970E+00
tf22818  1.27778E+03  1.51786E+00
tf22819  1.42130E+03  1.79601E+00
tf22820  1.56482E+03  2.07417E+00
tf22821  1.70833E+03  2.35233E+00
tf22822  1.85185E+03  2.55682E+00
tf22823  1.99537E+03  2.63081E+00
tf22824  2.13889E+03  2.70481E+00
tf22825  2.28241E+03  2.77881E+00
tf22826  2.42593E+03  2.85281E+00
tf22827  2.56945E+03  2.92681E+00
tf22828  2.71296E+03  3.00080E+00
tf22829  2.85648E+03  3.07480E+00
tf22830  3.00000E+03  3.14880E+00
*
*-----
* tf 229: density vs. temp for ZrO2
*-----
*
tf22900 'ZrO2 d vs t'  2  1.0  0.0  * name, # data pairs, scale facts
tf22910  273.15 5700.0
tf22911  5000.0 5700.0
*
*
*-----
* zirconia (porous)
*-----
*
* define a new material, porous zirconium oxide, which has
* properties similar to MELCOR default props except for
* density
*
* tabular functions 201-204:
* tf201: enthalpy vs temp, use standard MELCOR values
* tf202: temp vs enthalpy, use standard MELCOR values
* tf203: spec heat cap vs temp, use standard MELCOR values
* tf204: therm conductivity vs temp, use standard MELCOR values
* tf205: density vs temp, use 0.257 * Rho(ZrO2-dense)
*
mpmat10100 'zirconia (porous)'
*
mpmat10101  enh  201
mpmat10102  tmp  202
mpmat10103  cps  203
mpmat10104  thc  204
mpmat10105  rho  205

```

```

*
mpmat10151 den 1440.0 * 0.257 x rho(ZrO2-dense)
mpmat10152 mlt 2990.0
mpmat10153 lhf 7.06e5
*
*-----
* tf 201: enthalpy vs. temp for porous ZrO2
*-----
*
tf20100 'ZrO2(por) e vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf20101 1 1
tf20111 2.73150E+02 1.07126E+01
tf20112 4.16668E+02 7.48492E+04
tf20113 5.60187E+02 1.51506E+05
tf20114 7.03705E+02 2.29982E+05
tf20115 8.47224E+02 3.10277E+05
tf20116 9.90742E+02 3.92391E+05
tf20117 1.13426E+03 4.76323E+05
tf20118 1.27778E+03 5.62074E+05
tf20119 1.42130E+03 6.49644E+05
tf20120 1.56482E+03 7.39032E+05
tf20121 1.70833E+03 8.30240E+05
tf20122 1.85185E+03 9.23266E+05
tf20123 1.99537E+03 1.01811E+06
tf20124 2.13889E+03 1.11477E+06
tf20125 2.28241E+03 1.21326E+06
tf20126 2.42593E+03 1.31356E+06
tf20127 2.56945E+03 1.41568E+06
tf20128 2.71296E+03 1.51962E+06
tf20129 2.85648E+03 1.62537E+06
tf20130 3.00000E+03 2.43895E+06
*
*-----
* tf 202: temp vs. enthalpy for porous ZrO2
*-----
*
tf20200 'ZrO2(por) t vs e' 20 1.0 0.0 * name, # data pairs, scale facts
tf20201 1 1
tf20211 1.07126E+01 2.73150E+02
tf20212 7.48492E+04 4.16668E+02
tf20213 1.51506E+05 5.60187E+02
tf20214 2.29982E+05 7.03705E+02
tf20215 3.10277E+05 8.47224E+02
tf20216 3.92391E+05 9.90742E+02
tf20217 4.76323E+05 1.13426E+03
tf20218 5.62074E+05 1.27778E+03
tf20219 6.49644E+05 1.42130E+03
tf20220 7.39032E+05 1.56482E+03

```

```

tf20221    8.30240E+05    1.70833E+03
tf20222    9.23266E+05    1.85185E+03
tf20223    1.01811E+06    1.99537E+03
tf20224    1.11477E+06    2.13889E+03
tf20225    1.21326E+06    2.28241E+03
tf20226    1.31356E+06    2.42593E+03
tf20227    1.41568E+06    2.56945E+03
tf20228    1.51962E+06    2.71296E+03
tf20229    1.62537E+06    2.85648E+03
tf20230    2.43895E+06    3.00000E+03
*
*-----
* tf 203: cp vs. temp for porous ZrO2
*-----
*
tf20300 'ZrO2(por) cp vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf20311    2.73150E+02    5.15119E+02
tf20312    4.16668E+02    5.27792E+02
tf20313    5.60187E+02    5.40464E+02
tf20314    7.03705E+02    5.53137E+02
tf20315    8.47224E+02    5.65810E+02
tf20316    9.90742E+02    5.78483E+02
tf20317    1.13426E+03    5.91155E+02
tf20318    1.27778E+03    6.03828E+02
tf20319    1.42130E+03    6.16501E+02
tf20320    1.56482E+03    6.29173E+02
tf20321    1.70833E+03    6.41846E+02
tf20322    1.85185E+03    6.54519E+02
tf20323    1.99537E+03    6.67191E+02
tf20324    2.13889E+03    6.79864E+02
tf20325    2.28241E+03    6.92537E+02
tf20326    2.42593E+03    7.05209E+02
tf20327    2.56945E+03    7.17882E+02
tf20328    2.71296E+03    7.30555E+02
tf20329    2.85648E+03    7.43227E+02
tf20330    3.00000E+03    7.55900E+02
*
*-----
* tf 204: thermal cond vs. temp for porous ZrO2
*-----
*
tf20400 'ZrO2(por) k vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf20411    2.73150E+02    3.56528E-01
tf20412    4.16668E+02    4.12501E-01
tf20413    5.60187E+02    4.68473E-01
tf20414    7.03705E+02    5.24445E-01
tf20415    8.47224E+02    5.80417E-01
tf20416    9.90742E+02    6.36389E-01

```



```

tf20417      1.13426E+03      6.92362E-01
tf20418      1.27778E+03      7.48334E-01
tf20419      1.42130E+03      8.04306E-01
tf20420      1.56482E+03      8.60278E-01
tf20421      1.70833E+03      9.16250E-01
tf20422      1.85185E+03      9.72223E-01
tf20423      1.99537E+03      1.02819E+00
tf20424      2.13889E+03      1.12981E+00
tf20425      2.28241E+03      1.22467E+00
tf20426      2.42593E+03      1.31954E+00
tf20427      2.56945E+03      1.41440E+00
tf20428      2.71296E+03      1.50927E+00
tf20429      2.85648E+03      1.60413E+00
tf20430      3.00000E+03      1.69900E+00
*
*-----
* tf 205: density vs. temp for porous ZrO2
*-----
*
tf20500 'ZrO2(por) d vs t' 2 1.0 0.0 * name, # data pairs, scale facts
tf20510 273.15 1440.0
tf20511 5000.0 1440.0
*
*-----
* thoria
*-----
*
* tabular functions 211-214:
* tf211: enthalpy vs temp
* tf212: temp vs enthalpy
* tf213: spec heat cap vs temp
* tf214: therm conductivity vs temp
* tf215: density vs temp
*
mpmat10200 'thoria'
*
mpmat10201 enh 211
mpmat10202 tmp 212
mpmat10203 cps 213
mpmat10204 thc 214
mpmat10205 rho 215
*
mpmat10251 den 9860.0
mpmat10252 mlt 3320.0
mpmat10253 lhf 2.853e5
*
*-----
* tf 211: enthalpy vs. temp for thoria

```

```

*-----
*
tf21100 'thoria e vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf21101 1 1
tf21111 2.73150E+02 2.87695E+00
tf21112 4.16668E+02 3.50418E+04
tf21113 5.60187E+02 7.30700E+04
tf21114 7.03705E+02 1.12684E+05
tf21115 8.47224E+02 1.53431E+05
tf21116 9.90742E+02 1.95121E+05
tf21117 1.13426E+03 2.37660E+05
tf21118 1.27778E+03 2.80996E+05
tf21119 1.42130E+03 3.25099E+05
tf21120 1.56482E+03 3.69948E+05
tf21121 1.70833E+03 4.15531E+05
tf21122 1.85185E+03 4.61840E+05
tf21123 1.99537E+03 5.08866E+05
tf21124 2.13889E+03 5.56607E+05
tf21125 2.28241E+03 6.05058E+05
tf21126 2.42593E+03 6.54217E+05
tf21127 2.56945E+03 7.04081E+05
tf21128 2.71296E+03 7.54650E+05
tf21129 2.85648E+03 8.05921E+05
tf21130 3.00000E+03 8.57894E+05
*
*-----
* tf 212: temp vs. enthalpy for thoria
*-----
*
tf21200 'thoria t vs e' 20 1.0 0.0 * name, # data pairs, scale facts
tf21201 1 1
tf21211 2.87695E+00 2.73150E+02
tf21212 3.50418E+04 4.16668E+02
tf21213 7.30700E+04 5.60187E+02
tf21214 1.12684E+05 7.03705E+02
tf21215 1.53431E+05 8.47224E+02
tf21216 1.95121E+05 9.90742E+02
tf21217 2.37660E+05 1.13426E+03
tf21218 2.80996E+05 1.27778E+03
tf21219 3.25099E+05 1.42130E+03
tf21220 3.69948E+05 1.56482E+03
tf21221 4.15531E+05 1.70833E+03
tf21222 4.61840E+05 1.85185E+03
tf21223 5.08866E+05 1.99537E+03
tf21224 5.56607E+05 2.13889E+03
tf21225 6.05058E+05 2.28241E+03
tf21226 6.54217E+05 2.42593E+03
tf21227 7.04081E+05 2.56945E+03

```

```

tf21228      7.54650E+05      2.71296E+03
tf21229      8.05921E+05      2.85648E+03
tf21230      8.57894E+05      3.00000E+03
*
*-----
* tf 213: cp vs. temp for thoria
*-----
*
tf21300 'thoria cp vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf21301 1 1
tf21311      2.73150E+02      2.25329E+02
tf21312      4.16668E+02      2.57305E+02
tf21313      5.60187E+02      2.71284E+02
tf21314      7.03705E+02      2.80271E+02
tf21315      8.47224E+02      2.87338E+02
tf21316      9.90742E+02      2.93511E+02
tf21317      1.13426E+03      2.99212E+02
tf21318      1.27778E+03      3.04641E+02
tf21319      1.42130E+03      3.09901E+02
tf21320      1.56482E+03      3.15053E+02
tf21321      1.70833E+03      3.20130E+02
tf21322      1.85185E+03      3.25155E+02
tf21323      1.99537E+03      3.30142E+02
tf21324      2.13889E+03      3.35102E+02
tf21325      2.28241E+03      3.40040E+02
tf21326      2.42593E+03      3.44962E+02
tf21327      2.56945E+03      3.49871E+02
tf21328      2.71296E+03      3.54770E+02
tf21329      2.85648E+03      3.59661E+02
tf21330      3.00000E+03      3.64546E+02
*
*-----
* tf 214: thermal cond vs. temp for thoria
*-----
*
tf21400 'thoria k vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf21411      2.73150E+02      1.41632E+01
tf21412      4.16668E+02      9.92455E+00
tf21413      5.60187E+02      7.11986E+00
tf21414      7.03705E+02      5.35649E+00
tf21415      8.47224E+02      4.30518E+00
tf21416      9.90742E+02      3.69999E+00
tf21417      1.13426E+03      3.33838E+00
tf21418      1.27778E+03      3.08111E+00
tf21419      1.42130E+03      2.85236E+00
tf21420      1.56482E+03      2.63965E+00
tf21421      1.70833E+03      2.49874E+00
tf21422      1.85185E+03      2.49874E+00

```

```

tf21423  1.99537E+03  2.49874E+00
tf21424  2.13889E+03  2.49874E+00
tf21425  2.28241E+03  2.49874E+00
tf21426  2.42593E+03  2.49874E+00
tf21427  2.56945E+03  2.49874E+00
tf21428  2.71296E+03  2.49874E+00
tf21429  2.85648E+03  2.49874E+00
tf21430  3.00000E+03  2.49874E+00
*
*-----
* tf 215: density vs. temp for thoria
*-----
*
tf21500 'thoria d vs t'  2  1.0  0.0  * name, # data pairs, scale facts
tf21510   273.15 9860.0
tf21511   5000.0 9860.0
*
*-----
* tantalum
*-----
*
* tabular functions 231-235:
* tf231: enthalpy vs temp
* tf232: temp vs enthalpy
* tf233: spec heat cap vs temp
* tf234: therm conductivity vs temp
* tf235: density vs temp
*
mpmat10300 'tantalum'
*
mpmat10301  enh  231
mpmat10302  tmp  232
mpmat10303  cps  233
mpmat10304  thc  234
mpmat10305  rho  235
*
mpmat10351  den  9860.0
mpmat10352  mlt  3320.0
mpmat10353  lhf  2.853e5
*
*-----
* tf 231: enthalpy vs. temp for tantalum
*-----
*
tf23100 'tantalum e vs t'  20  1.0  0.0  * name, # data pairs, scale facts
tf23101  1  1
tf23111   2.73150E+02   4.94962E+02
tf23112   4.16668E+02   2.12159E+04

```

tf23113	5.60187E+02	4.22127E+04
tf23114	7.03705E+02	6.34852E+04
tf23115	8.47224E+02	8.50336E+04
tf23116	9.90742E+02	1.06858E+05
tf23117	1.13426E+03	1.28958E+05
tf23118	1.27778E+03	1.51333E+05
tf23119	1.42130E+03	1.73985E+05
tf23120	1.56482E+03	1.96912E+05
tf23121	1.70833E+03	2.20116E+05
tf23122	1.85185E+03	2.43595E+05
tf23123	1.99537E+03	2.67349E+05
tf23124	2.13889E+03	2.91380E+05
tf23125	2.28241E+03	3.15686E+05
tf23126	2.42593E+03	3.40268E+05
tf23127	2.56945E+03	3.65126E+05
tf23128	2.71296E+03	3.90260E+05
tf23129	2.85648E+03	4.15670E+05
tf23130	3.00000E+03	4.41355E+05

*

*-----

* tf 232: temp vs. enthalpy for tantalum

*-----

*

tf23200 'tantalum t vs e' 20 1.0 0.0 * name, # data pairs, scale facts

tf23201 1 1

tf23211	4.94962E+02	2.73150E+02
tf23212	2.12159E+04	4.16668E+02
tf23213	4.22127E+04	5.60187E+02
tf23214	6.34852E+04	7.03705E+02
tf23215	8.50336E+04	8.47224E+02
tf23216	1.06858E+05	9.90742E+02
tf23217	1.28958E+05	1.13426E+03
tf23218	1.51333E+05	1.27778E+03
tf23219	1.73985E+05	1.42130E+03
tf23220	1.96912E+05	1.56482E+03
tf23221	2.20116E+05	1.70833E+03
tf23222	2.43595E+05	1.85185E+03
tf23223	2.67349E+05	1.99537E+03
tf23224	2.91380E+05	2.13889E+03
tf23225	3.15686E+05	2.28241E+03
tf23226	3.40268E+05	2.42593E+03
tf23227	3.65126E+05	2.56945E+03
tf23228	3.90260E+05	2.71296E+03
tf23229	4.15670E+05	2.85648E+03
tf23230	4.41355E+05	3.00000E+03

*

*-----

* tf 233: cp vs. temp for tantalum

