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Comparison of MELCOR Modeling Techniques and Effects of Vessel Water Injection on a Low-Pressure, Short-Term, Station Blackout at the Grand Gulf Nuclear Station

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MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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Engineering Technology Division

COMPARISON OF MELCOR MODELING TECHNIQUES AND EFFECTS OF VESSEL WATER INJECTION ON A LOW-PRESSURE, SHORT-TERM STATION BLACKOUT AT THE GRAND GULF NUCLEAR STATION

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ABSTRACT

A fully qualified, best-estimate MELCOR deck has been prepared for the Grand Gulf Nuclear Station and has been run using MELCOR 1.8.3 (1.8 PN) for a low-pressure, short-term, station blackout severe accident. The same severe accident sequence has been run with the same MELCOR version for the same plant using the deck prepared during the NUREG-1150 study. A third run was also completed with the best-estimate deck but without the Lower Plenum Debris Bed (BH) Package to model the lower plenum. The results from the three runs have been compared, and substantial differences have been found. The timing of important events is shorter, and the calculated source terms are in most cases larger for the NUREG-1150 deck results. However, some of the source terms calculated by the NUREG-1150 deck are not conservative when compared to the best-estimate deck results. These results identified some deficiencies in the NUREG-1150 model of the Grand Gulf Nuclear Station.

Injection recovery sequences have also been simulated by injecting water into the vessel after core relocation started. This marks the first use of the new BH Package of MELCOR to investigate the effects of water addition to a lower plenum debris bed. The calculated results indicate that vessel failure can be prevented by injecting water at a sufficiently early stage. No pressure spikes in the vessel were predicted during the water injection. The MELCOR code has proven to be a useful tool for severe accident management strategies.

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ACRONYMS

ac	alternating current
ADS	automatic depressurization system (8 SRVs)
ACH	active core height (150 in. or 3.81 m)
BH	lower plenum debris bed (package of MELCOR)
BWR	boiling water reactor
CR	control rods
dc	direct current
ECCS	emergency core-cooling-systems
EPGs	emergency procedure guidelines
FSAR	final safety analysis report
HPCS	high-pressure core spray system
LOCA	loss-of-coolant accident
LPCI	low-pressure coolant injection
LP	lower plenum
LPCS	low-pressure core spray system
LWR	light-water reactor
MSIV	main steam isolation valve
NRC	U.S. Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PRA	probabilistic risk assessment
PWR	pressurized-water reactor
RCIC	reactor core isolation cooling system
RCS	reactor coolant system
RHR	residual heat removal system
SLCS	standby liquid control system
SNL	Sandia National Laboratories
SRV	safety relief valve
STCP	Source Term Code Package

ACKNOWLEDGMENTS

The best-estimate MELCOR 1.8.3 (1.8 PN) Grand Gulf deck of this project was prepared by J. J. Carbajo and R. H. Morris based on a previous deck completed in 1991 by B. W. Patton. The previous deck was prepared for version 1.8.0 of MELCOR and only modeled the containment and the cavity of the Grand Gulf Plant. Carbajo reviewed the original deck, modified it as required to make it compatible with MELCOR 1.8.3, added the control volumes, flow paths, and heat slabs of the reactor vessel and the input for the radionuclide package. Morris prepared the core and the BH Package input. Each preparer reviewed the portion of the deck completed by the other to fully qualify the final MELCOR deck.

The assistance provided by the Grand Gulf Nuclear Station staff is hereby acknowledged. The report was reviewed by S. A. Hodge, S. R. Greene, and R. H. Morris of Oak Ridge National Laboratory (ORNL), by Grand Gulf plant staff, General Electric personnel, and U.S. Nuclear Regulatory Commission (NRC) staff. Appreciation is extended to all the report reviewers. Special thanks to J. N. Ridgely, the NRC Technical Monitor, for his useful contributions to this project. This project was sponsored by the NRC, Office of Nuclear Regulatory Research, Division of Systems Technology.

EXECUTIVE SUMMARY

INTRODUCTION AND OBJECTIVE

The purposes of this work are to prepare a fully qualified, best-estimate MELCOR deck for the Grand Gulf Nuclear Station; to run a low-pressure, short-term, station blackout accident sequence; and to compare these results to those for the same transient obtained by using a MELCOR deck prepared for the same plant during the NUREG-1150 project. Another objective of this work is to simulate injection recovery scenarios in which power is regained late in the station blackout accident sequence and water is injected into the vessel to arrest the severe accident progression. The plant analyzed, the Grand Gulf Nuclear Station, Unit 1, is a 3,833-MW(t) boiling water reactor (BWR-6) with a Mark-III containment. The severe accident analyzed is a station blackout with all ac power lost. The batteries remain available to operate the safety relief valves (SRVs).

Manual actuation of the automatic depressurization system (ADS) SRVs simultaneously opens 8 of the 20 SRVs of the plant. This manual operation is used to depressurize the vessel in accordance with Rev. 3 of the "Emergency Procedure Guidelines" (EPGs) of the BWR Owner's Group. These EPGs call for depressurization when the water level in the core has decreased to approximately one-third of the active core height. The MELCOR severe accident code, version 1.8.3 (1.8 PN), was employed for these calculations.

The NUREG-1150 deck is the same deck used in that study except for some minor modifications implemented to make it compatible with version 1.8.3 (1.8 PN) of MELCOR and to better model the transient analyzed (depressurization and a containment failure mode were added). The best-estimate deck is more detailed and more accurately models the Grand Gulf plant. This deck includes a detailed model of the reactor vessel lower plenum and the lower head to be used with the Lower Plenum Debris Bed (BH) Package of MELCOR. The NUREG-1150 deck does not have this detailed model and does not use the BH Package. A third deck was prepared with all the features of the best-estimate model but without use of the BH Package.