```

*-----
*
tf23300 'tantalum cp vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf23301 1 1
tf23311 2.73150E+02 1.43417E+02
tf23312 4.16668E+02 1.45339E+02
tf23313 5.60187E+02 1.47261E+02
tf23314 7.03705E+02 1.49183E+02
tf23315 8.47224E+02 1.51104E+02
tf23316 9.90742E+02 1.53026E+02
tf23317 1.13426E+03 1.54948E+02
tf23318 1.27778E+03 1.56869E+02
tf23319 1.42130E+03 1.58791E+02
tf23320 1.56482E+03 1.60713E+02
tf23321 1.70833E+03 1.62635E+02
tf23322 1.85185E+03 1.64556E+02
tf23323 1.99537E+03 1.66478E+02
tf23324 2.13889E+03 1.68400E+02
tf23325 2.28241E+03 1.70321E+02
tf23326 2.42593E+03 1.72243E+02
tf23327 2.56945E+03 1.74165E+02
tf23328 2.71296E+03 1.76087E+02
tf23329 2.85648E+03 1.78008E+02
tf23330 3.00000E+03 1.79930E+02
*
*-----
* tf 234: thermal cond vs. temp for tantalum
*-----
*
tf23400 'tantalum k vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf23411 2.73150E+02 7.15522E+01
tf23412 4.16668E+02 6.95105E+01
tf23413 5.60187E+02 6.74688E+01
tf23414 7.03705E+02 6.59461E+01
tf23415 8.47224E+02 6.45650E+01
tf23416 9.90742E+02 6.31839E+01
tf23417 1.13426E+03 6.26736E+01
tf23418 1.27778E+03 6.23133E+01
tf23419 1.42130E+03 6.19530E+01
tf23420 1.56482E+03 6.15927E+01
tf23421 1.70833E+03 6.12324E+01
tf23422 1.85185E+03 7.26125E+01
tf23423 1.99537E+03 7.36133E+01
tf23424 2.13889E+03 7.46141E+01
tf23425 2.28241E+03 7.56149E+01
tf23426 2.42593E+03 7.66157E+01
tf23427 2.56945E+03 7.76165E+01
tf23428 2.71296E+03 7.86173E+01

```

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```

tf23429    2.85648E+03    7.96181E+01
tf23430    3.00000E+03    8.06189E+01
*
*-----
* tf 235: density vs. temp for tantalum
*-----
*
tf23500 'tantalum d vs t' 2 1.0 0.0 * name, # data pairs, scale facts
tf23510 273.15 16600.0
tf23511 5000.0 16600.0
*
r*i*f 'sens.dat'
.
*eor* melcor
*
* MELCOR MP1 input deck
*
* started 8/20/93
*
nocopy
forceplot 0.05 5
softdtmin .01 1000
cymesf 100 10
*
*****
* exec package input *
*****
*
title      'mp1'
jobid      'mp1'
*
diagf      'mp1.dia'
outputf    'mp1.out'
plotf      'mp1.ptf'
messagef   'mp1.mes'
restartf    'mp1.rst'
statusf    'mp1.mai'
crtout
*
*
restart 0
cpuleft 10.
cpulim 1.e6
*
*tend
tend      10000.0
*
*****

```

```

*          time    dtmax    dtmin    dtedt    dtplt    dtrst    dcrest
*
time1      1900.0    0.1      0.0001    2000.0     50.0     1000.0
*
time2      8500.0    0.1      0.0001     500.0      50.0      500.0
*
time3      9600.0    1.0      0.001     500.0     100.0     500.0
*
*****
*
* enable additional cor output
*
coredv01  1  1  1  1  1  1 * turn on volume fraction plot output
*
* disable dt/dz (no steam flow)
*
cortst01  0  0  0  0  0  1  1  0  0  0
*
r*i*f 'sens2.dat'
*
.
*
*eor*hispltm
file1  'mp1.ptf'
title, mp1 experiment base case
nologo,wide
*
*
title, debris reg debris temps, axial level 8
vlabel, temperature (K)
limits 2000.0, 10000.0, 0.0, 3500.0
plot, time, cor-tdp.108, line = solid, sym='1', le='ring 1', file=1
cplot, time, cor-tdp.208, line = dot, sym='2', le='ring 2', file=1
cplot, time, cor-tdp.308, line = sdash, sym='3', le='ring 3', file=1
data, le='DBC1100', line = dot, sym=', '
*readfile, '/user/tjtautg/mp1/data/debris.dat', 'DBC1100'
data, le='DBC1113', line = dot, sym=', '
*readfile, '/user/tjtautg/mp1/data/debris.dat', 'DBC1113'
lege,lr
*
title, debris reg debris temps, axial level 9
vlabel, temperature (K)
limits 2000.0, 10000.0, 0.0, 3500.0
plot, time, cor-tdp.109, line = solid, sym='1', le='ring 1', file=1
cplot, time, cor-tdp.209, line = dot, sym='2', le='ring 2', file=1
cplot, time, cor-tdp.309, line = sdash, sym='3', le='ring 3', file=1
data, le='DBC1300', line = dot, sym=', '
*readfile, '/user/tjtautg/mp1/data/debris.dat', 'DBC1300'

```

```

data, le='DBC1339', line = dot, sym=''
*readfile,'/user/tjtautg/mp1/data/debris.dat','DBC1339'
lege,lr
*
title, debris reg debris temps, axial level 10
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 3500.0
plot, time, cor-tdp.110, line = solid, sym='1', le='ring 1', file=1
cplot, time, cor-tdp.210, line = dot, sym='2', le='ring 2', file=1
cplot, time, cor-tdp.310, line = sdash, sym='3', le='ring 3', file=1
data, le='DBC1500', line = dot, sym=', '
*readfile,'/user/tjtautg/mp1/data/debris.dat','DBC1500'
data, le='DBC1526', line = dot, sym=''
*readfile,'/user/tjtautg/mp1/data/debris.dat','DBC1526'
lege,lr
*
title, debris reg debris temps, axial level 11
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 3500.0
plot, time, cor-tdp.111, line = solid, sym='1', le='ring 1', file=1
cplot, time, cor-tdp.211, line = dot, sym='2', le='ring 2', file=1
cplot, time, cor-tdp.311, line = sdash, sym='3', le='ring 3', file=1
data, le='DBC1800', line = dot, sym=', '
*readfile,'/user/tjtautg/mp1/data/debris.dat','DBC1800'
lege,lr
*
title, debris reg debris temps, ring 1
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 3500.0
plot, time, cor-tdp.113, line = solid, sym='3', le='level 13', file=1
cplot, time, cor-tdp.112, line = dot, sym='2', le='level 12', file=1
cplot, time, cor-tdp.111, line = sdash, sym='1', le='level 11', file=1
cplot, time, cor-tdp.110, line = mdash, sym='0', le='level 10', file=1
cplot, time, cor-tdp.109, line = ldash, sym='9', le='level 9', file=1
cplot, time, cor-tdp.108, line = dotdash, sym='8', le='level 8', file=1
data, le='DBC1100', line = dot, sym=', '
*readfile,'/user/tjtautg/mp1/data/debris.dat','DBC1100'
data, le='DBC1300', line = dot, sym=''
*readfile,'/user/tjtautg/mp1/data/debris.dat','DBC1300'
data, le='DBC1500', line = dot, sym='&'
*readfile,'/user/tjtautg/mp1/data/debris.dat','DBC1500'
data, le='DBC1800', line = dot, sym='<'
*readfile,'/user/tjtautg/mp1/data/debris.dat','DBC1800'
lege,lr
*
title, debris reg debris temps, ring 2
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 3500.0

```

```

plot, time, cor-tdp.213, line = solid, sym='3', le='level 13', file=1
cplot, time, cor-tdp.212, line = dot, sym='2', le='level 12', file=1
cplot, time, cor-tdp.211, line = sdash, sym='1', le='level 11', file=1
cplot, time, cor-tdp.210, line = mdash, sym='0', le='level 10', file=1
cplot, time, cor-tdp.209, line = ldash, sym='9', le='level 9', file=1
cplot, time, cor-tdp.208, line = dotdash, sym='8', le='level 8', file=1
data, le='DBC1113', line = dot, sym=', '
*readfile, '/user/tjtautg/mp1/data/debris.dat', 'DBC1113'
data, le='DBC1526', line = dot, sym='''
*readfile, '/user/tjtautg/mp1/data/debris.dat', 'DBC1526'
lege,lr
*
title, debris reg debris temps, ring 3
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 3500.0
plot, time, cor-tdp.313, line = solid, sym='3', le='level 13', file=1
cplot, time, cor-tdp.312, line = dot, sym='2', le='level 12', file=1
cplot, time, cor-tdp.311, line = sdash, sym='1', le='level 11', file=1
cplot, time, cor-tdp.310, line = mdash, sym='0', le='level 10', file=1
cplot, time, cor-tdp.309, line = ldash, sym='9', le='level 9', file=1
cplot, time, cor-tdp.308, line = dotdash, sym='8', le='level 8', file=1
data, le='DBC1339', line = dot, sym=', '
*readfile, '/user/tjtautg/mp1/data/debris.dat', 'DBC1339'
data, le='DBC1526', line = dot, sym='''
*readfile, '/user/tjtautg/mp1/data/debris.dat', 'DBC1526'
lege,lr
*
title, crust reg clad temps, axial level 5
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tcl.105, line = solid, sym='1', le='ring 1', file=1
cplot, time, cor-tcl.205, line = dotdash, sym='2', le='ring 2', file=1
cplot, time, cor-tcl.305, line = sdash, sym='3', le='ring 3', file=1
data, le='CRC63-2', line = dot, sym=', '
*readfile, '/user/tjtautg/mp1/data/crust.dat', 'CRC63-2'
data, le='CRC63-4', line = dot, sym='''
*readfile, '/user/tjtautg/mp1/data/crust.dat', 'CRC63-4'
lege,lr
*
title, crust reg clad temps, axial level 6
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tcl.106, line = solid, sym='1', le='ring 1', file=1
cplot, time, cor-tcl.206, line = dotdash, sym='2', le='ring 2', file=1
cplot, time, cor-tcl.306, line = sdash, sym='3', le='ring 3', file=1
data, le='CRC73-0', line = dot, sym=', '
*readfile, '/user/tjtautg/mp1/data/crust.dat', 'CRC73-0'
lege,lr

```

```

*
title, crust reg clad temps, axial level 7
vlabel, temperature (K)
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tcl.107, line = solid, sym='1', le='ring 1', file=1
cplot, time, cor-tcl.207, line = dotdash, sym='2', le='ring 2', file=1
cplot, time, cor-tcl.307, line = sdash, sym='3', le='ring 3', file=1
data, le='CRC82-1', line = dot, sym='',
*readfile,'/user/tjtautg/mp1/data/crust.dat','CRC82-1'
data, le='CRC82-3', line = dot, sym=''
*readfile,'/user/tjtautg/mp1/data/crust.dat','CRC82-3'
lege,lr
*
title, crust reg clad temps, ring 1
vlabel, temperature (K)
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tcl.107, line = solid, sym='7', le='level 7', file=1
cplot, time, cor-tcl.106, line = dotdash, sym='6', le='level 6', file=1
cplot, time, cor-tcl.105, line = sdash, sym='5', le='level 5', file=1
data, le='CRC73-0', line = dot, sym='',
*readfile,'/user/tjtautg/mp1/data/crust.dat','CRC73-0'
lege,lr
*
title, crust reg clad temps, ring 2
vlabel, temperature (K)
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tcl.207, line = solid, sym='7', le='level 7', file=1
cplot, time, cor-tcl.206, line = dotdash, sym='6', le='level 6', file=1
cplot, time, cor-tcl.205, line = sdash, sym='5', le='level 5', file=1
data, le='CRC63-2', line = dot, sym='',
*readfile,'/user/tjtautg/mp1/data/crust.dat','CRC63-2'
data, le='CRC63-4', line = dot, sym=''
*readfile,'/user/tjtautg/mp1/data/crust.dat','CRC63-4'
data, le='CRC82-1', line = dot, sym='&'
*readfile,'/user/tjtautg/mp1/data/crust.dat','CRC82-1'
data, le='CRC82-3', line = dot, sym='<'
*readfile,'/user/tjtautg/mp1/data/crust.dat','CRC82-3'
lege,lr
*
title, crust reg clad temps, ring 3
vlabel, temperature (K)
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tcl.307, line = solid, sym='7', le='level 7', file=1
cplot, time, cor-tcl.306, line = dotdash, sym='6', le='level 6', file=1
cplot, time, cor-tcl.305, line = sdash, sym='5', le='level 5', file=1
lege,lr
*
title, stub reg clad and os temps, axial levels 1 & 2

```

```

vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tcl.102, line = solid, sym='1', le='clad, ring 1', file=1
cplot, time, cor-tcl.202, line = dotdash, sym='2', le='clad, ring 2', file=1
cplot, time, cor-tcl.302, line = sdash, sym='3', le='clad, ring 3', file=1
cplot, time, cor-tss.101, line = mdash, sym='1', le='os, ring 1', file=1
cplot, time, cor-tss.201, line = dashdash, sym='2', le='os, ring 2', file=1
cplot, time, cor-tss.301, line = ldash, sym='3', le='os, ring 3', file=1
data, le='GSK0013', line = dot, sym='<'
*readfile,'/user/tjtautg/mp1/data/stub.dat','GSK0013'
data, le='GSK0018', line = dot, sym='@'
*readfile,'/user/tjtautg/mp1/data/stub.dat','GSK0018'
lege,ul
*
title, stub reg clad temps, axial level 3
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tcl.103, line = solid, sym='1', le='ring 1', file=1
cplot, time, cor-tcl.203, line = dotdash, sym='2', le='ring 2', file=1
cplot, time, cor-tcl.303, line = sdash, sym='3', le='ring 3', file=1
data, le='FRK2714', line = dot, sym=', '
*readfile,'/user/tjtautg/mp1/data/stub.dat','FRK2714'
data, le='FRK2731', line = dot, sym='''
*readfile,'/user/tjtautg/mp1/data/stub.dat','FRK2731'
lege,ul
*
title, stub reg clad temps, axial level 4
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tcl.104, line = solid, sym='4', le='ring 1', file=1
cplot, time, cor-tcl.204, line = dotdash, sym='3', le='ring 2', file=1
cplot, time, cor-tcl.304, line = sdash, sym='2', le='ring 3', file=1
data, le='FRS5400', line = dot, sym=', '
*readfile,'/user/tjtautg/mp1/data/crust.dat','FRS5400'
data, le='FRK5444', line = dot, sym='''
*readfile,'/user/tjtautg/mp1/data/crust.dat','FRK5444'
lege,ul
*
title, stub reg clad temps, ring 1
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tcl.104, line = solid, sym='4', le='level 4', file=1
cplot, time, cor-tcl.103, line = dotdash, sym='3', le='level 3', file=1
cplot, time, cor-tcl.102, line = sdash, sym='2', le='level 2', file=1
data, le='FRS5400', line = dot, sym=', '
*readfile,'/user/tjtautg/mp1/data/crust.dat','FRS5400'
data, le='FRK2714', line = dot, sym='''
*readfile,'/user/tjtautg/mp1/data/stub.dat','FRK2714'