TIMING OF IMPORTANT EVENTS

The timing of the important events calculated with the best-estimate decks and with the NUREG-1150 deck are presented in Table ES.1. There are substantial differences between the calculated times. The best-estimate deck predicts a later timing than the NUREG-1150 deck for every event with the exception of the "gap" release phase duration, which is slightly longer (by 4 min) for the NUREG-1150 deck. The major difference is for vessel penetration failure, which is predicted to occur more than twice as long after core uncovering for the best-estimate deck than for the NUREG-1150 deck. This is a direct consequence of the use of the BH Package model and of the larger inventory of steel in the core and lower plenum employed in the best-estimate deck. For the same reason, the "early-in-vessel" release phase duration is 168 min for the best-estimate deck as opposed to only 14 min for the NUREG-1150 deck. Because shorter times are conservative results, it appears that the NUREG-1150 deck calculated timing of events is conservative.

IN-CONTAINMENT SOURCE TERMS

The in-containment source terms are presented in Table ES.2 for the best-estimate deck, in Table ES.3 for the best-estimate deck without BH, and in Table ES.4 for the NUREG-1150 deck. There are substantial differences in these results. The majority (but not all) of the source terms calculated by the NUREG-1150 deck are larger than the equivalent source terms calculated by the best-estimate deck, and therefore, conservative. The "total" in-containment source term fractions calculated with the NUREG-1150 deck are larger than the corresponding values calculated by the best-estimate deck for all classes except for class 1 (noble gases), class 2 (Cs), class 6 (Ru), class 10 (U) and class 16 (CsI). The differences for classes 1 and 6 are minimal, the difference for class 2 is 24%; for class 10, 850%; and for class 16, 27%—all larger in the best-estimate deck than in the NUREG-1150 deck. The "gap" in-containment source term fractions calculated with the NUREG-1150 deck are larger except for class 5 (Te). Most of the "early in-vessel" source term fractions are larger for the best-estimate deck for classes 1, 2, 5, and 16 vs those for classes 3 and 12 that are larger for

Table ES.1. Comparison of the times of events for the station blackout at Grand Gulf using three different models

Event	Time with best-estimate deck (min)	Time with best-estimate deck (h)	Time with best-estimate deck without BH (min)	Time with best-estimate deck without BH (h)	Time with NUREG-1150 deck (min)	Time with NUREG-1150 deck (h)
Core uncovering	31	0.5	31	0.5	29	0.5
Vessel depressurization	59	1.0	59	1.0	48	0.8
Gap release initiation	81	1.4	81	1.4	65	1.1
Gap release ended	120	2.0	120	2.0	109	1.8
Gap release phase duration	39	0.7	39	0.7	43	0.7
Core relocation started	114	1.9	114	1.9	111	1.9
First core plate failure	184	3.1	184	3.1	121	2.0
Vessel failure	288	4.8	184.4	3.1	122	2.0
Early in-vessel release phase duration	168	2.8	64.4	1.1	14	0.2
Containment failure	2,580	43.0	2,534	42.2	2,199	36.7
Time between vessel and containment failures	2,292	38.2	2,349	39.1	2,077	34.6
Calculation ended	2,833	47.2	2,800	46.7	2,642	44.0
Ex-vessel release phase duration	2,545	42.4	2,615	43.6	2,520	42.0

Table ES.2. Source terms released into containment for the station blackout with the best-estimate deck

		Phase	Gap Release	Early In-vessel	Ex-vessel	Late In-vessel	Total
	Duration	(min)	39	168	2,545	2,545	2,752
		(h)	0.7	2.8	42.4	42.4	45.9
Class	Element	Inventory (kg)	Fraction	Fraction	Fraction	Fraction	Fraction
1	Noble gases	463.7	0.1442	0.8315	0.0236	0.0006	0.9999
2	Cs	246.4	0.1422	0.4800	0.0224	0.2182	0.8628
3	Ba, Sr	207.5	0	0.0026	0.1154	0	0.1180
4	I	20.93	-	-	-	-	-
5	Te	40.79	0.0368	0.5592	0.0248	0.0363	0.6571
6	Ru	307.0	0	0	0.0001	0	0.0001
7	Mo	350.6	0	0	0	0	0
8	Ce	593.9	0	0	0.0017	0	0.0017
9	La	571.0	0	0	0.0001	0	0.0001
10	U	138,300	0	0	0.0034	0	0.0034
11	Cd	1.41	0	0	0.0149	0	0.0149
12	Sn	8.59	0.0007	0.0304	0.1892	0	0.2203
16	CsI	42.85	0.1138	0.4977	0.0236	0.2513	0.8864

Notes: All fractions are from the initial inventories of fission products, except for class 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted. Class 4 (I) releases are combined with class 2 (Cs) to form class 16 (CsI).