```

```

lege,lr
*
title, stub reg clad temps, ring 2
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tcl.204, line = solid, sym='4', le='level 4', file=1
cplot, time, cor-tcl.203, line = dotdash, sym='3', le='level 3', file=1
cplot, time, cor-tcl.202, line = sdash, sym='2', le='level 2', file=1
data, le='FRK2731', line = dot, sym=', '
*readfile, '/user/tjtautg/mp1/data/stub.dat', 'FRK2731'
lege,lr
*
title, stub reg clad temps, ring 3
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tcl.304, line = solid, sym='4', le='level 4', file=1
cplot, time, cor-tcl.303, line = dotdash, sym='3', le='level 3', file=1
cplot, time, cor-tcl.302, line = sdash, sym='2', le='level 2', file=1
data, le='FRK5444', line = dot, sym=', '
*readfile, '/user/tjtautg/mp1/data/crust.dat', 'FRK5444'
lege,lr
*
title, structure temperatures
vlabel, temperature (())K
limits 2000.0, 10000.0, 0.0, 2500.0
plot, time, cor-tss.301, line = solid, sym='.', le='os, level 1', file=1
cplot, time, cor-tss.307, line = sdash, sym='%', le='os, level 7', file=1
cplot, time, hs-temp.1000001, line = dotdash, sym=',', le='hs10000', file=1
cplot, time, hs-temp.1020701, line = ldash, sym='"', le='hs10207', file=1
lege,ul
*
title, time steps
vlabel, time step (())s
limits 0, 0, 0, 0
plot, time, dt, line = solid, sym=',', le='system', file=1
cplot, time, cor-dt, line = dot, sym='"', le='cor', file=1
lege,ul
*
title, cvh volume pressures
vlabel, pressure (())Pa
limits 0, 0, 0, 0
plot, time, cvh-p.101, line = solid, sym='1', le='cv 101', file=1
cplot, time, cvh-p.102, line = dot, sym='2', le='cv 102', file=1
cplot, time, cvh-p.103, line = sdash, sym='3', le='cv 103', file=1
lege,ul
*
title, cvh volume temperatures
vlabel, temperature (())K

```

```

limits 0, 0, 0, 0
plot, time, cvh-tvap.101, line = solid, sym='1', le='cv 101', file=1
cplot, time, cvh-tvap.102, line = dot, sym='2', le='cv 102', file=1
cplot, time, cvh-tvap.103, line = sdash, sym='3', le='cv 103', file=1
lege,ul
*
title, ACRR Power
vlabel, Power (kW)
ulabel, TIME (s)
limits 0, 10000, 0, 0
uplot, line = solid, sym=', '
*readfile, '/user/tjtautg/mp1/data/reapow.dat'
-12345,-12345
lege,ul
*

```

B.2 MP-2

```

*eor* melgen
*
*
* 10/25 began designing mp2 deck
* 10/27 use bundle power from data file for fission power
* 10/28 corrected peaking factors to use integrated shape
*      factors; implemented mass-dependent fission power
* 10/29 changed critical minimum Zr thickness to 0 to hold
*      up fuel pellets in the crust region; removed add
*      factor of 273.15 from hs boundary temp cf
* 11/1  used tskpcs2 and tskpcs3 for hs bound temps
*
*
*****
* exec package input *
*****
*
title      'mp2'
restartf   'mp2.rst'
outputf    'mp2.gout'
diagf      'mp2.gdia'
*
tstart 25.0 * initial problem time is 25.0
*
*****
* cor package input *
*****
*
*-----

```



```

* general core input
*-----
*      nrad naxl ntlp ncvol nlh npntot
cor00000  3   15   1   3   10   1 *
*      rfuel  rclad  drgap  pitch  dxcan  dxss  dzlh
cor00001  4.51e-3  4.815e-3  7.6e-4  1.27e-2  1.0e0  1.0e0  1.26e-1
cor00002  pwr  ag-in-cd                * bwr type, b4c poison
* view factors: can-clad, sheath-can, cell-cell(rad), cell-cell(axial),
*      pool-struc  (from MELPROG DF-4 report)
cor00003      0.25      0.25      0.25  0.25  0.25
*
cor00004  0  -15  0 * no TP, cf #10 for fission power, no extra gap cond
*
cor00008  0.0  0.0 * critical minimum thicknesses for zr, steel
*
* increase failure temperature for lower head and penetrations
*
cor00009  1000.0  1000.0  3800.0  1.0 * htc's for pen, lh, lh failure temp
*
cor00011  5  helium  1.0e-6  2.24e-4 * gap cond from pd, helium gap,
*      * thickness, Rdif
*
*-----
* axial segment input
*-----
*
* axial geometry
corz0101 -12.6e-2  12.6e-2  0.750  0.513 * zbot, dz, porosities
corz0201  0.0      2.00e-2  0.750  0.513 * zbot, dz, porosities
corz0301  2.00e-2  2.00e-2   0.750  0.513 *
corz0401  4.00e-2  2.00e-2   0.750  0.513 *
corz0501  6.00e-2  2.00e-2   0.750  0.513 *
corz0601  8.00e-2  2.00e-2   0.750  0.513 *
corz0701  10.0e-2  1.167e-2  0.750  0.513 *
corz0801  11.167e-2  1.167e-2  0.750  0.513 *
corz0901  12.333e-2  1.167e-2  0.750  0.513 *
* set intact porosity to almost 1 to support debris
corz1001  13.50e-2  2.75e-2  0.750  0.513 *
corz1101  16.25e-2  2.75e-2  0.750  0.513 *
corz1201  19.00e-2  2.75e-2  0.750  0.513 *
corz1301  21.75e-2  2.75e-2  0.750  0.513 *
corz1401  24.50e-2  2.75e-2  0.750  0.513 *
corz1501  27.25e-2  2.75e-2  0.750  0.513 *
* boundary heat structures, isup
corz0102  10000  10 *
corz0202  10102  10 *
corz0302  10103  0 *
corz0402  10104  0 *

```

```

corz0502 10105 0 *
corz0602 10106 0 *
corz0702 10207 01 *
corz0802 10208 0 *
corz0902 10209 01 *
Corz1002 10310 0 *
corz1102 10311 0 *
corz1202 10312 0 *
corz1302 10313 0 *
corz1402 10314 0 *
corz1502 10315 0 *
*
* axial peaking factors
*
corz0103 0.0
corz0203 .315
corz0303 .345
corz0403 .352
corz0503 .371
corz0603 .487
corz0703 .183
corz0803 .157
corz0903 .164
corz1003 2.397
corz1103 2.433
corz1203 2.470
corz1303 2.325
corz1403 2.362
corz1503 2.760
*
* radial input:
corr0101 6.158e-4 * ring cross-sectional area
corr0201 1.675e-3 * ring cross-sectional area
corr0301 3.682e-3 * ring cross-sectional area
*
corr0102 10116 * upper boundary heat structure
corr0202 10116 * upper boundary heat structure
corr0302 10116 * upper boundary heat structure
*
* radial peaking factors
*
corr0103 0.638
corr0203 0.758
corr0303 1.604
*
* cell-specific input:
*
*-----

```

* lower plenum cells:

*-----

*

cor10101 -1 101 * no ref cell, channel, bypass cvh volumes
cor10102 0.0 0.0 6.171e-1 0.0 0.0 0.0 0.0 0.0 * fuel, clad masses
cor10103 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
* Dhyd: clad sheath part deb can in can out
cor10104 1.0e-2 1.0e-2 8.724e-2 2.0e-3 1.0e-2 1.0e-2
cor10105 1.108e-2 0.0 * radial bound area, channel, byp area
* surf area: fuel, clad, os, can in
cor10106 0.0 0.0 1.108e-2 0.0

*

cor20101 101 101 * no ref cell, channel, bypass cvh volumes
cor20102 0.0 0.0 1.678e0 0.0 0.0 0.0 0.0 0.0 * fuel, clad masses
cor20105 2.138e-2 0.0 * radial bound area, channel, byp area
* surf area: fuel, clad, os, can in
cor20106 0.0 0.0 2.138e-2 0.0

*

cor30101 101 101 * no ref cell, channel, bypass cvh volumes
cor30102 0.0 0.0 3.690e0 0.0 0.0 0.0 0.0 0.0 * fuel, clad masses
cor30105 3.452e-2 0.0 * radial bound area, channel, byp area
* surf area: fuel, clad, os, can in
cor30106 0.0 0.0 3.452e-2 0.0

*

*-----

* stub region:

*-----

*

* ring 1:

*

cor10201 -1 101 * no ref cell, channel, bypass cvh volumes
cor10202 4.779e-2 1.037e-2 0.0 0.0 0.0 0.0 0.0 0.0 * fuel, clad masses
cor10203 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
* Dhyd: clad sheath part deb can in can out
cor10204 9.630e-3 1.0e-2 2.0e-3 1.0e-2 1.0e-2
cor10205 1.759e-3 3.245e-4 * radial bound area, channel, byp area
* surf area: fuel, clad, os, can in
cor10206 2.269e-3 2.421e-3 0.0 0.0

*

cor10301 102 101 * ref cell, channel cvh volume
cor10303 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
cor10401 102 101 * ref cell, channel cvh volume
cor10403 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
cor10501 102 101 * ref cell, channel cvh volume
cor10503 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
cor10601 102 101 * ref cell, channel cvh volume
cor10603 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)

*

```

* ring 2:
*
cor20201 102 101 * ref cell, channel, bypass cvh volumes
cor20202 1.195e-1 2.593e-2 0.0 0.0 0.0 0.0 0.0 0.0 * fuel, clad masses
cor20203 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
cor20205 3.393e-3 9.466e-4 * radial bound area, channel, byp area
* surf area: fuel, clad, os, can in
cor20206 5.671e-3 6.053e-3 0.0 0.0
*
cor20301 202 101 * ref cell, channel cvh volume
cor20303 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
cor20401 202 101 * ref cell, channel cvh volume
cor20403 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
cor20501 202 101 * ref cell, channel cvh volume
cor20503 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,cs,cn,cb,dp)
cor20601 202 101 * ref cell, channel cvh volume
cor20603 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
*
*
* ring 3:
*
cor30201 102 101 * ref cell, channel, bypass cvh volumes
cor30202 2.151e-1 4.668e-2 * fuel, clad masses
cor30203 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
cor30205 5.479e-3 2.371e-3 * radial bound area, channel, byp area
* surf area: fuel, clad, os, can in
cor30206 1.021e-2 1.090e-2 0.0 0.0
*
cor30301 302 101 * ref cell, channel cvh volume
cor30303 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
cor30401 302 101 * ref cell, channel cvh volume
cor30403 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
cor30501 302 101 * ref cell, channel cvh volume
cor30503 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
cor30601 302 101 * ref cell, channel cvh volume
cor30603 300.0 300.0 300.0 300.0 300.0 300.0 * T(fu,cl,os,cn,cb,dp)
*
*-----
* crust region:
*-----
*
* ring 1:
*
cor10701 -1 102 * ref cell, channel, bypass cvh volumes
cor10703 305.0 305.0 305.0 305.0 305.0 305.0 * T(fu,cl,os,cn,cb,dp)
cor10704 9.630e-3 1.0e-2 2.0e-3 1.0e-2 1.0e-2 * Dh:cl,os,dp,cni,cno
cor10705 1.027e-3 3.245e-4 * radial bound area, channel, byp area
cor10706 1.323e-3 1.412e-3 0.0 0.0 * surf a: fu, cl, os, cani

```

```

cor107kfu 2.554e-2 0.0 * alternate fuel mass specification
cor107kcl 5.083e-3 0.0 0.0 * alternate clad mass specification
* cong deb: UO2, Zr, ZrO2, SS, SSox, CRP
cor107ycl 2.704e-3 1.232e-2 4.54e-3 7.263e-3 0.0 6.163e-3
*
cor10801 107 102 * ref cell, channel cvh volume
cor10803 301.2 301.2 301.2 301.2 301.2 301.2 * T(fu,cl,os,cn,cb,dp)
cor10901 107 102 * ref cell, channel cvh volume
cor10903 301.1 301.1 301.1 301.1 301.1 301.1 * T(fu,cl,os,cn,cb,dp)
*
* ring 2:
*
cor20701 107 102 * ref cell, channel, bypass cvh volumes
cor20703 305.0 305.0 305.0 305.0 305.0 305.0 * T(fu,cl,os,cn,cb,dp)
cor20706 3.306e-3 3.529e-3 0.0 0.0 * surf a: fu, cl, os, cani
cor207kfu 6.384e-2 0.0 * alternate fuel mass specification
cor207kcl 1.271e-2 0.0 0.0 * alternate clad mass specification
* cong deb: UO2, Zr, ZrO2, SS, SSox, CRP
cor207ycl 6.760e-3 3.081e-2 1.135e-2 1.816e-2 0.0 1.541e-2
cor20705 1.980e-3 9.466e-4 * radial bound area, channel, byp area
*
cor20801 207 102 * ref cell, channel cvh volume
cor20803 301.2 301.2 301.2 301.2 301.2 301.2 * T(fu,cl,os,cn,cb,dp)
cor20901 207 102 * ref cell, channel cvh volume
cor20903 301.1 301.1 301.1 301.1 301.1 301.1 * T(fu,cl,os,cn,cb,dp)
*
*
* ring 3:
*
cor30701 107 102 * ref cell, channel, bypass cvh volumes
cor30703 305.0 305.0 305.0 305.0 305.0 305.0 * T(fu,cl,os,cn,cb,dp)
*cor30705 3.197e-3 2.371e-3 * radial bound area, channel, byp area
cor30705 3.197e-3 1.74144e-3 * radial bound area, channel, byp area
cor30706 5.951e-3 6.353e-3 0.0 0.0 * surf a: fu, cl, os, cani
cor307kfu 1.149e-1 0.0 * alternate fuel mass specification
cor307kcl 2.288e-2 0.0 0.0 * alternate clad mass specification
* cong deb: UO2, Zr, ZrO2, SS, SSox, CRP
cor307ycl 1.217e-2 5.546e-2 2.043e-2 3.268e-2 0.0 2.773e-2
*
cor30801 307 102 * ref cell, channel cvh volume
cor30803 301.2 301.2 301.2 301.2 301.2 301.2 * T(fu,cl,os,cn,cb,dp)
cor30901 307 102 * ref cell, channel cvh volume
cor30903 301.1 301.1 301.1 301.1 301.1 301.1 * T(fu,cl,os,cn,cb,dp)
*
*-----
* debris region:
*-----
*

```

```

*
* ring 1:
*
cor11001 -1 103 * ref cell, channel, bypass cvh volumes
cor11004 9.630e-3 1.0e-2 2.0e-3 1.0e-2 1.0e-2 * Dh:cl,os,dp,cni,cno
*cor11005 2.401e-3 6.158e-4 * radial bound area, channel, byp area
cor11005 2.401e-3 6.156e-4 * radial bound area, channel, byp area
cor11006 0.0 0.0 0.0 0.0 * surf area: fuel, clad, os, can in
cor110kfu 0.0 0.0 * alternate fuel mass specification
cor110kcl 0.0 0.0 0.0 * alternate clad mass specification
cor110kdp 5.731e-2 0.0 1.191e-2 * part deb masses: UO2, Zr, ZrO2
*
cor11101 110 103 * ref cell, channel cvh volume
cor11201 110 103 * ref cell, channel cvh volume
cor11301 110 103 * ref cell, channel cvh volume
cor11401 110 103 * ref cell, channel cvh volume
cor11501 110 103 * ref cell, channel cvh volume
*

* initial temps:
cor11003 307.9 307.9 307.9 307.9 307.9 307.9 * T(fu,cl,os,cn,cb,dp)
cor11103 318.3 318.3 318.3 318.3 318.3 318.3 * T(fu,cl,os,cn,cb,dp)
cor11203 318.1 318.1 318.1 318.1 318.1 318.1 * T(fu,cl,os,cn,cb,dp)
cor11303 318.1 318.1 318.1 318.1 318.1 318.1 * T(fu,cl,os,cn,cb,dp)
cor11403 316.1 316.1 316.1 316.1 316.1 316.1 * T(fu,cl,os,cn,cb,dp)
cor11503 306.3 306.3 306.3 306.3 306.3 306.3 * T(fu,cl,os,cn,cb,dp)
*

* ring 2:
*
cor21001 110 103 * ref cell, channel, bypass cvh volumes
cor21005 4.631e-3 1.675e-3 * radial bound area, channel, byp area
cor21006 0.0 0.0 0.0 0.0 * surf area: fuel, clad, os, can in
cor210kfu 0.0 0.0 * alternate fuel mass specification
cor210kcl 0.0 0.0 0.0 * alternate clad mass specification
cor210kdp 1.672e-1 0.0 3.475e-2 * part deb masses: UO2, Zr, ZrO2
*
cor21101 210 103 * ref cell, channel cvh volume
cor21201 210 103 * ref cell, channel cvh volume
cor21301 210 103 * ref cell, channel cvh volume
cor21401 210 103 * ref cell, channel cvh volume
cor21501 210 103 * ref cell, channel cvh volume
*

* initial temps:
cor21003 307.9 307.9 307.9 307.9 307.9 307.9 * T(fu,cl,os,cn,cb,dp)
cor21103 318.3 318.3 318.3 318.3 318.3 318.3 * T(fu,cl,os,cn,cb,dp)
cor21203 318.1 318.1 318.1 318.1 318.1 318.1 * T(fu,cl,os,cn,cb,dp)
cor21303 318.1 318.1 318.1 318.1 318.1 318.1 * T(fu,cl,os,cn,cb,dp)
cor21403 316.1 316.1 316.1 316.1 316.1 316.1 * T(fu,cl,os,cn,cb,dp)