Table ES.3. Source terms released into containment for the station blackout with the best-estimate deck without BH

		Phase	Gap Release	Early In-vessel	Ex-vessel	Late In-vessel	Total
	Duration	(min)	39	65	2,615	2,615	2,719
		(h)	0.7	1.1	43.6	43.6	45.3
Class	Element	Inventory (kg)	Fraction	Fraction	Fraction	Fraction	Fraction
1	Noble gases	463.7	0.1456	0.7733	0.0615	0.0173	0.9977
2	Cs	246.3	0.1453	0.4203	0.0593	0.2249	0.8480
3	Ba, Sr	207.5	0	0.0018	0.3252	0.0002	0.3272
4	I	20.93	-	-	-	-	-
5	Te	40.79	0.0400	0.5098	0.0660	0.0809	0.6967
6	Ru	307.0	0	0	0	0	0
7	Mo	350.6	0	0	0.9335	0	0.9335
8	Ce	593.9	0	0	0.0440	0	0.0440
9	La	571.0	0	0	0.0013	0	0.0013
10	U	138,300	0	0	0.0003	0	0.0003
11	Cd	1.41	0	0	0.9336	0	0.9336
12	Sn	8.59	0.0007	0.0216	0.8868	0	0.9091
16	CsI	42.75	0.1155	0.4356	0.0619	0.2736	0.8866

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted. Class 4 (I) releases are combined with class 2 (Cs) to form class 16 (CsI).

Table ES.4. Source terms released into containment for the station blackout with the NUREG-1150 deck

		Phase	Gap Release	Early In-vessel	Ex-vessel	Late In-vessel	Total
	Duration	(min)	43	14	2,520	2,520	2,577
		(h)	0.7	0.2	42	42	42.9
Class	Element	Inventory (kg)	Fraction	Fraction	Fraction	Fraction	Fraction
1	Noble gases	463.2	0.3871	0.4405	0.1228	0.0493	0.9997
2	Cs	245.9	0.2517	0.2203	0.1192	0.1024	0.6936
3	Ba, Sr	207.3	0.0002	0.0058	0.6050	0.0007	0.6117
4	I	20.91	-	-	-	-	-
5	Te	40.75	0.0100	0.3263	0.3238	0.0682	0.7283
6	Ru	306.7	0	0	0	0	0
7	Mo	350.3	0	0	0.9970	0	0.9970
8	Ce	593.4	0	0	0.1372	0	0.1372
9	La	570.5	0	0	0.0040	0	0.0040
10	U	143,700	0	0	0.0004	0	0.0004
11	Cd	1.41	0	0	0.9967	0	0.9967
12	Sn	8.58	0.0025	0.0423	0.9173	0.0065	0.9686
16	CsI	42.78	0.2283	0.2262	0.1237	0.1199	0.6981

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted. Class 4 (I) releases are combined with class 2 (Cs) to form class 16 (CsI).

the NUREG-1150 deck. The "ex-vessel" source term fraction for class 10 (U) and the "late in-vessel" source term fractions for classes 2 (Cs) and 16 (CsI) are also larger for the best-estimate deck.

Very large "total" release fractions (almost 100%) are predicted with the NUREG-1150 deck for classes 7 (Mo), 11 (Cd), and 12 (Sn). These releases occur during the "ex-vessel" release phase. Significant "total" releases are also predicted for class 3 (with 61%) and for class 8 (with 14%) by use of the NUREG-1150 deck. The best-estimate deck does not predict these large releases for classes 3, 7, 8, 11 and 12. These large releases are also predicted by the best-estimate deck without the BH model, which indicates that prediction of these large releases could be a consequence of the lack of the BH model.

Large discrepancies between the results obtained with these three decks appear for classes 3, 7–12. As expected, smaller "early in-vessel" releases are predicted for the NUREG-1150 deck than for the best-estimate deck, since the "early in-vessel" phase duration is much shorter (14 min) than for the best-estimate deck (168 min). However, for two classes (3 and 12), the NUREG-1150 deck predicts larger "early in-vessel" releases than the best-estimate deck.

The NUREG-1150 deck predicts larger releases (by a factor of 3) of nonradioactive aerosols into containment than does the best-estimate deck.

ENVIRONMENTAL SOURCE TERMS

The source terms released into the environment are presented in Table ES.5 for the best-estimate deck, in Table ES.6 for the best-estimate deck without BH, and in Table ES.7 for the NUREG-1150 deck. Comparison of releases at about the same time after containment failure for the three decks is given in Table ES.8. The NUREG-1150 deck predicts larger releases than the best-estimate deck except for classes 2 and 16. Two reasons account for these differences: first, the NUREG-1150 deck predicts larger in-containment source terms except for classes 2 and 16; second, the NUREG-1150 deck does not model the enclosure building around the containment. The enclosure building retains some of the fission products released from the containment and thereby precludes their escape into the environment.

The environmental releases of classes 1 and 5 are very similar for the two-best-estimate decks, which indicates that these releases are independent of the use of the BH

Table ES.5. Cumulative source terms released into the environment for the station blackout with the best-estimate deck

Time after containment failure						
	(s)	2,365	3,365	7,775	11,774	15,173
	(min)	3.9	56	130	196	253
	(h)	0.7	0.9	2.2	3.3	4.2
Class	**Element**	**Fraction**	**Fraction**	**Fraction**	**Fraction**	**Fraction**
1	Noble gases	0.6374	0.7465	0.8001	0.8264	0.8460
2	Cs	0.0034	0.0067	0.0087	0.0095	0.0100
3	Ba, Sr	8×10^{-7}	9.8×10^{-7}	1.1×10^{-6}	1.2×10^{-6}	1.2×10^{-6}
4	I	-	-	-	-	-
5	Te	0.0009	0.0018	0.0024	0.0026	0.0028
6	Ru	1.4×10^{-10}	1.5×10^{-10}	1.6×10^{-10}	1.6×10^{-10}	1.6×10^{-10}
7	Mo	1.6×10^{-10}	2.0×10^{-10}	2.4×10^{-10}	2.6×10^{-10}	2.9×10^{-10}
8	Ce	4.6×10^{-8}	5.8×10^{-8}	6.7×10^{-8}	7.4×10^{-8}	8.2×10^{-8}
9	La	4.6×10^{-8}	5.7×10^{-8}	6.6×10^{-8}	7.3×10^{-8}	8.2×10^{-8}
10	U	5.1×10^{-8}	6.3×10^{-8}	7.2×10^{-8}	8.0×10^{-8}	8.8×10^{-8}
11	Cd	2.8×10^{-5}	3.5×10^{-5}	4.1×10^{-5}	4.5×10^{-5}	5.1×10^{-5}
12	Sn	2.2×10^{-6}	2.8×10^{-6}	3.3×10^{-6}	3.6×10^{-6}	4.1×10^{-6}
16	CsI	0.0048	0.0091	0.0118	0.0129	0.0135

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted. All released I forms class 16 (CsI).

Table ES.6. Cumulative source term released into the environment for the station blackout with the best-estimate deck without BH

Time after containment failure		(s) 7,981	15,981
		(min) 133	266
		(h) 2.2	4.4
Class	Element	Fraction	Fraction
1	Noble gases	0.7845	0.8456
2	Cs	0.0039	0.0047
3	Ba, Sr	1.1×10^{-5}	1.2×10^{-5}
4	I	-	-
5	Te	0.0018	0.0022
6	Ru	3.3×10^{-8}	4.7×10^{-8}
7	Mo	0.0010	0.0011
8	Ce	9.4×10^{-8}	1.3×10^{-7}
9	La	9.8×10^{-8}	1.4×10^{-7}
10	U	7.1×10^{-6}	8.6×10^{-6}
11	Cd	0.0083	0.0086
12	Sn	0.0019	0.0019
13–15			
16	CsI	0.0052	0.0063

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted since this class combines with Cs of class 2 to form CsI (class 16).

Table ES.7. Cumulative source term released into the environment for the station blackout with the NUREG-1150 deck

Time after containment failure					
	(s)	7,790	14,989	22,188	26,595
	(min)	130	250	370	443
	(h)	2.2	4.2	6.2	7.4
Class	Element	Fraction	Fraction	Fraction	Fraction
1	Noble gases	0.9939	0.9967	0.9975	0.9977
2	Cs	0.0041	0.0043	0.0046	0.0049
3	Ba, Sr	2.9×10^{-5}	3.3×10^{-5}	3.7×10^{-5}	4.0×10^{-5}
4	I	-	-	-	-
5	Te	0.0120	0.0136	0.0142	0.0143
6	Ru	9.2×10^{-8}	1.2×10^{-7}	1.7×10^{-7}	2×10^{-7}
7	Mo	0.0258	0.0259	0.0259	0.0259
8	Ce	2.4×10^{-6}	2.5×10^{-6}	2.6×10^{-6}	2.7×10^{-6}
9	La	5.3×10^{-7}	6.4×10^{-7}	8.3×10^{-7}	9.5×10^{-7}
10	U	2.2×10^{-5}	2.6×10^{-5}	3.3×10^{-5}	3.7×10^{-5}
11	Cd	0.0764	0.0800	0.0827	0.0836
12	Sn	0.0314	0.0316	0.0316	0.0316
13–15					
16	CsI	0.0046	0.0049	0.0053	0.0056

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No release of class 4 (I) are predicted. Class 4 (I) releases are combined with class 2 (Cs) to form class 16 (CsI).

Table ES.8. Source terms calculated by MELCOR released into environment for Grand Gulf using three different models

Model		Best-estimate	Best-estimate without BH	NUREG-1150
Duration	(s)	15,173	15,981	14,989
	(min)	253	266	250
	(h)	4.2	4.4	4.2
Class	**Element**	**Fraction**	**Fraction**	**Fraction**
1	Noble gases	0.8460	0.8456	0.9967
2	Cs	0.0100	0.0047	0.0043
3	Ba, Sr	1.2×10^{-6}	1.2×10^{-5}	3.3×10^{-5}
4	I	-	-	-
5	Te	0.0028	0.0022	0.0136
6	Ru	1.6×10^{-10}	4.7×10^{-8}	1.2×10^{-7}
7	Mo	2.9×10^{-10}	0.0011	0.0259
8	Ce	8.2×10^{-8}	1.3×10^{-7}	2.5×10^{-6}
9	La	8.2×10^{-8}	1.4×10^{-7}	6.4×10^{-7}
10	U	8.8×10^{-8}	8.6×10^{-6}	2.6×10^{-5}
11	Cd	5.1×10^{-5}	0.0086	0.0800
12	Sn	4.1×10^{-6}	0.0019	0.0316
16	CsI	0.0135	0.0063	0.0049

Notes: All fractions are from the initial inventories of fission products, except for class 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted since this class combines with class 2 (Cs) to Form class 16 (CsI).

Package. However, the releases for classes 2, 3, 7, 11, 12, and 16 are very similar for the two decks without the BH model, which indicates these releases are dependent on the use of the BH Package.

MAIN MODEL DIFFERENCES

The main model differences that account for the different results between the best-estimate deck and the NUREG-1150 deck are the absence of the BH model, the reduced steel inventory in the core and lower plenum, and the less detailed model of the containment (excluding the enclosure building) employed by the NUREG-1150 model.