```

```

cor21503 306.3 306.3 306.3 306.3 306.3 306.3 * T(fu,cl,os,cn,cb,dp)
*
* ring 3:
*
cor31001 110 103 * ref cell, channel, bypass cvh volumes
cor31005 7.479e-3 3.682e-3 * radial bound area, channel, byp area
cor31006 0.0 0.0 0.0 0.0 * surf area: fuel, clad, os, can in
cor310kfu 0.0 0.0 * alternate fuel mass specification
cor310kcl 0.0 0.0 0.0 * alternate clad mass specification
cor310kdp 4.187e-1 0.0 8.705e-2 * part deb masses: UO2, Zr, ZrO2
*
cor31101 310 103 * ref cell, channel cvh volume
cor31201 310 103 * ref cell, channel cvh volume
cor31301 310 103 * ref cell, channel cvh volume
cor31401 310 103 * ref cell, channel cvh volume
cor31501 310 103 * ref cell, channel cvh volume
*
* initial temps:
cor31003 307.9 307.9 307.9 307.9 307.9 307.9 * T(fu,cl,os,cn,cb,dp)
cor31103 318.3 318.3 318.3 318.3 318.3 318.3 * T(fu,cl,os,cn,cb,dp)
cor31203 318.1 318.1 318.1 318.1 318.1 318.1 * T(fu,cl,os,cn,cb,dp)
cor31303 318.1 318.1 318.1 318.1 318.1 318.1 * T(fu,cl,os,cn,cb,dp)
cor31403 316.1 316.1 316.1 316.1 316.1 316.1 * T(fu,cl,os,cn,cb,dp)
cor31503 306.3 306.3 306.3 306.3 306.3 306.3 * T(fu,cl,os,cn,cb,dp)
*
*-----
* lower head input
*-----
corlhd01 1 1 1.0e-5 300.0 1.0e-6 101 101 * rings,m,t,a,cv's
corlhd02 2 2 1.0e-5 300.0 1.0e-6 101 101 * rings,m,t,a,cv's
corlhd03 3 3 1.0e-5 300.0 1.0e-6 101 101 * rings,m,t,a,cv's
*
* penetration input
corpen01 -1 1 1.0e-5 300.0 1.0e-5 1.0e-5 1.0e-5 * try for no pen'n
* core inlet temp
cortin01 101 101 * for cv 101 (channel), use same volume (no dt/dz done)
*
*
*-----
* fission power control functions
*-----
*
* stub region power
*
cf01100 'stub fission' add 30 1.41 0.0 *
* coupling factor for stub region: ~~~~~~
*
* add total uo2 mass in stub region:

```

```

*
cf01111  1.0  0.0  cor-muo2-db.102  *
cf01112  1.0  0.0  cor-muo2-db.103  *
cf01113  1.0  0.0  cor-muo2-db.104  *
cf01114  1.0  0.0  cor-muo2-db.105  *
cf01115  1.0  0.0  cor-muo2-db.106  *
cf01116  1.0  0.0  cor-muo2-db.202  *
cf01117  1.0  0.0  cor-muo2-db.203  *
cf01118  1.0  0.0  cor-muo2-db.204  *
cf01119  1.0  0.0  cor-muo2-db.205  *
cf01120  1.0  0.0  cor-muo2-db.206  *
cf01121  1.0  0.0  cor-muo2-db.302  *
cf01122  1.0  0.0  cor-muo2-db.303  *
cf01123  1.0  0.0  cor-muo2-db.304  *
cf01124  1.0  0.0  cor-muo2-db.305  *
cf01125  1.0  0.0  cor-muo2-db.306  *
cf01126  1.0  0.0  cor-muo2-fu.102  *
cf01127  1.0  0.0  cor-muo2-fu.103  *
cf01128  1.0  0.0  cor-muo2-fu.104  *
cf01129  1.0  0.0  cor-muo2-fu.105  *
cf01130  1.0  0.0  cor-muo2-fu.106  *
cf01131  1.0  0.0  cor-muo2-fu.202  *
cf01132  1.0  0.0  cor-muo2-fu.203  *
cf01133  1.0  0.0  cor-muo2-fu.204  *
cf01134  1.0  0.0  cor-muo2-fu.205  *
cf01135  1.0  0.0  cor-muo2-fu.206  *
cf01136  1.0  0.0  cor-muo2-fu.302  *
cf01137  1.0  0.0  cor-muo2-fu.303  *
cf01138  1.0  0.0  cor-muo2-fu.304  *
cf01139  1.0  0.0  cor-muo2-fu.305  *
cf01140  1.0  0.0  cor-muo2-fu.306  *
*
* crust region power
*
cf01200  'crust fission' add 18 1.79 0.0 *
* peaking factor for crust region:~~~~~
*
* add total uo2 mass in crust region:
*
cf01211  1.0  0.0  cor-muo2-db.107  *
cf01212  1.0  0.0  cor-muo2-db.108  *
cf01213  1.0  0.0  cor-muo2-db.109  *
cf01214  1.0  0.0  cor-muo2-db.207  *
cf01215  1.0  0.0  cor-muo2-db.208  *
cf01216  1.0  0.0  cor-muo2-db.209  *
cf01217  1.0  0.0  cor-muo2-db.307  *
cf01218  1.0  0.0  cor-muo2-db.308  *
cf01219  1.0  0.0  cor-muo2-db.309  *

```



```

cf01220 1.0 0.0 cor-muo2-fu.107 *
cf01221 1.0 0.0 cor-muo2-fu.108 *
cf01222 1.0 0.0 cor-muo2-fu.109 *
cf01223 1.0 0.0 cor-muo2-fu.207 *
cf01224 1.0 0.0 cor-muo2-fu.208 *
cf01225 1.0 0.0 cor-muo2-fu.209 *
cf01226 1.0 0.0 cor-muo2-fu.307 *
cf01227 1.0 0.0 cor-muo2-fu.308 *
cf01228 1.0 0.0 cor-muo2-fu.309 *
*
* debris region power
*
cf01300 'debris fission' add 36 4.59 0.0 *
* peaking factor for debris region: ^^^^^^
*
* add total uo2 mass in debris region:
*
cf01311 1.0 0.0 cor-muo2-db.110 *
cf01312 1.0 0.0 cor-muo2-db.111 *
cf01313 1.0 0.0 cor-muo2-db.112 *
cf01314 1.0 0.0 cor-muo2-db.113 *
cf01315 1.0 0.0 cor-muo2-db.114 *
cf01316 1.0 0.0 cor-muo2-db.115 *
cf01317 1.0 0.0 cor-muo2-db.210 *
cf01318 1.0 0.0 cor-muo2-db.211 *
cf01319 1.0 0.0 cor-muo2-db.212 *
cf01320 1.0 0.0 cor-muo2-db.213 *
cf01321 1.0 0.0 cor-muo2-db.214 *
cf01322 1.0 0.0 cor-muo2-db.215 *
cf01323 1.0 0.0 cor-muo2-db.310 *
cf01324 1.0 0.0 cor-muo2-db.311 *
cf01325 1.0 0.0 cor-muo2-db.312 *
cf01326 1.0 0.0 cor-muo2-db.313 *
cf01327 1.0 0.0 cor-muo2-db.314 *
cf01328 1.0 0.0 cor-muo2-db.315 *
*
cf01329 1.0 0.0 cor-muo2-fu.110 *
cf01330 1.0 0.0 cor-muo2-fu.111 *
cf01331 1.0 0.0 cor-muo2-fu.112 *
cf01332 1.0 0.0 cor-muo2-fu.113 *
cf01333 1.0 0.0 cor-muo2-fu.114 *
cf01334 1.0 0.0 cor-muo2-fu.115 *
cf01335 1.0 0.0 cor-muo2-fu.210 *
cf01336 1.0 0.0 cor-muo2-fu.211 *
cf01337 1.0 0.0 cor-muo2-fu.212 *
cf01338 1.0 0.0 cor-muo2-fu.213 *
cf01339 1.0 0.0 cor-muo2-fu.214 *
cf01340 1.0 0.0 cor-muo2-fu.215 *

```

```

cf01341  1.0  0.0  cor-muo2-fu.310  *
cf01342  1.0  0.0  cor-muo2-fu.311  *
cf01343  1.0  0.0  cor-muo2-fu.312  *
cf01344  1.0  0.0  cor-muo2-fu.313  *
cf01345  1.0  0.0  cor-muo2-fu.314  *
cf01346  1.0  0.0  cor-muo2-fu.315  *
*
cf01400  'powr (w/kwacrr)'  add  3  1.0  0.0  *
*
cf01411  1.0  0.0  cfvalu.11  *
cf01412  1.0  0.0  cfvalu.12  *
cf01413  1.0  0.0  cfvalu.13  *
*
cf01500  'fission power'  multiply  2  1.0  0.0  *
*
cf01511  1.0  0.0  edf.10.1  *
cf01512  1.0  0.0  cfvalu.14  *
*
edf01000  bndlpow  1  read  * reactor power, 1 channels, read edf
edf01001  '/i1/tjtautg/mp2/data/power.dat'  * data file name
edf01002  2e13.6  * format for data fields
*
cf01600  'fp integral'  integ  2  1.0  0.0  *
cf01611  1.0  0.0  cfvalu.15  *
cf01612  1.0  0.0  time
*
*
*****
* sc package input  *
*****
*
* minimum mass coeff's:
sc15021  1502  1.0e-7  1  * minimum component mass
sc15022  1502  1.0e-6  2  * minimum mass for temperature control
*
* fission power coeff's:
sc13021  1312  1.0  2  * fission power absorption in cl
sc13022  1312  1.0  6  * fission power absorption in dp
*
*****
* cvh package input  *
*****
*
*-----
* cv #101 - stub region channel volume
*-----
*
cv10100  'channel volume'  2  2  1  * non-eq thermo, vertical flow, rcs volume

```

```

cv10103 3.642e-3 * velocity area (flow area of stub region)
cv101a0 2 * option 2 for specifying properties
cv101a1 pvol 6.888e4 * volume initial conditions: atm press
cv101a2 tatm 300.0 *
cv101a3 ph2o 0.0 * no water vapor
cv101a4 mfrc.9 1.0 * atmosphere is all helium
cv101b1 -12.6000e-2 0.0
cv101b2 0.0 1.0e-6
cv101b3 10.0e-2 3.660e-4
*
*-----
* cv #102 - crust region channel volume
*-----
*
cv10200 'channel volume' 2 2 1 * non-eq thermo, vertical flow, rcs volume
cv10203 3.642e-3 * velocity area (flow area of crust region)
cv102a0 2 * option 2 for specifying properties
cv102a1 pvol 6.888e4 * volume initial conditions: atm press
cv102a2 tatm 300.0 *
cv102a3 ph2o 0.0 * no water vapor
cv102a4 mfrc.9 1.0 * atmosphere is all helium
cv102b1 10.0e-2 0.0
cv102b2 13.5e-2 1.2765e-4
*
*-----
* cv #103 - crust region channel volume 1
*-----
*
cv10300 'debris 1' 2 2 1 * non-eq thermo, vertical flow, rcs volume
cv10303 5.972e-3 * velocity area (flow area of debris region)
cv103a0 2 * option 2 for specifying properties
cv103a1 pvol 6.888e4 * volume initial conditions: atm press
cv103a2 tatm 300.0 *
cv103a3 ph2o 0.0 * no water vapor
cv103a4 mfrc.9 1.0 * atmosphere is all helium
cv103b1 13.5e-2 0.0
cv103b2 30.0e-2 9.974e-4
*
*
*****
* fl package input *
*****
*
*-----
* fl #101 - stub to crust
*-----
*
fl10100 stub->crust 101 102 10.0e-2 10.0e-2 * from, to, inlet and outlet altitudes

```

```

fl10101 3.642e-3 4.45e-2 1.0 * area, length, fraction open
fl101s1 3.642e-3 4.45e-2 1.173e-2 * area, length, hyd diam
*
*-----
* fl #102 - crust to debris
*-----
*
fl10200 crust->debris 102 103 13.5e-2 13.5e-2 * from, to, inlet and outlet altitude
fl10201 3.642e-3 10.0e-2 1.0 * area, length, fraction open
fl102s1 3.642e-3 10.0e-2 1.173e-2 * area, length, hyd diam
*
*****
* hs package input *
*****
*
*-----
* hs 10000
*-----
*
hs10000000 31 2 1 * 31 nodes, cylindrical geom, ss initialization performed
hs10000001 'lp-1' * hs name
hs10000002 -12.600e-2 1.0 * bottom elevation, vertical surface
* location data:
hs10000100 -1 1 4.362e-2 * node locations follow, ifrmt=1, inner radius
hs10000101 5.067e-2 11 * outer radius of layer 1: Thoria
hs10000102 5.156e-2 16 * outer radius of layer 2: Tantalum
hs10000103 7.620e-2 26 * outer radius of layer 3: ZrO2 (porous)
hs10000104 8.400e-2 31 * outer radius of layer 4: Stainless Steel
* composition data:
hs10000200 -1 * composition data follows
hs10000201 'stainless steel' 10 * layer 1: Thoria
hs10000202 'stainless steel' 15 * layer 2: Tantalum
hs10000203 'stainless steel' 25 * layer 3: ZrO2 (porous)
hs10000204 'stainless steel' 30 * layer 4: Stainless Steel
* internal heat source (none):
hs10000300 0 * no internal source
* inside boundary data:
hs10000400 1 101 int 1.0 1.0 * conv b.c., bound vol, int bound,
* crit. pool & atms fractions
hs10000401 0.7 equiv-band 9.63e-3 * emiss of Thoria, rad'n model,
* rad'n path length (Dfu)
hs10000500 3.452e-2 8.724e-2 12.6e-2 * area, char len (Dh used), axial len
* outside boundary data:
hs10000600 8101 -1 'ext' 1.0 1.0 * b.c. in cf101, no bv, ext surf, etc
*
*-----
* hs 10102
*-----