INJECTION RECOVERY SEQUENCES

The results for the injection recovery sequences are presented in Table ES.9. The *first two columns* and the *last line* of the table show the results for the base case without water injection. The *third column* of the table shows the water injection times for the 21 injection recovery sequences simulated. To simulate recovery, water injection was started at various times following the onset of fuel rod relocation at 114 min (6,850 s). This is the first application of the new BH Package of MELCOR to investigate the effects of water addition to a lower plenum debris bed. The following points summarize the results:

1. Vessel failure can be prevented if water at a rate of 7,450 gal/min (467.6 kg/s) is injected into the vessel on or before 268.3 min or 16,100 s (accident time). This is about 2-1/2 h after fuel relocation begins.
2. For these calculations, lower plenum dryout was followed immediately by bottom head penetration failure. Water injected into the vessel after penetration failure occurred at 288 min but before 452 min prevented gross failure of the lower head.
3. The earlier the water injection, the less hydrogen generated in-vessel. For reflood sequences initiated before 283 min, the larger the mass flow rate of water injected, the smaller the mass of hydrogen generated. For reflood sequences after 342 min, the larger the mass flow rate of water injected, the larger the mass of hydrogen generated.

Table ES.9. Injection recovery sequences run with MELCOR for the Grand Gulf plant

Base case event	Occurred at time (min)	Water injection at (min)	Mass flow rate (kg/s)	Injected into	Pressure spike (MPa)	(psia)	H_2 generated (kg)	Accident terminated
Control blade relocation	92							
Fuel rod relocation	114							
		117	467.6	Core	-		120	Yes[a]
		183	467.6	Core	4.8	(700)	264	Yes[b]
Core plate 1 failure	184							
		184.1	467.6	Core	4.8	(700)	265	Yes[c]
Core plate 2 failure	192.8							
		193	467.6	Core	1.0	(150)	298	Yes[d]
Core plate 3 failure	268							
		268.3	467.6	Core	0.34	(50)	378	Yes[e]
		283	15	Core	-		610	No[e,f,g]
		283	467.6	Core	-		388	No[e,g,h]
LP dryout and penetration failure	288							
		342	15	LP by BH	-		752	No[e,g]
		342	467.6	LP by BH	-		868	No[e,g]
		345	15	LP by BH	-		724	No[e,g]
		344.8	467.6	LP by BH	-		789	No[e,g]

Table ES.9. (Continued)

Base case event	Occurred at time (min)	Water injection at (min)	Mass flow rate (kg/s)	Injected into	Pressure spike (MPa)	(psia)	H_2 generated (kg)	Accident terminated
		345	467.6	LP by BH	-		975	No[g,i]
Core plate 4 failure	345.1							
		345.2	467.6	LP by BH	-		972	No[g]
		346.3	15	LP by BH	-		858	No[g]
		450	10	LP by BH	-		710	No[g]
		450	467.6	LP by BH	-		750	No[g]
		452	10	LP by BH	-		691	No[j]
		452	467.6	LP by BH	-		690	No[k]
		458.3	10	LP by BH	0.7	(100)	640	No[l]
		458.3	467.6	LP by BH	1.37	(200)	652	No[m]
Lower head failure	465							
Calculation ended	500	**Base case**	0	-	-		689	No

NOTES
LP: Lower plenum
BH: Lower Plenum Bebris Bead Package of MELCOR

[a]None of the four core plates failed
[b]Only core plate 1 failed at 184 min
[c]Core plates 2, 3, and 4 did not fail
[d]Core plates 3 and 4 did not fail
[e]Core plate 4 did not fail
[f]Penetration failed at 289 min
[g]Lower head did not fail
[h]Penetration failed at 291 min
[i]Core plate 4 failed at 345 min
[j]Lower head failed at 473 min
[k]Lower head failed at 458.5 min
[l]Lower head failed at 497.7 min
[m]Lower head failed at 467 min

4. No large pressure spikes were predicted by MELCOR during the reflood of either the core or the lower plenum debris bed.
5. The source terms released into containment are smaller for the injection recovery sequences than for the base station blackout accident sequence without injection recovery. When vessel failure is prevented by the water injection, only two release phases occurred: "gap" and "early in-vessel". The "gap" release phase is the same for both recovered and unrecovered sequences. The "early in-vessel" release phase is shorter for the recovered sequences because the injected water cools the core, thereby terminating fission product release.
6. The MELCOR code has proven to be a useful tool for studying severe accident management strategies.

1. INTRODUCTION

Some nuclear plant computer models employed in severe accident calculations have been based on modifications of computer code input files originally developed to represent other plants. These "approximate" computer models were used extensively in the NUREG-1150 study.[1] For the case of boiling-water reactors (BWRs), an original deck was developed for Peach Bottom Atomic Power Station to be used in MELCOR code[2] severe accident calculations. This original Peach Bottom deck was modified or adjusted for application to the La Salle Nuclear Plant and then adjusted again to represent the Grand Gulf Nuclear Station. Each stage of these modifications or adjustments is an approximation with inherent errors and inaccuracies. A similar approach has been used in pressurized-water reactor (PWR) severe accident analyses.

Since NUREG-1150 is a widely used reference study,[1] the validity of the "approximate" or "adjusted" input decks applied therein should be assessed. Briefly stated, it is useful to verify whether the results of the NUREG-1150 study would have been significantly different had fully qualified, best-estimate computer models been used in lieu of the "adjusted" computer models.

2. OBJECTIVE AND APPROACH

2.1 OBJECTIVE AND SCOPE

The primary objective of this work is to assess the validity of the results obtained with "approximate" or "adjusted" computer models. For this purpose, a "fully qualified, best-estimate" MELCOR input deck has been prepared for the Grand Gulf Nuclear Station. This deck has been run for a low-pressure, short-term station blackout severe accident sequence with the MELCOR code,[2] version 1.8.3 (1.8 PN). This accident sequence has also been run with the same version of the MELCOR code but with the input deck used in the NUREG-1150 study. A third run has also been performed with a "modified" best-estimate deck. The results from these three MELCOR calculations have been compared, the differences have been highlighted, and explanations for the observed differences have been identified.

The main parameters considered and compared in this study are the timing of important events and the associated source terms. Where significant differences appear, there is a clear need to reevaluate the previously-used technique of simply adjusting the MELCOR input deck developed for one plant to approximate the progression of an accident sequence at another plant.

A secondary objective of this work is to simulate injection recovery scenarios. For this purpose, the efficacy of injecting water into the reactor vessel after the onset of core relocation but before vessel failure has been assessed on the bases of the source terms and other accident parameters for sequences in which core recovery is attempted.

The "fully qualified, best-estimate" input deck is defined as an input deck in which each input parameter is calculated or prepared by one analyst and independently checked by a second analyst. All deck values are checked against actual design, plant conditions, and plant procedures [with the exception of the "Steam Cooling" procedure of the *Emergency Procedures Guidelines* (EPGs), Rev. 3 (Ref. 3) that has been used instead of EPGs Rev. 4 (Ref. 4)]. Revision 3 of the EPGs calls for manual depressurization by opening the eight safety relief valves (SRVs) of the automatic depressurization system (ADS) when the core water level is at about one-third of the active core height (ACH) or when the temperature of the suppression pool water reaches 148°F (338 K), whichever occurs first. The Grand Gulf

Nuclear Station currently uses procedures based on Rev. 4 of the EPGs[4], which calls for manual depressurization when the core water level is at two-thirds of the ACH.

The severe accident analyzed is a short-term, low-pressure, station blackout sequence. This station blackout accident sequence assumes that all ac power is lost, but dc power needed to activate the SRVs remains available until the unit batteries are lost (after about 6 h). Independent failure of the reactor core isolation cooling (RCIC) system contributes to loss of vessel injection capability at the time that ac power is lost.

For the best-estimate and the NUREG-1150 decks, manual depressurization is performed in accordance with Rev. 3 of the EPGs, which requires reactor vessel depressurization ("low-pressure" sequence) when the water level in the core is at one-third of ACH. None of the emergency core cooling systems (ECCSs) would be operational due to the loss of ac power. Furthermore, it is assumed that the firewater systems are not available for water injection. Without water injection into the vessel, the accident progresses very rapidly into core uncovering and vessel failure (hence the "short-term" qualifier).

2.2 APPROACH

The MELCOR severe accident code, version 1.8.3 (1.8 PN) (Ref. 2), was used to perform the calculations. The MELCOR code is being developed and enhanced by Sandia National Laboratories (SNL) and, for BWR applications, by Oak Ridge National Laboratory (ORNL) for the U.S. Nuclear Regulatory Commission (NRC).

MELCOR is a fully integrated computer code that models the progression of severe accidents in nuclear power plants using light-water reactors (LWRs). MELCOR has been developed as a second-generation probabilistic risk assessment (PRA) tool and is the successor to the source term code package (STCP).[5] The entire spectrum of severe accident phenomena, including vessel and containment thermal-hydraulic response, core heatup, degradation and relocation, and radionuclide release and transport, is treated in MELCOR in a unified code framework for both BWRs and PWRs. The development emphasis for MELCOR has been focused on building a reasonably fast-running code capable of being used in parametric studies with detailed mechanistic modeling where possible.

Release of fission products from the fuel is determined by application of CORSOR, CORSOR-M, or CORSOR-Booth models as specified by the user. A dynamic surface-to-volume ratio can also be applied to either of the two first models to account for changes in the core geometry. Released fission products may exist as vapors, aerosols, or both, depending on the material's vapor pressure. If the vapor mass is greater than the saturation value for the fission product vapor, the excess vapor mass is converted to aerosol mass.

MELCOR contains a number of physics packages or modules that model essential phenomena and plant features. Key packages include those modeling control volume thermodynamics and hydrodynamics, heat sink structure thermal response, core heatup and degradation, reactor cavity interactions (i.e., core-concrete interaction using the CORCON-MOD3), and radionuclide behavior.

Thermal-hydraulic behavior is modeled in MELCOR in terms of control volumes and flowpaths in the control volume hydrodynamics (CVH) and the flowpath (FL) packages. No formal distinction is made between the reactor coolant system (RCS) and the containment volumes; the same models and solution algorithms are used for both, and the resulting equations are solved simultaneously.

The core package calculates the thermal response of structures in the core and lower plenum. This package treats all important models of heat transfer within the core, as well as oxidation, debris formation, and relocation of core and structural materials during melting, candling, and slumping. Lower head heatup, failure, and debris ejection are also modeled. The package represents a significant improvement in modeling capabilities over the models in the STCP,[5] especially in the area of core relocation. The debris can be quenched with the water in the lower plenum and can also be treated by the Lower Plenum Debris Bed (BH) Package developed by ORNL.[2] This BH Package is believed to provide realistic estimates for the lower plenum and vessel failure phenomena.

The aerosol dynamics portion of MELCOR is based on the MAEROS computer code. MELCOR does not calculate resuspension of deposited aerosol mass. Vapor condensation and evaporation on heat structures and aerosol surfaces are evaluated by the same models as in TRAPMELT3.

For ex-vessel release of radionuclides, the VANESA model has been implemented in MELCOR. It has been coupled to CORCON-MOD3 for each time step.

The MELCOR code is executed in two steps. In the first step, the MELGEN module is executed and all the input data are checked and processed for problem initialization at time zero. In the second step, the MELCOR module advances the calculation over time.