```

```

*
hs10102000 46 2 1 * 46 nodes, cylindrical geom, ss initialization performed
hs10102001 'stub-1' * hs name
hs10102002 0.0 1.0 * bottom elevation, vertical surface
* location data:
hs10102100 -1 1 4.362e-2 * node locations follow, ifrmt=1, inner radius
hs10102101 5.721e-2 21 * outer radius of layer 1: Thoria
hs10102102 5.839e-2 26 * outer radius of layer 2: Tantalum
hs10102103 6.782e-2 36 * outer radius of layer 3: ZrO2 (porous)
hs10102104 7.778e-2 41 * outer radius of layer 4: Aluminum
hs10102105 8.414e-2 46 * outer radius of layer 5: Stainless Steel
* composition data:
hs10102200 -1 * composition data follows
hs10102201 'thoria' 20 * layer 1: Thoria
hs10102202 'tantalum' 25 * layer 2: Tantalum
hs10102203 'zirconia (porous)' 35 * layer 3: ZrO2 (porous)
hs10102204 'aluminum' 40 * layer 4: Aluminum
hs10102205 'stainless steel' 45 * layer 5: Stainless Steel
* internal heat source (none):
hs10102300 0 * no internal source
* inside boundary data:
hs10102400 1 101 int 1.0 1.0 * b.c., bound vol, int bound,
* crit. pool & atms fractions
hs10102401 0.7 equiv-band 9.63e-3 * emiss, rad'n model, rad'n path len (Dfu)
hs10102500 5.479e-3 1.173e-2 2.0e-2 * area, char len (Dh used), axial len
* outside boundary data:
hs10102600 8101 -1 'ext' 1.0 1.0 * b.c. in cf101, no bv, ext surf, etc
*
*-----
* hs 10103-10106
*-----
*
hs10103000 46 2 1 * 46 nodes, cylindrical geom, ss initialization performed
hs10104000 46 2 1 * 46 nodes, cylindrical geom, ss initialization performed
hs10105000 46 2 1 * 46 nodes, cylindrical geom, ss initialization performed
hs10106000 46 2 1 * 46 nodes, cylindrical geom, ss initialization performed
*
hs10103001 'stub-2' * hs name
hs10104001 'stub-3' * hs name
hs10105001 'stub-4' * hs name
hs10106001 'stub-5' * hs name
*
hs10103002 2.0e-2 1.0 * bottom elevation, vertical surface
hs10104002 4.0e-2 1.0 * bottom elevation, vertical surface
hs10105002 6.0e-2 1.0 * bottom elevation, vertical surface
hs10106002 8.0e-2 1.0 * bottom elevation, vertical surface
*
hs10103100 10102 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius

```

```

hs10104100 10102 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10105100 10102 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10106100 10102 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
*
hs10103200 10102 * composition data elsewhere
hs10104200 10102 * composition data elsewhere
hs10105200 10102 * composition data elsewhere
hs10106200 10102 * composition data elsewhere
*
hs10103300 0 * no internal source
hs10104300 0 * no internal source
hs10105300 0 * no internal source
hs10106300 0 * no internal source
*
hs10103400 1 101 int 1.0 1.0 * bc, bound vol, int bound, etc
hs10104400 1 101 int 1.0 1.0 * bc, bound vol, int bound, etc
hs10105400 1 101 int 1.0 1.0 * bc, bound vol, int bound, etc
hs10106400 1 101 int 1.0 1.0 * bc, bound vol, int bound, etc
*
hs10103401 0.7 equiv-band 9.63e-3 * emiss, rad'n model, path len (Dfu)
hs10104401 0.7 equiv-band 9.63e-3 * emiss, rad'n model, path len (Dfu)
hs10105401 0.7 equiv-band 9.63e-3 * emiss, rad'n model, path len (Dfu)
hs10106401 0.7 equiv-band 9.63e-3 * emiss, rad'n model, path len (Dfu)
*
hs10103500 5.479e-3 1.173e-2 2.0e-2 * area, char len (Dh used), axial len
hs10104500 5.479e-3 1.173e-2 2.0e-2 * area, char len (Dh used), axial len
hs10105500 5.479e-3 1.173e-2 2.0e-2 * area, char len (Dh used), axial len
hs10106500 5.479e-3 1.173e-2 2.0e-2 * area, char len (Dh used), axial len
*
hs10103600 8101 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
hs10104600 8101 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
hs10105600 8101 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
hs10106600 8101 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
*
*-----
* hs 10207
*-----
*
hs10207000 46 2 1 * 46 nodes, cylindrical geom, ss initialization performed
hs10207001 'crust-1' * hs name
hs10207002 10.0e-2 1.0 * bottom elevation, vertical surface
* location data:
hs10207100 10102 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
* composition data:
hs10207200 10102 * composition data elsewhere
hs10207300 0 * no internal source
* inside boundary data:
hs10207400 1 102 int 1.0 1.0 * convective b.c., bound volume 101, int boundary,

```

```

                                * crit. pool & atms fractions
hs10207401  0.7  equiv-band  9.63e-3 * emiss, rad'n model, path len (Dfu)
hs10207500  3.197e-3  1.173e-2  1.167e-2 * area, char len (Dh used), axial len
* outside boundary data:
hs10207600  8101  -1  'ext'  1.0  1.0 * bc in cf101, no bv, etc
                                * exterior surface, etc

*
*-----
* hs 10208-10209
*-----
*
hs10208000  46  2  1 * 46 nodes, cylindrical geom, ss initialization performed
hs10209000  46  2  1 * 46 nodes, cylindrical geom, ss initialization performed
*
hs10208001  'crust-2' * hs name
hs10209001  'crust-3' * hs name
*
hs10208002  11.667e-2  1.0 * bottom elevation, vertical surface
hs10209002  12.333e-2  1.0 * bottom elevation, vertical surface
*
hs10208100  10102  1  4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10209100  10102  1  4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
*
hs10208200  10102  * composition data elsewhere
hs10209200  10102  * composition data elsewhere
*
hs10208300  0  * no internal source
hs10209300  0  * no internal source
*
hs10208400  1  102  int  1.0  1.0 * bc, bound vol, int bound, etc
hs10209400  1  102  int  1.0  1.0 * bc, bound vol, int bound, etc
*
hs10208401  0.7  equiv-band  9.63e-3 * emis of Thoria, rad'n model, char len (Dfu)
hs10209401  0.7  equiv-band  9.63e-3 * emis of Thoria, rad'n model, char len (Dfu)
*
hs10208500  3.197e-3  1.173e-2  1.167e-2 * area, char len (Dh used), axial len
hs10209500  3.197e-3  1.173e-2  1.167e-2 * area, char len (Dh used), axial len
*
hs10208600  8101  -1  'ext'  1.0  1.0 * bc in cf101, no bv, etc
hs10209600  8101  -1  'ext'  1.0  1.0 * bc in cf101, no bv, etc
*
*-----
* hs 10310
*-----
*
hs10310000  46  2  1 * 46 nodes, cylindrical geom, ss initialization performed
hs10310001  'debris-1' * hs name
hs10310002  13.5e-2  1.0 * bottom elevation, vertical surface

```

```

* location data:
hs10310100 -1 1 4.362e-2 * node locations follow, ifrmt=1, inner radius
hs10310101 4.375e-2 6 * outer radius of layer 1: Tungsten
hs10310102 5.721e-2 21 * outer radius of layer 2: Thoria
hs10310103 5.839e-2 26 * outer radius of layer 3: Tantalum
hs10310104 6.782e-2 36 * outer radius of layer 4: ZrO2 (porous)
hs10310105 7.778e-2 41 * outer radius of layer 5: Aluminum
hs10310106 8.414e-2 46 * outer radius of layer 6: Stainless Steel
* composition data:
hs10310200 -1 * composition data follows
hs10310201 'tantalum' 5 * layer 1: Thoria
hs10310202 'thoria' 20 * layer 2: Thoria
hs10310203 'tantalum' 25 * layer 3: Tantalum
hs10310204 'zirconia (porous)' 35 * layer 4: ZrO2 (porous)
hs10310205 'aluminum' 40 * layer 5: Aluminum
hs10310206 'stainless steel' 45 * layer 6: Stainless Steel
*
hs10310300 0 * no internal source
* inside boundary data:
hs10310400 1 103 int 1.0 1.0 * convective b.c., bound volume 101, int boundary,
* crit. pool & atms fractions
hs10310401 0.7 equiv-band 9.63e-3 * emiss, rad'n model, path len (Dfu)
hs10310500 7.479e-3 8.724e-2 2.75e-2 * area, char len (Dh used), axial len
* outside boundary data:
hs10310600 8102 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
* exterior surface, etc
*
*-----
* hs 10311-10315
*-----
*
hs10311000 46 2 1 * 46 nodes, cylindrical geom, ss initialization performed
hs10312000 46 2 1 * 46 nodes, cylindrical geom, ss initialization performed
hs10313000 46 2 1 * 46 nodes, cylindrical geom, ss initialization performed
hs10314000 46 2 1 * 46 nodes, cylindrical geom, ss initialization performed
hs10315000 46 2 1 * 46 nodes, cylindrical geom, ss initialization performed
*
hs10311001 'debris-2' * hs name
hs10312001 'debris-3' * hs name
hs10313001 'debris-4' * hs name
hs10314001 'debris-5' * hs name
hs10315001 'debris-6' * hs name
*
hs10311002 16.25e-2 1.0 * bottom elevation, vertical surface
hs10312002 19.00e-2 1.0 * bottom elevation, vertical surface
hs10313002 21.75e-2 1.0 * bottom elevation, vertical surface
hs10314002 24.50e-2 1.0 * bottom elevation, vertical surface
hs10315002 27.25e-2 1.0 * bottom elevation, vertical surface

```



```

*
hs10311100 10310 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10312100 10310 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10313100 10310 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10314100 10310 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
hs10315100 10310 1 4.362e-2 * node locations elsewhere, ifrmt=1, inner radius
*
hs10311200 10310 * composition data elsewhere
hs10312200 10310 * composition data elsewhere
hs10313200 10310 * composition data elsewhere
hs10314200 10310 * composition data elsewhere
hs10315200 10310 * composition data elsewhere
*
hs10311300 0 * no internal source
hs10312300 0 * no internal source
hs10313300 0 * no internal source
hs10314300 0 * no internal source
hs10315300 0 * no internal source
*
hs10311400 1 103 int 1.0 1.0 * bc, bound vol, int bound, etc
hs10312400 1 103 int 1.0 1.0 * bc, bound vol, int bound, etc
hs10313400 1 103 int 1.0 1.0 * bc, bound vol, int bound, etc
hs10314400 1 103 int 1.0 1.0 * bc, bound vol, int bound, etc
hs10315400 1 103 int 1.0 1.0 * bc, bound vol, int bound, etc
*
hs10311401 0.7 equiv-band 9.63e-3 * emis of Thoria, rad'n model, char len (Dfu)
hs10312401 0.7 equiv-band 9.63e-3 * emis of Thoria, rad'n model, char len (Dfu)
hs10313401 0.7 equiv-band 9.63e-3 * emis of Thoria, rad'n model, char len (Dfu)
hs10314401 0.7 equiv-band 9.63e-3 * emis of Thoria, rad'n model, char len (Dfu)
hs10315401 0.7 equiv-band 9.63e-3 * emis of Thoria, rad'n model, char len (Dfu)
*
hs10311500 7.479e-3 8.724e-2 2.75e-2 * area, char len (Dh used), axial len
hs10312500 7.479e-3 8.724e-2 2.75e-2 * area, char len (Dh used), axial len
hs10313500 7.479e-3 8.724e-2 2.75e-2 * area, char len (Dh used), axial len
hs10314500 7.479e-3 8.724e-2 2.75e-2 * area, char len (Dh used), axial len
hs10315500 7.479e-3 8.724e-2 2.75e-2 * area, char len (Dh used), axial len
*
hs10311600 8102 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
hs10312600 8102 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
hs10313600 8102 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
hs10314600 8102 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
hs10315600 8102 -1 'ext' 1.0 1.0 * bc in cf101, no bv, etc
*
*-----
* hs 10116
*-----
*
hs10116000 36 1 1 * # nodes, rectang geom, ss init'n performed

```

```

hs10116001 'upper plate' * hs name
hs10116002 30.0e-2 0.0 * bottom elevation, vertical surface
* location data:
hs10116100 -1 1 0.0 * node locations follow, ifrmt=1, inner radius
hs10116101 31.905e-2 11 * layer 1: thoria
hs10116102 38.255e-2 31 * layer 2: zirconia
hs10116103 40.533e-2 36 * layer 3: stainless steel
* composition data:
hs10116200 -1 * composition data follow
hs10116201 thoria 10 * layer 1: thoria
hs10116202 'zirconia (porous)' 30 * layer 2: zirconia
hs10116203 'stainless steel' 35 * layer 3: stainless steel
*
hs10116300 0 * no internal source
* inside boundary data:
hs10116400 1 103 int 1.0 1.0 * conv b.c., bound vol 103, int bound, etc
hs10116401 0.7 equiv-band 2.0e-3 * emis of Thoria,rad model,path len (Dfu)
hs10116500 5.978e-3 8.724e-2 8.724e-2 * area, char l (Dh used), axial len
* outside boundary data:
hs10116600 8102 -1 'ext' 1.0 1.0 * Tc b.c. in cf101, no bv, etc
*
*-----
* cf 101 (for hs bound temps)
*-----
*
cf10100 'tskpcs3' equals 1 1.0 0.0 *
cf10101 300.0
*
cf10111 1.0 0.0 edf.11.1 *
*
edf01100 tskpcs3 1 read * hs bound temp, 1 channels, read edf
edf01101 '/i1/tjtautg/mp2/data/tskpcs3.dat' * data file name
edf01102 2e13.6 * format for data fields
*
*-----
* cf 102 (for hs bound temps)
*-----
*
cf10200 'hs bound t' equals 1 1.0 0.0 *
cf10201 300.0
*
cf10211 1.0 0.0 edf.12.1 *
*
edf01200 tskpcs2 1 read * hs bound temp, 1 channels, read edf
edf01201 '/i1/tjtautg/mp2/data/tskpcs2.dat' * data file name
edf01202 2e13.6 * format for data fields
*
*

```

```

*****
* ncg package input *
*****
*
ncg001  h2  4
ncg002  o2  5
ncg003  co  6
ncg004  co2 7
ncg005  ch4 8
ncg006  he  9
*
*
*****
* mp package input *
*****
*
***          material 5 is zircaloy
*
*   change default values for zircaloy to raise melting
*   temperature 102 k to be consistent with melprog and matpro
***
mpmat00500  zircaloy
mpmat00501  enh  220
mpmat00502  cps  221
mpmat00503  tmp  222
mpmat00504  thc  223
mpmat00550  mlt  2200.    *change melt temp to 2200 k, default=2098. k
*
tf22000  'ezirc'  16  1.0
tf22011    300.0    0.0
tf22012    400.0  21915.0
tf22013    640.0 105110.0
tf22014   1090.0 263960.0
tf22015   1093.0 265275.5
tf22016   1113.0 276195.5
tf22017   1133.0 288245.5
tf22018   1153.0 301585.5
tf22019   1173.0 316935.5
tf22020   1193.0 332795.5
tf22021   1213.0 346685.5
tf22022   1233.0 357565.5
tf22023   1248.0 363753.0
tf22024   2200.0 702665.0
tf22025   2200.01 927665.0
tf22026   3598.0 1425353.0
*
tf22100  'cpzirc'  15  1.0
tf22111   273.15  275.0

```

tf22112	400.0	302.0
tf22113	640.0	331.0
tf22114	1090.0	375.0
tf22115	1093.0	502.0
tf22116	1113.0	590.0
tf22117	1133.0	615.0
tf22118	1153.0	719.0
tf22119	1173.0	816.0
tf22120	1193.0	770.0
tf22121	1213.0	619.0
tf22122	1233.0	469.0
tf22123	1248.0	356.0
tf22124	2098.0	356.0
tf22125	5000.0	356.0

*

tf22200	'tzirc'	16	1.0
tf22211	0.0		300.0
tf22212	21915.0		400.0
tf22213	105110.0		640.0
tf22214	263960.0		1090.0
tf22215	265275.5		1093.0
tf22216	276195.5		1113.0
tf22217	288245.5		1133.0
tf22218	301585.5		1153.0
tf22219	316935.5		1173.0
tf22220	332795.5		1193.0
tf22221	346685.5		1213.0
tf22222	357565.5		1233.0
tf22223	363753.0		1248.0
tf22224	702665.0		2200.0
tf22225	927665.0		2200.01
tf22226	1425353.0		3598.0

*

tf22300	'thczr'	20	1.0
tf22311	2.73150E+02		1.23889E+01
tf22312	4.16668E+02		1.41522E+01
tf22313	5.60187E+02		1.59397E+01
tf22314	7.03705E+02		1.77515E+01
tf22315	8.47224E+02		1.95875E+01
tf22316	9.90742E+02		2.14478E+01
tf22317	1.13426E+03		2.33323E+01
tf22318	1.27778E+03		2.52410E+01
tf22319	1.42130E+03		2.71740E+01
tf22320	1.56482E+03		2.91313E+01
tf22321	1.70833E+03		3.11128E+01
tf22322	1.85185E+03		3.31185E+01
tf22323	1.99537E+03		3.51485E+01
tf22324	2.13889E+03		3.72028E+01

```

tf22325    2.28241E+03    3.92813E+01
tf22326    2.42593E+03    4.13840E+01
tf22327    2.56945E+03    4.35110E+01
tf22328    2.71296E+03    4.56622E+01
tf22329    2.85648E+03    4.78377E+01
tf22330    3.00000E+03    5.00374E+01
*
*-----
* U02
*-----
*
*   change default thermal conductivity and density for U02
*
***
mpmat00600  uranium-dioxide
mpmat00601  thc  224
mpmat00602  rho  225
mpmat00651  den  9850.0
*
*-----
* tf 224: thermal cond vs temp for uo2
*-----
tf22400    'thcuo2'    20    1.0
tf22411    2.73150E+02    9.75888E+02
tf22412    4.16668E+02    1.30172E+03
tf22413    5.60187E+02    1.62559E+03
tf22414    7.03705E+02    1.94518E+03
tf22415    8.47224E+02    2.25697E+03
tf22416    9.90742E+02    2.55602E+03
tf22417    1.13426E+03    2.83602E+03
tf22418    1.27778E+03    3.08952E+03
tf22419    1.42130E+03    3.30851E+03
tf22420    1.56482E+03    3.48520E+03
tf22421    1.70833E+03    3.61300E+03
tf22422    1.85185E+03    3.68760E+03
tf22423    1.99537E+03    3.70762E+03
tf22424    2.13889E+03    3.67499E+03
tf22425    2.28241E+03    3.59470E+03
tf22426    2.42593E+03    3.47412E+03
tf22427    2.56945E+03    3.32199E+03
tf22428    2.71296E+03    3.14742E+03
tf22429    2.85648E+03    2.95903E+03
tf22430    3.00000E+03    2.76435E+03
*
*-----
* tf 225: density vs. temp for U02
*-----
*

```

```

tf22500 'U02 d vs t' 2 1.0 0.0 * name, # data pairs, scale facts
tf22510 273.15 9850.0
tf22511 5000.0 9850.0
*
*
*-----
* SS
*-----
*
* change default thermal conductivity, density and melting temp for SS
*
***
mpmat00700 stainless-steel
mpmat00701 thc 226
mpmat00702 rho 227
mpmat00703 cps 236
mpmat00704 enh 237
mpmat00705 tmp 238
mpmat00751 den 7954.0
mpmat00752 mlt 3799.0
mpmat00753 lhf 2.68e5
*
*-----
* tf 226: thermal cond vs temp for ss
*-----
tf22600 'thcss' 20 1.0
tf22611 2.73150E+02 1.27435E+01
tf22612 4.16668E+02 1.54560E+01
tf22613 5.60187E+02 1.81685E+01
tf22614 7.03705E+02 2.08810E+01
tf22615 8.47226E+02 2.35935E+01
tf22616 9.90742E+02 2.63060E+01
tf22617 1.13426E+03 2.90185E+01
tf22618 1.27778E+03 3.17310E+01
tf22619 1.42130E+03 3.44435E+01
tf22620 1.56482E+03 3.71560E+01
tf22621 1.70833E+03 2.63882E+01
tf22622 1.85185E+03 2.00000E+01
tf22623 1.99537E+03 2.00000E+01
tf22624 2.13889E+03 2.00000E+01
tf22625 2.28241E+03 2.00000E+01
tf22626 2.42593E+03 2.00000E+01
tf22627 2.56945E+03 2.00000E+01
tf22628 2.71296E+03 2.00000E+01
tf22629 2.85648E+03 2.00000E+01
tf22630 3.00000E+03 2.00000E+01
*
*-----

```

* tf 227: density vs. temp for SS

*-----

*

tf22700 'SS d vs t' 2 1.0 0.0 * name, # data pairs, scale facts

tf22710 273.15 7954.0

tf22711 5000.0 7954.0

*

*-----

* tf 236: spec heat capacity vs temp for ss

*-----

tf23600 'cpss' 16 1.0

tf23601 1 1

tf23611 273.15 475.6

tf23612 400.0 498.1

tf23613 500.0 515.8

tf23614 600.0 533.5

tf23615 700.0 551.3

tf23616 800.0 569.0

tf23617 900.0 586.7

tf23618 1000.0 604.4

tf23619 1100.0 622.1

tf23620 1200.0 639.8

tf23621 1300.0 657.5

tf23622 1400.0 675.2

tf23623 1500.0 693.0

tf23624 1600.0 710.7

tf23625 1700.0 728.4

tf23626 3800.0 728.4

*

*

*-----

* tf 237: specific enthalpy vs temp for ss

*-----

tf23700 'enhss' 18 1.0

tf23701 1 1

tf23711 300.0 0.0

tf23712 400.0 48926.0

tf23713 500.0 99624.0

tf23714 600.0 152092.0

tf23715 700.0 206332.0

tf23716 800.0 262343.0

tf23717 900.0 320125.0

tf23718 1000.0 379679.0

tf23719 1100.0 441003.0

tf23720 1200.0 504099.0

tf23721 1300.0 568966.0

tf23722 1400.0 635604.0

tf23723 1500.0 704014.0

```

tf23724  1600.0  774194.0
tf23725  1700.0  846146.0
tf23726  3799.0  2375058.0
tf23727  3799.01 2643058.0
tf23728  3800.0  2643786.0
*
*
*-----
* tf 238: temp vs. specific enthalpy for ss
*-----
tf23800  'tmpss'  18  1.0
tf23801  1  1
tf23811  0.0  300.0
tf23812  48926.0  400.0
tf23813  99624.0  500.0
tf23814  152092.0  600.0
tf23815  206332.0  700.0
tf23816  262343.0  800.0
tf23817  320125.0  900.0
tf23818  379679.0  1000.0
tf23819  441003.0  1100.0
tf23820  504099.0  1200.0
tf23821  568966.0  1300.0
tf23822  635604.0  1400.0
tf23823  704014.0  1500.0
tf23824  774194.0  1600.0
tf23825  846146.0  1700.0
tf23826  1114146.0  1700.01
tf23827  1186986.0  1800.0
tf23828  2643786.0  3800.0
*tf23826  2375058.0  3799.0
*tf23827  2643058.0  3799.01
*
*
*-----
* ZrO2
*-----
*
* change default thermal conductivity and density for ZrO2
*
***
mpmat00800  zirconium-oxide
mpmat00801  thc  228
mpmat00802  rho  229
mpmat00851  den  5700.0
*
*-----
* tf 228: thermal cond vs temp for ZrO2

```



```

*-----
tf22800 'thczro2' 20 1.0
tf22811 2.73150E+02 0.01
tf22812 4.16668E+02 0.01
tf22813 5.60187E+02 1.27067E-01
tf22814 7.03705E+02 4.05225E-01
tf22815 8.47228E+02 6.83382E-01
tf22816 9.90742E+02 9.61540E-01
tf22817 1.13426E+03 1.23970E+00
tf22818 1.27778E+03 1.51786E+00
tf22819 1.42130E+03 1.79601E+00
tf22820 1.56482E+03 2.07417E+00
tf22821 1.70833E+03 2.35233E+00
tf22822 1.85185E+03 2.55682E+00
tf22823 1.99537E+03 2.63081E+00
tf22824 2.13889E+03 2.70481E+00
tf22825 2.28241E+03 2.77881E+00
tf22826 2.42593E+03 2.85281E+00
tf22827 2.56945E+03 2.92681E+00
tf22828 2.71296E+03 3.00080E+00
tf22829 2.85648E+03 3.07480E+00
tf22830 3.00000E+03 3.14880E+00
*
*-----
* tf 229: density vs. temp for ZrO2
*-----
*
tf22900 'ZrO2 d vs t' 2 1.0 0.0 * name, # data pairs, scale facts
tf22910 273.15 5700.0
tf22911 5000.0 5700.0
*
*
*-----
* zirconia (porous)
*-----
*
* define a new material, porous zirconium oxide, which has
* properties similar to MELCOR default props except for
* density
*
* tabular functions 201-204:
* tf201: enthalpy vs temp, use standard MELCOR values
* tf202: temp vs enthalpy, use standard MELCOR values
* tf203: spec heat cap vs temp, use standard MELCOR values
* tf204: therm conductivity vs temp, use standard MELCOR values
* tf205: density vs temp, use 0.257 * Rho(ZrO2-dense)
*
mpmat10100 'zirconia (porous)'

```

```

*
mpmat10101  enh  201
mpmat10102  tmp  202
mpmat10103  cps  203
mpmat10104  thc  204
mpmat10105  rho  205
*
mpmat10151  den  1440.0 * 0.257 x rho(ZrO2-dense)
mpmat10152  mlt  2990.0
mpmat10153  lhf  7.06e5
*
*-----
* tf 201: enthalpy vs. temp for porous ZrO2
*-----
*
tf20100 'ZrO2(por) e vs t'  20  1.0  0.0 * name, # data pairs, scale facts
tf20101  1  1
tf20111  2.73150E+02  1.07126E+01
tf20112  4.16668E+02  7.48492E+04
tf20113  5.60187E+02  1.51506E+05
tf20114  7.03705E+02  2.29982E+05
tf20115  8.47224E+02  3.10277E+05
tf20116  9.90742E+02  3.92391E+05
tf20117  1.13426E+03  4.76323E+05
tf20118  1.27778E+03  5.62074E+05
tf20119  1.42130E+03  6.49644E+05
tf20120  1.56482E+03  7.39032E+05
tf20121  1.70833E+03  8.30240E+05
tf20122  1.85185E+03  9.23266E+05
tf20123  1.99537E+03  1.01811E+06
tf20124  2.13889E+03  1.11477E+06
tf20125  2.28241E+03  1.21326E+06
tf20126  2.42593E+03  1.31356E+06
tf20127  2.56945E+03  1.41568E+06
tf20128  2.71296E+03  1.51962E+06
tf20129  2.85648E+03  1.62537E+06
tf20130  3.00000E+03  2.43895E+06
*
*-----
* tf 202: temp vs. enthalpy for porous ZrO2
*-----
*
tf20200 'ZrO2(por) t vs e'  20  1.0  0.0 * name, # data pairs, scale facts
tf20201  1  1
tf20211  1.07126E+01  2.73150E+02
tf20212  7.48492E+04  4.16668E+02
tf20213  1.51506E+05  5.60187E+02
tf20214  2.29982E+05  7.03705E+02

```

tf20215	3.10277E+05	8.47224E+02
tf20216	3.92391E+05	9.90742E+02
tf20217	4.76323E+05	1.13426E+03
tf20218	5.62074E+05	1.27778E+03
tf20219	6.49644E+05	1.42130E+03
tf20220	7.39032E+05	1.56482E+03
tf20221	8.30240E+05	1.70833E+03
tf20222	9.23266E+05	1.85185E+03
tf20223	1.01811E+06	1.99537E+03
tf20224	1.11477E+06	2.13889E+03
tf20225	1.21326E+06	2.28241E+03
tf20226	1.31356E+06	2.42593E+03
tf20227	1.41568E+06	2.56945E+03
tf20228	1.51962E+06	2.71296E+03
tf20229	1.62537E+06	2.85648E+03
tf20230	2.43895E+06	3.00000E+03

*

*-----

* tf 203: cp vs. temp for porous ZrO2

*-----

*

tf20300 'Z02(por) cp vs t' 20 1.0 0.0 * name, # data pairs, scale facts

tf20311	2.73150E+02	5.15119E+02
tf20312	4.16668E+02	5.27792E+02
tf20313	5.60187E+02	5.40464E+02
tf20314	7.03705E+02	5.53137E+02
tf20315	8.47224E+02	5.65810E+02
tf20316	9.90742E+02	5.78483E+02
tf20317	1.13426E+03	5.91155E+02
tf20318	1.27778E+03	6.03828E+02
tf20319	1.42130E+03	6.16501E+02
tf20320	1.56482E+03	6.29173E+02
tf20321	1.70833E+03	6.41846E+02
tf20322	1.85185E+03	6.54519E+02
tf20323	1.99537E+03	6.67191E+02
tf20324	2.13889E+03	6.79864E+02
tf20325	2.28241E+03	6.92537E+02
tf20326	2.42593E+03	7.05209E+02
tf20327	2.56945E+03	7.17882E+02
tf20328	2.71296E+03	7.30555E+02
tf20329	2.85648E+03	7.43227E+02
tf20330	3.00000E+03	7.55900E+02

*

*-----

* tf 204: thermal cond vs. temp for porous ZrO2

*-----

*

tf20400 'ZrO2(por) k vs t' 20 1.0 0.0 * name, # data pairs, scale facts

tf20411	2.73150E+02	3.56528E-01
tf20412	4.16668E+02	4.12501E-01
tf20413	5.60187E+02	4.68473E-01
tf20414	7.03705E+02	5.24445E-01
tf20415	8.47224E+02	5.80417E-01
tf20416	9.90742E+02	6.36389E-01
tf20417	1.13426E+03	6.92362E-01
tf20418	1.27778E+03	7.48334E-01
tf20419	1.42130E+03	8.04306E-01
tf20420	1.56482E+03	8.60278E-01
tf20421	1.70833E+03	9.16250E-01
tf20422	1.85185E+03	9.72223E-01
tf20423	1.99537E+03	1.02819E+00
tf20424	2.13889E+03	1.12981E+00
tf20425	2.28241E+03	1.22467E+00
tf20426	2.42593E+03	1.31954E+00
tf20427	2.56945E+03	1.41440E+00
tf20428	2.71296E+03	1.50927E+00
tf20429	2.85648E+03	1.60413E+00
tf20430	3.00000E+03	1.69900E+00

*

*-----

* tf 205: density vs. temp for porous ZrO2

*-----

*

tf20500 'ZrO2(por) d vs t' 2 1.0 0.0 * name, # data pairs, scale facts

tf20510 273.15 1440.0

tf20511 5000.0 1440.0

*

*-----

* thoria

*-----

*

* tabular functions 211-214:

* tf211: enthalpy vs temp

* tf212: temp vs enthalpy

* tf213: spec heat cap vs temp

* tf214: therm conductivity vs temp

* tf215: density vs temp

*

mpmat10200 'thoria'

*

mpmat10201 enh 211

mpmat10202 tmp 212

mpmat10203 cps 213

mpmat10204 thc 214

mpmat10205 rho 215

*

```

mpmat10251 den 9860.0
mpmat10252 mlt 3320.0
mpmat10253 lhf 2.853e5