2.3 PREVIOUS WORK

Source term calculations have been performed in the past for the Grand Gulf Nuclear Station.[6] However, these calculations have been performed with the STCP[5] or its component (stand-alone) codes. The station blackout accident sequences previously analyzed are either long-term sequences, with the RCIC system operational, or high-pressure, short-term sequences (without vessel depressurization). Detailed source term results for the short-term station blackout with depressurization were not performed in connection with Ref. 6.

Other calculations that do address the low-pressure, short-term, station blackout sequence at the Grand Gulf Nuclear Station have been completed in the past[7] using the BWRSAR,[8,9] the BWR-LTAS,[10] or the MELCOR[11] version 1.8.0 codes. These studies did not calculate source terms, but the timing of significant events (vessel failure, containment failure, etc.). Comparison of the MELCOR results from the present calculations with previous results is provided in Chap. 6.

3. DESCRIPTION OF GRAND GULF NUCLEAR STATION

3.1 GENERAL PLANT

The Grand Gulf Nuclear Station, Unit 1, is a General Electric BWR-6 reactor with a Mark-III containment located in Port Gibson, Mississippi. The thermal power of the reactor is 3,833 MW(t) with a net electrical output of 1,250 MW(e). The unit began commercial operation in July 1985 and is operated by Entergy Operations, Inc. A schematic of the plant in Fig. 3.1 shows the turbine building, the auxiliary building, the primary containment (Mark-III), and the enclosure building. The primary containment is surrounded by the enclosure building and the auxiliary building.

The core of the reactor contains 800 assemblies with 9 x 9-5 fuel (81 rods per assembly) and 193 control blades. The ACH or fuel height is 150 in. (12.5 ft or 3.81 m).

3.2 THE SAFETY RELIEF VALVES AND THE AUTOMATIC DEPRESSURIZATION SYSTEM

The Safety Relief Valves (SRVs) and the Automatic Depressurization System (ADS) play an important role in the sequence of events of the station blackout analyzed here. The Grand Gulf Plant has a total of 20 SRVs. The SRVs vent steam from the reactor vessel into the pressure suppression pool via the valve arrangement shown in Fig. 3.2 (taken from Ref. 12). The SRVs are located on headers upstream of the main steam isolation valves on each of the four main steam lines leaving the reactor vessel. The SRV discharge quenchers are located symmetrically around the pressure suppression pool. The ADS simultaneously opens 8 of the 20 SRVs (numbers 1, 4, 6, 8, 11, 13, 15 and 18 as indicated on Fig. 3.2).

The SRVs can operate at different modes; they can operate "automatically" or "manually." There are two modes of automatic operation: "spring lift" and "power-actuated relief." In the "spring-lift" mode of operation, dc power is not needed, and the SRVs open by the pressure of the steam compressing a spring in the valves. Eight of the SRVs open by spring lift at 1,165 psig (8.032 MPa), six at 1,180 psig (8.136 MPa), and the other six at 1,190 psig (8.205 MPa).

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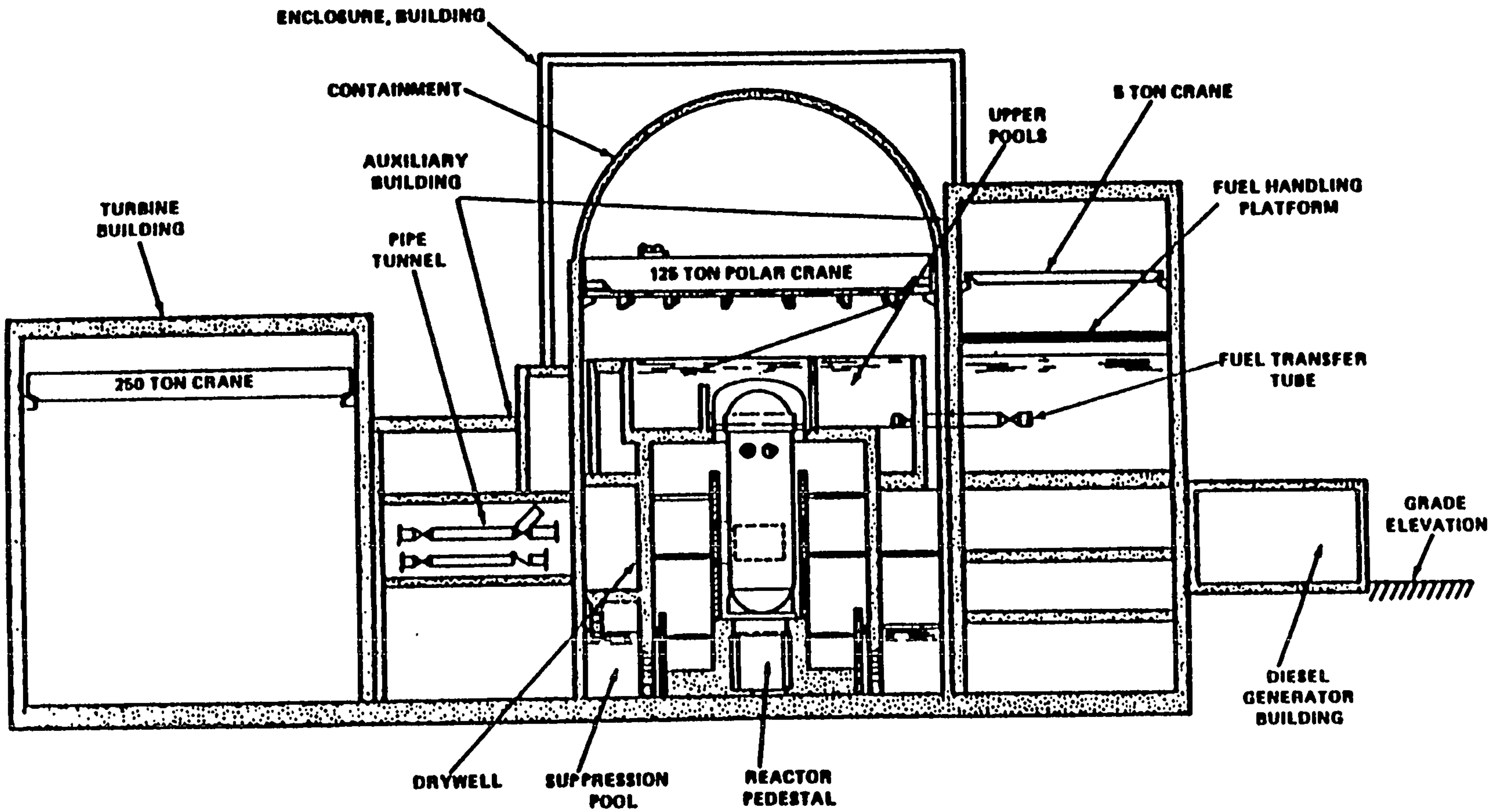