```

*

*-----

* tf 211: enthalpy vs. temp for thoria

*-----

*

tf21100 'thoria e vs t' 20 1.0 0.0 * name, # data pairs, scale facts

tf21101 1 1

tf21111 2.73150E+02 2.87695E+00

tf21112 4.16668E+02 3.50418E+04

tf21113 5.60187E+02 7.30700E+04

tf21114 7.03705E+02 1.12684E+05

tf21115 8.47224E+02 1.53431E+05

tf21116 9.90742E+02 1.95121E+05

tf21117 1.13426E+03 2.37660E+05

tf21118 1.27778E+03 2.80996E+05

tf21119 1.42130E+03 3.25099E+05

tf21120 1.56482E+03 3.69948E+05

tf21121 1.70833E+03 4.15531E+05

tf21122 1.85185E+03 4.61840E+05

tf21123 1.99537E+03 5.08866E+05

tf21124 2.13889E+03 5.56607E+05

tf21125 2.28241E+03 6.05058E+05

tf21126 2.42593E+03 6.54217E+05

tf21127 2.56945E+03 7.04081E+05

tf21128 2.71296E+03 7.54650E+05

tf21129 2.85648E+03 8.05921E+05

tf21130 3.00000E+03 8.57894E+05

*

*-----

* tf 212: temp vs. enthalpy for thoria

*-----

*

tf21200 'thoria t vs e' 20 1.0 0.0 * name, # data pairs, scale facts

tf21201 1 1

tf21211 2.87695E+00 2.73150E+02

tf21212 3.50418E+04 4.16668E+02

tf21213 7.30700E+04 5.60187E+02

tf21214 1.12684E+05 7.03705E+02

tf21215 1.53431E+05 8.47224E+02

tf21216 1.95121E+05 9.90742E+02

tf21217 2.37660E+05 1.13426E+03

tf21218 2.80996E+05 1.27778E+03

tf21219 3.25099E+05 1.42130E+03

tf21220 3.69948E+05 1.56482E+03

tf21221 4.15531E+05 1.70833E+03

```

tf21222    4.61840E+05    1.85185E+03
tf21223    5.08866E+05    1.99537E+03
tf21224    5.56607E+05    2.13889E+03
tf21225    6.05058E+05    2.28241E+03
tf21226    6.54217E+05    2.42593E+03
tf21227    7.04081E+05    2.56945E+03
tf21228    7.54650E+05    2.71296E+03
tf21229    8.05921E+05    2.85648E+03
tf21230    8.57894E+05    3.00000E+03
*
*-----
* tf 213: cp vs. temp for thoria
*-----
*
tf21300 'thoria cp vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf21301 1 1
tf21311    2.73150E+02    2.25329E+02
tf21312    4.16668E+02    2.57305E+02
tf21313    5.60187E+02    2.71284E+02
tf21314    7.03705E+02    2.80271E+02
tf21315    8.47224E+02    2.87338E+02
tf21316    9.90742E+02    2.93511E+02
tf21317    1.13426E+03    2.99212E+02
tf21318    1.27778E+03    3.04641E+02
tf21319    1.42130E+03    3.09901E+02
tf21320    1.56482E+03    3.15053E+02
tf21321    1.70833E+03    3.20130E+02
tf21322    1.85185E+03    3.25155E+02
tf21323    1.99537E+03    3.30142E+02
tf21324    2.13889E+03    3.35102E+02
tf21325    2.28241E+03    3.40040E+02
tf21326    2.42593E+03    3.44962E+02
tf21327    2.56945E+03    3.49871E+02
tf21328    2.71296E+03    3.54770E+02
tf21329    2.85648E+03    3.59661E+02
tf21330    3.00000E+03    3.64546E+02
*
*-----
* tf 214: thermal cond vs. temp for thoria
*-----
*
tf21400 'thoria k vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf21411    2.73150E+02    1.41632E+01
tf21412    4.16668E+02    9.92455E+00
tf21413    5.60187E+02    7.11986E+00
tf21414    7.03705E+02    5.35649E+00
tf21415    8.47224E+02    4.30518E+00
tf21416    9.90742E+02    3.69999E+00

```

```

tf21417  1.13426E+03  3.33838E+00
tf21418  1.27778E+03  3.08111E+00
tf21419  1.42130E+03  2.85236E+00
tf21420  1.56482E+03  2.63965E+00
tf21421  1.70833E+03  2.49874E+00
tf21422  1.85185E+03  2.49874E+00
tf21423  1.99537E+03  2.49874E+00
tf21424  2.13889E+03  2.49874E+00
tf21425  2.28241E+03  2.49874E+00
tf21426  2.42593E+03  2.49874E+00
tf21427  2.56945E+03  2.49874E+00
tf21428  2.71296E+03  2.49874E+00
tf21429  2.85648E+03  2.49874E+00
tf21430  3.00000E+03  2.49874E+00
*
*-----
* tf 215: density vs. temp for thoria
*-----
*
tf21500  'thoria d vs t'  2  1.0  0.0  * name, # data pairs, scale facts
tf21510   273.15 9860.0
tf21511   5000.0 9860.0
*
*-----
* tantalum
*-----
*
* tabular functions 231-235:
* tf231: enthalpy vs temp
* tf232: temp vs enthalpy
* tf233: spec heat cap vs temp
* tf234: therm conductivity vs temp
* tf235: density vs temp
*
mpmat10300  'tantalum'
*
mpmat10301  enh  231
mpmat10302  tmp  232
mpmat10303  cps  233
mpmat10304  thc  234
mpmat10305  rho  235
*
mpmat10351  den  9860.0
mpmat10352  mlt  3320.0
mpmat10353  lhf  2.853e5
*
*-----
* tf 231: enthalpy vs. temp for tantalum

```

```

*-----
*
tf23100 'tantalum e vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf23101 1 1
tf23111 2.73150E+02 4.94962E+02
tf23112 4.16668E+02 2.12159E+04
tf23113 5.60187E+02 4.22127E+04
tf23114 7.03705E+02 6.34852E+04
tf23115 8.47224E+02 8.50336E+04
tf23116 9.90742E+02 1.06858E+05
tf23117 1.13426E+03 1.28958E+05
tf23118 1.27778E+03 1.51333E+05
tf23119 1.42130E+03 1.73985E+05
tf23120 1.56482E+03 1.96912E+05
tf23121 1.70833E+03 2.20116E+05
tf23122 1.85185E+03 2.43595E+05
tf23123 1.99537E+03 2.67349E+05
tf23124 2.13889E+03 2.91380E+05
tf23125 2.28241E+03 3.15686E+05
tf23126 2.42593E+03 3.40268E+05
tf23127 2.56945E+03 3.65126E+05
tf23128 2.71296E+03 3.90260E+05
tf23129 2.85348E+03 4.15670E+05
tf23130 3.00000E+03 4.41355E+05
*
*-----
* tf 232: temp vs. enthalpy for tantalum
*-----
*
tf23200 'tantalum t vs e' 20 1.0 0.0 * name, # data pairs, scale facts
tf23201 1 1
tf23211 4.94962E+02 2.73150E+02
tf23212 2.12159E+04 4.16668E+02
tf23213 4.22127E+04 5.60187E+02
tf23214 6.34852E+04 7.03705E+02
tf23215 8.50336E+04 8.47224E+02
tf23216 1.06858E+05 9.90742E+02
tf23217 1.28958E+05 1.13426E+03
tf23218 1.51333E+05 1.27778E+03
tf23219 1.73985E+05 1.42130E+03
tf23220 1.96912E+05 1.56482E+03
tf23221 2.20116E+05 1.70833E+03
tf23222 2.43595E+05 1.85185E+03
tf23223 2.67349E+05 1.99537E+03
tf23224 2.91380E+05 2.13889E+03
tf23225 3.15686E+05 2.28241E+03
tf23226 3.40268E+05 2.42593E+03
tf23227 3.65126E+05 2.56945E+03

```



```

tf23228      3.90260E+05      2.71296E+03
tf23229      4.15670E+05      2.85648E+03
tf23230      4.41355E+05      3.00000E+03
*
*-----
* tf 233: cp vs. temp for tantalum
*-----
*
tf23300 'tantalum cp vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf23301 1 1
tf23311      2.73150E+02      1.43417E+02
tf23312      4.16668E+02      1.45339E+02
tf23313      5.60187E+02      1.47261E+02
tf23314      7.03705E+02      1.49183E+02
tf23315      8.47224E+02      1.51104E+02
tf23316      9.90742E+02      1.53026E+02
tf23317      1.13426E+03      1.54948E+02
tf23318      1.27778E+03      1.56869E+02
tf23319      1.42130E+03      1.58791E+02
tf23320      1.56482E+03      1.60713E+02
tf23321      1.70833E+03      1.62635E+02
tf23322      1.85185E+03      1.64556E+02
tf23323      1.99537E+03      1.66478E+02
tf23324      2.13889E+03      1.68400E+02
tf23325      2.28241E+03      1.70321E+02
tf23326      2.42593E+03      1.72243E+02
tf23327      2.56945E+03      1.74165E+02
tf23328      2.71296E+03      1.76087E+02
tf23329      2.85648E+03      1.78008E+02
tf23330      3.00000E+03      1.79930E+02
*
*-----
* tf 234: thermal cond vs. temp for tantalum
*-----
*
tf23400 'tantalum k vs t' 20 1.0 0.0 * name, # data pairs, scale facts
tf23411      2.73150E+02      7.15522E+01
tf23412      4.16668E+02      6.95105E+01
tf23413      5.60187E+02      6.74688E+01
tf23414      7.03705E+02      6.59461E+01
tf23415      8.47224E+02      6.45650E+01
tf23416      9.90742E+02      6.31839E+01
tf23417      1.13426E+03      6.26736E+01
tf23418      1.27778E+03      6.23133E+01
tf23419      1.42130E+03      6.19530E+01
tf23420      1.56482E+03      6.15927E+01
tf23421      1.70833E+03      6.12324E+01
tf23422      1.85185E+03      7.26125E+01

```

```

tf23423    1.99537E+03    7.36133E+01
tf23424    2.13889E+03    7.46141E+01
tf23425    2.28241E+03    7.56149E+01
tf23426    2.42593E+03    7.66157E+01
tf23427    2.56945E+03    7.76165E+01
tf23428    2.71296E+03    7.86173E+01
tf23429    2.85648E+03    7.96181E+01
tf23430    3.00000E+03    8.06189E+01
*
*-----
* tf 235: density vs. temp for tantalum
*-----
*
tf23500 'tantalum d vs t' 2 1.0 0.0 * name, # data pairs, scale facts
tf23510 273.15 16600.0
tf23511 5000.0 16600.0
*
r*i*f 'sens.dat'
.
*
*eor* melcor
*
*
* MELCOR MP2 input deck
*
* started 8/20/93
*
nocopy
forceplot 0.05 5
softdtmin .01 1000
cymesf 100 10
*
*****
* exec package input *
*****
*
title      'mp2'
jobid      'mp2'
*
diagf      'mp2.dia'
outputf    'mp2.out'
plotf      'mp2.ptf'
messagef    'mp2.mes'
restartf    'mp2.rst'
statusf     'mp2.mai'
crtout
*
*

```

```

restart 0
cpuleft 10.
cpulim 1.e6
*
*tend
tend 20000.0
*
*****
*          time  dtmax  dtmin  dtedt  dtplt  dtrst  dcrest
*
time1      0.0  0.5    0.0001  2000.0   100.0   2000.0
*
time2     14000.0  0.5    0.0001  1000.0   100.0   1000.0
*
*****
*
* enable additional cor output
*
coredv01 1 1 1 1 1 1 * turn on volume fraction plot output
*
* enable individual material candling, disable dt/dz
*
cortst01 0 0 0 0 2 1 1 0 0 0
*
r*i*f 'sens2.dat'
*
.
*
*eor* hispltm
*
file1 'mp2.ptf'
title, mp2 experiment base case
nologo,wide
*
*
TITLE, DEBRIS REG DEBRIS TEMPS, AXIAL LEVEL 10
VLABEL, TEMPERATURE ((K)
limits 0, 20000, 0, 3500
PLOT, TIME, COR-TDP.110, LINE = SOLID, SYM='1', LE='CELL 110', FILE=1
CPLOT, TIME, COR-TDP.210, LINE = DOTDASH, SYM='2', LE='CELL 210', FILE=1
CPLOT, TIME, COR-TDP.310, LINE = SDASH, SYM='3', LE='CELL 310', FILE=1
DATA, LE='DBC1400', LINE = DOT, SYM=', '
*readfile,'/i1/tjtautg/mp2/data/debris.dat','DBC1400'
DATA, LE='DBC1401', LINE = DOT, SYM='''
*readfile,'/i1/tjtautg/mp2/data/debris.dat','DBC1401'
DATA, LE='DBC1601', LINE = DOT, SYM='&'
*readfile,'/i1/tjtautg/mp2/data/debris.dat','DBC1601'
lege,lr

```

```

*
TITLE, DEBRIS REG DEBRIS TEMPS, AXIAL LEVEL 11
VLABEL, TEMPERATURE (())K
limits 0, 20000, 0, 3500
PLOT, TIME, COR-TDP.111, LINE = SOLID, SYM='1', LE='CELL 111', FILE=1
CPLOT, TIME, COR-TDP.211, LINE = DOTDASH, SYM='2', LE='CELL 211', FILE=1
CPLOT, TIME, COR-TDP.311, LINE = SDASH, SYM='3', LE='CELL 311', FILE=1
DATA, LE='DBC1801', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC1801'
lege,lr
*
TITLE, DEBRIS REG DEBRIS TEMPS, AXIAL LEVEL 12
VLABEL, TEMPERATURE (())K
limits 0, 20000, 0, 3500
PLOT, TIME, COR-TDP.112, LINE = SOLID, SYM='1', LE='CELL 112', FILE=1
CPLOT, TIME, COR-TDP.212, LINE = DOTDASH, SYM='2', LE='CELL 212', FILE=1
CPLOT, TIME, COR-TDP.312, LINE = SDASH, SYM='3', LE='CELL 312', FILE=1
DATA, LE='DBC2100', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC2100'
DATA, LE='DBC2102', LINE = DOT, SYM='''
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC2102'
DATA, LE='DBC2103', LINE = DOT, SYM='&'
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC2103'
lege,lr
*
TITLE, DEBRIS REG DEBRIS TEMPS, AXIAL LEVEL 13
VLABEL, TEMPERATURE (())K
limits 0, 20000, 0, 3500
PLOT, TIME, COR-TDP.113, LINE = SOLID, SYM='1', LE='CELL 113', FILE=1
CPLOT, TIME, COR-TDP.213, LINE = DOTDASH, SYM='2', LE='CELL 213', FILE=1
CPLOT, TIME, COR-TDP.313, LINE = SDASH, SYM='3', LE='CELL 313', FILE=1
lege,lr
*
TITLE, DEBRIS REG DEBRIS TEMPS, AXIAL LEVEL 14
VLABEL, TEMPERATURE (())K
limits 0, 20000, 0, 3500
PLOT, TIME, COR-TDP.114, LINE = SOLID, SYM='1', LE='CELL 114', FILE=1
CPLOT, TIME, COR-TDP.214, LINE = DOTDASH, SYM='2', LE='CELL 214', FILE=1
CPLOT, TIME, COR-TDP.314, LINE = SDASH, SYM='3', LE='CELL 314', FILE=1
DATA, LE='DBC2501', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC2501'
lege,lr
*
TITLE, DEBRIS REG DEBRIS TEMPS, AXIAL LEVEL 15
VLABEL, TEMPERATURE (())K
limits 0, 20000, 0, 3500
PLOT, TIME, COR-TDP.115, LINE = SOLID, SYM='1', LE='CELL 115', FILE=1
CPLOT, TIME, COR-TDP.215, LINE = DOTDASH, SYM='2', LE='CELL 215', FILE=1

```

```

CPLLOT, TIME, COR-TDP.315, LINE = SDASH, SYM='3', LE='CELL 315', FILE=1
DATA, LE='DBC3000', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC3000'
lege,lr
*
TITLE, DEBRIS REG DEBRIS TEMPS, RING 1
VLABEL, TEMPERATURE (())K
limits 0, 20000, 0, 3500
PLOT, TIME, COR-TDP.115, LINE = LDASH, SYM='5', LE='CELL 115', FILE=1
CPLLOT, TIME, COR-TDP.114, LINE = DOTDASH, SYM='4', LE='CELL 114', FILE=1
CPLLOT, TIME, COR-TDP.113, LINE = SOLID, SYM='3', LE='CELL 113', FILE=1
CPLLOT, TIME, COR-TDP.112, LINE = DASHDASH, SYM='2', LE='CELL 112', FILE=1
CPLLOT, TIME, COR-TDP.111, LINE = SDASH, SYM='1', LE='CELL 111', FILE=1
CPLLOT, TIME, COR-TDP.110, LINE = MDASH, SYM='0', LE='CELL 110', FILE=1
DATA, LE='DBC1400', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC1400'
DATA, LE='DBC1401', LINE = DOT, SYM=' '
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC1401'
DATA, LE='DBC1601', LINE = DOT, SYM='&'
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC1601'
DATA, LE='DBC1801', LINE = DOT, SYM='<'
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC1801'
DATA, LE='DBC2100', LINE = DOT, SYM='@'
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC2100'
DATA, LE='DBC2501', LINE = DOT, SYM='_ '
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC2501'
DATA, LE='DBC3000', LINE = DOT, SYM=';'
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC3000'
lege,next
*
TITLE, DEBRIS REG DEBRIS TEMPS, RING 2
VLABEL, TEMPERATURE (())K
limits 0, 20000, 0, 3500
PLOT, TIME, COR-TDP.215, LINE = LDASH, SYM='5', LE='CELL 215', FILE=1
CPLLOT, TIME, COR-TDP.214, LINE = DOTDASH, SYM='4', LE='CELL 214', FILE=1
CPLLOT, TIME, COR-TDP.213, LINE = SOLID, SYM='3', LE='CELL 213', FILE=1
CPLLOT, TIME, COR-TDP.212, LINE = DASHDASH, SYM='2', LE='CELL 212', FILE=1
CPLLOT, TIME, COR-TDP.211, LINE = SDASH, SYM='1', LE='CELL 211', FILE=1
CPLLOT, TIME, COR-TDP.210, LINE = MDASH, SYM='0', LE='CELL 210', FILE=1
DATA, LE='DBC2102', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC2102'
lege,next
*
TITLE, DEBRIS REG DEBRIS TEMPS, RING 3
VLABEL, TEMPERATURE (())K
limits 0, 20000, 0, 3500
PLOT, TIME, COR-TDP.315, LINE = LDASH, SYM='5', LE='CELL 315', FILE=1
CPLLOT, TIME, COR-TDP.314, LINE = DOTDASH, SYM='4', LE='CELL 314', FILE=1

```

```

CPLLOT, TIME, COR-TDP.313, LINE = SOLID, SYM='3', LE='CELL 313', FILE=1
CPLLOT, TIME, COR-TDP.312, LINE = DASHDASH, SYM='2', LE='CELL 312', FILE=1
CPLLOT, TIME, COR-TDP.311, LINE = SDASH, SYM='1', LE='CELL 311', FILE=1
CPLLOT, TIME, COR-TDP.310, LINE = MDASH, SYM='0', LE='CELL 310', FILE=1
DATA, LE='DBC2103', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/debris.dat', 'DBC2103'
lege,next
*
TITLE, CRUST REG CLAD TEMPS, AXIAL LEVEL 7
VLABEL, TEMPERATURE (())K
limits 0, 20000.0, 0.0, 2500.0
PLOT, TIME, COR-TCL.107, LINE = SOLID, SYM='1', LE='CELL 107', FILE=1
CPLLOT, TIME, COR-TCL.207, LINE = DOTDASH, SYM='2', LE='CELL 207', FILE=1
CPLLOT, TIME, COR-TCL.307, LINE = SDASH, SYM='3', LE='CELL 307', FILE=1
DATA, LE='FRS1000', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'FRS1000'
DATA, LE='FRK1044', LINE = DOT, SYM='''
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'FRK1044'
DATA, LE='CRC11-2', LINE = DOT, SYM='&'
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'CRC11-2'
DATA, LE='CRC11-4', LINE = DOT, SYM='<'
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'CRC11-4'
lege,ul
*
TITLE, CRUST REG CLAD TEMPS, AXIAL LEVEL 8
VLABEL, TEMPERATURE (())K
limits 0, 20000.0, 0.0, 2500.0
PLOT, TIME, COR-TCL.108, LINE = SOLID, SYM='1', LE='CELL 108', FILE=1
CPLLOT, TIME, COR-TCL.208, LINE = DOTDASH, SYM='2', LE='CELL 208', FILE=1
CPLLOT, TIME, COR-TCL.308, LINE = SDASH, SYM='3', LE='CELL 308', FILE=1
DATA, LE='CRC12-0', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'CRC12-0'
lege,ul
*
TITLE, CRUST REG CLAD TEMPS, AXIAL LEVEL 9
VLABEL, TEMPERATURE (())K
limits 0, 20000.0, 0.0, 2500.0
PLOT, TIME, COR-TCL.109, LINE = SOLID, SYM='1', LE='CELL 109', FILE=1
CPLLOT, TIME, COR-TCL.209, LINE = DOTDASH, SYM='2', LE='CELL 209', FILE=1
CPLLOT, TIME, COR-TCL.309, LINE = SDASH, SYM='3', LE='CELL 309', FILE=1
DATA, LE='CRC13-1', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'CRC13-1'
DATA, LE='CRC13-3', LINE = DOT, SYM='''
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'CRC13-3'
lege,ul
*
TITLE, CRUST REG CLAD TEMPS, RING 1
VLABEL, TEMPERATURE (())K

```

```

limits 0, 20000.0, 0.0, 2500.0
PLOT, TIME, COR-TCL.109, LINE = SOLID, SYM='9', LE='CELL 109', FILE=1
CPLLOT, TIME, COR-TCL.108, LINE = DOT, SYM='8', LE='CELL 108', FILE=1
CPLLOT, TIME, COR-TCL.107, LINE = SDASH, SYM='7', LE='CELL 107', FILE=1
DATA, LE='FRS1000', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'FRS1000'
DATA, LE='CRC11-2', LINE = DOT, SYM=' '
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'CRC11-2'
DATA, LE='CRC12-0', LINE = DOT, SYM='&'
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'CRC12-0'
DATA, LE='CRC13-1', LINE = DOT, SYM='<'
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'CRC13-1'
lege,ul

```

*

TITLE, CRUST REG CLAD TEMPS, RING 2

VLABEL, TEMPERATURE (())K

limits 0, 20000.0, 0.0, 2500.0

```

PLOT, TIME, COR-TCL.209, LINE = SOLID, SYM='9', LE='CELL 209', FILE=1
CPLLOT, TIME, COR-TCL.208, LINE = DOT, SYM='8', LE='CELL 208', FILE=1
CPLLOT, TIME, COR-TCL.207, LINE = SDASH, SYM='7', LE='CELL 207', FILE=1
DATA, LE='CRC11-4', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'CRC11-4'
DATA, LE='CRC13-3', LINE = DOT, SYM=' '
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'CRC13-3'
lege,ul

```

*

TITLE, CRUST REG CLAD TEMPS, RING 3

VLABEL, TEMPERATURE (())K

limits 0, 20000.0, 0.0, 2500.0

```

PLOT, TIME, COR-TCL.309, LINE = SOLID, SYM='9', LE='CELL 309', FILE=1
CPLLOT, TIME, COR-TCL.308, LINE = DOT, SYM='8', LE='CELL 308', FILE=1
CPLLOT, TIME, COR-TCL.307, LINE = SDASH, SYM='7', LE='CELL 307', FILE=1
DATA, LE='FRK1044', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'FRK1044'
lege,ul

```

*

TITLE, STUB REG TEMPS, AXIAL LEVELS 1, 2 & 3

VLABEL, TEMPERATURE (())K

limits 0, 20000.0, 0.0, 2500.0

```

PLOT, TIME, COR-TCL.102, LINE = SOLID, SYM='1', LE='CLAD, CELL 102', FILE=1
CPLLOT, TIME, COR-TCL.202, LINE = DASHDASH, SYM='2', LE='CLAD, CELL 202', FILE=1
CPLLOT, TIME, COR-TCL.302, LINE = SDASH, SYM='3', LE='CLAD, CELL 302', FILE=1
CPLLOT, TIME, COR-TCL.103, LINE = LDASH, SYM='1', LE='CLAD, CELL 103', FILE=1
CPLLOT, TIME, COR-TCL.203, LINE = DOTDASH, SYM='2', LE='CLAD, CELL 203', FILE=1
CPLLOT, TIME, COR-TCL.303, LINE = MDASH, SYM='3', LE='CLAD, CELL 303', FILE=1
CPLLOT, TIME, COR-TSS.101, LINE = SOLID, SYM='1', LE='OS, CELL 103', FILE=1
CPLLOT, TIME, COR-TSS.201, LINE = SDASH, SYM='2', LE='OS, CELL 203', FILE=1
CPLLOT, TIME, COR-TSS.301, LINE = DOTDASH, SYM='3', LE='OS, CELL 303', FILE=1

```

```

DATA, LE='GSK0013', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/grid.dat', 'GSK0013'
DATA, LE='GSK0018', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/grid.dat', 'GSK0018'
lege,ul
*
TITLE, STUB REG CLAD TEMPS, AXIAL LEVEL 4
VLABEL, TEMPERATURE (K)
limits 0, 20000.0, 0.0, 2500.0
PLOT, TIME, COR-TCL.104, LINE = SOLID, SYM='1', LE='CELL 104', FILE=1
CPLOT, TIME, COR-TCL.204, LINE = DOTDASH, SYM='2', LE='CELL 204', FILE=1
CPLOT, TIME, COR-TCL.304, LINE = SDASH, SYM='3', LE='CELL 304', FILE=1
DATA, LE='FRK0514', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/stub.dat', 'FRK0514'
DATA, LE='FRK0531', LINE = DOT, SYM=' '
*readfile, '/i1/tjtautg/mp2/data/stub.dat', 'FRK0531'
lege,ul
*
TITLE, STUB REG CLAD TEMPS, AXIAL LEVELS 5 & 6
VLABEL, TEMPERATURE (K)
limits 0, 20000.0, 0.0, 2500.0
PLOT, TIME, COR-TCL.105, LINE = SOLID, SYM='1', LE='CELL 105', FILE=1
CPLOT, TIME, COR-TCL.205, LINE = DASHDASH, SYM='2', LE='CELL 205', FILE=1
CPLOT, TIME, COR-TCL.305, LINE = SDASH, SYM='3', LE='CELL 305', FILE=1
CPLOT, TIME, COR-TCL.106, LINE = LDASH, SYM='1', LE='CELL 106', FILE=1
CPLOT, TIME, COR-TCL.206, LINE = DOTDASH, SYM='2', LE='CELL 206', FILE=1
CPLOT, TIME, COR-TCL.306, LINE = MDASH, SYM='3', LE='CELL 306', FILE=1
DATA, LE='FRS1000', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'FRS1000'
DATA, LE='FRK1044', LINE = DOT, SYM=' '
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'FRK1044'
lege,ul
*
TITLE, STUB REG CLAD TEMPS, RING 1
VLABEL, TEMPERATURE (K)
limits 0, 20000.0, 0.0, 2500.0
PLOT, TIME, COR-TCL.106, LINE = DOTDASH, SYM='6', LE='CELL 106', FILE=1
CPLOT, TIME, COR-TCL.105, LINE = LDASH, SYM='5', LE='CELL 105', FILE=1
CPLOT, TIME, COR-TCL.104, LINE = SOLID, SYM='4', LE='CELL 104', FILE=1
CPLOT, TIME, COR-TCL.103, LINE = DASHDASH, SYM='3', LE='CELL 103', FILE=1
CPLOT, TIME, COR-TCL.102, LINE = SDASH, SYM='2', LE='CELL 102', FILE=1
DATA, LE='GSK0013', LINE = DOT, SYM=', '
*readfile, '/i1/tjtautg/mp2/data/grid.dat', 'GSK0013'
DATA, LE='FRK0514', LINE = DOT, SYM=' '
*readfile, '/i1/tjtautg/mp2/data/stub.dat', 'FRK0514'
DATA, LE='FRS1000', LINE = DOT, SYM='&'
*readfile, '/i1/tjtautg/mp2/data/crust.dat', 'FRS1000'
lege,ul

```



```

*
TITLE, STUB REG CLAD TEMPS, RING 2
VLABEL, TEMPERATURE (())K
limits 0, 20000.0, 0.0, 2500.0
PLOT, TIME, COR-TCL.206, LINE = DOTDASH, SYM='6', LE='CELL 206', FILE=1
CPLOT, TIME, COR-TCL.205, LINE = LDASH, SYM='5', LE='CELL 205', FILE=1
CPLOT, TIME, COR-TCL.204, LINE = SOLID, SYM='4', LE='CELL 204', FILE=1
CPLOT, TIME, COR-TCL.203, LINE = DASHDASH, SYM='3', LE='CELL 203', FILE=1
CPLOT, TIME, COR-TCL.202, LINE = SDASH, SYM='2', LE='CELL 202', FILE=1
DATA, LE='GSK0018', LINE = DOT, SYM='',
*readfile,'/i1/tjtautg/mp2/data/grid.dat','GSK0018'
DATA, LE='FRK0531', LINE = DOT, SYM=''
*readfile,'/i1/tjtautg/mp2/data/stub.dat','FRK0531'
lege,ul
*
TITLE, STUB REG CLAD TEMPS, RING 3
VLABEL, TEMPERATURE (())K
limits 0, 20000.0, 0.0, 2500.0
PLOT, TIME, COR-TCL.306, LINE = DOTDASH, SYM='6', LE='CELL 306', FILE=1
CPLOT, TIME, COR-TCL.305, LINE = LDASH, SYM='5', LE='CELL 305', FILE=1
CPLOT, TIME, COR-TCL.304, LINE = SOLID, SYM='4', LE='CELL 304', FILE=1
CPLOT, TIME, COR-TCL.303, LINE = DASHDASH, SYM='3', LE='CELL 303', FILE=1
CPLOT, TIME, COR-TCL.302, LINE = SDASH, SYM='2', LE='CELL 302', FILE=1
DATA, LE='FRK1044', LINE = DOT, SYM=''
*readfile,'/i1/tjtautg/mp2/data/crust.dat','FRK1044'
lege,ul
*
TITLE, TIME STEPS
VLABEL, TIME STEP (())S
limits 0, 20000.0, 0, 0
PLOT, TIME, DT, LINE = SOLID, SYM='', LE='SYSTEM', FILE=1
CPLOT, TIME, COR-DT, LINE = DOT, SYM='', LE='COR', FILE=1
lege,ul
*
TITLE, CVH VOLUME PRESSURES
VLABEL, PRESSURE (())PA
limits 0, 20000.0, 0, 0
PLOT, TIME, CVH-P.101, LINE = SOLID, SYM='1', LE='CV 101', FILE=1
CPLOT, TIME, CVH-P.102, LINE = DOT, SYM='2', LE='CV 102', FILE=1
CPLOT, TIME, CVH-P.103, LINE = SDASH, SYM='3', LE='CV 103', FILE=1
lege,ul
*
TITLE, CVH VOLUME TEMPERATURES
VLABEL, TEMPERATURE (())K
limits 0, 20000.0, 0, 0
PLOT, TIME, CVH-TVAP.101, LINE = SOLID, SYM='1', LE='CV 101', FILE=1
CPLOT, TIME, CVH-TVAP.102, LINE = DOT, SYM='2', LE='CV 102', FILE=1
CPLOT, TIME, CVH-TVAP.103, LINE = SDASH, SYM='3', LE='CV 103', FILE=1

```

```
lege,ul
*
TITLE, ACRR POWER
VLABEL, POWER (KW)
ULABEL, TIME (S)
limits 0, 20000, 0, 700.0
UPLOT, LINE = SOLID, SYM=', '
*readfile, '/11/tjtautg/mp2/data/power.dat'
-12345, -12345
lege,ul
*
```

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