Fig. 3.1 Grand Gulf Nuclear Station schematic

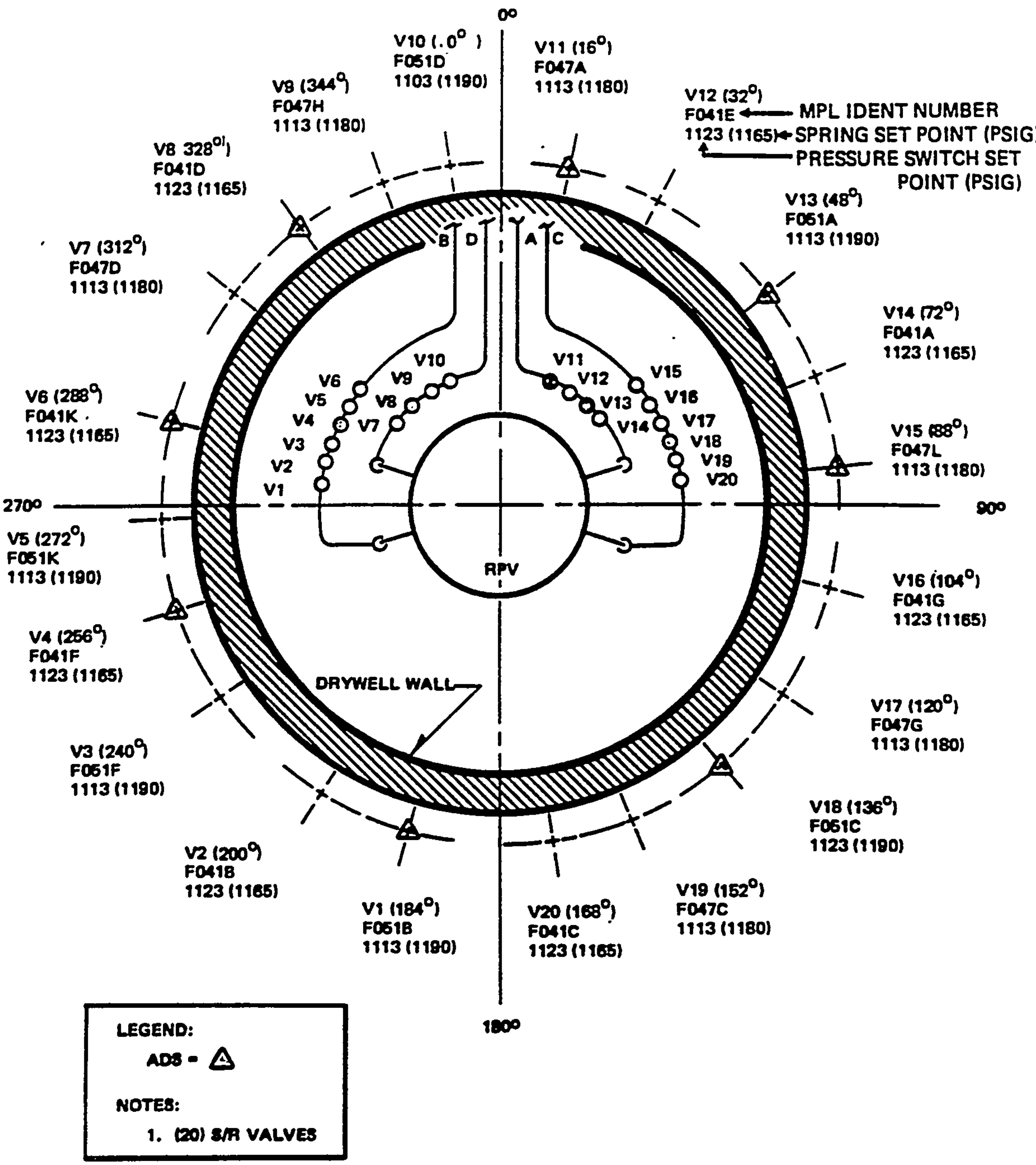

Fig. 3.2 Safety relief valve arrangement

The other mode of automatic operation is the "power-actuated relief" mode. During a station blackout, while dc power remains available, the SRVs would operate under this mode, in which the SRVs open at lower pressures than in the "spring lift" mode. Six SRVs open or close at higher pressures the "first time" of operation than they do in subsequent operations. As indicated in Table 3.1 (taken from Ref. 12), SRVs 1 and 2 have higher opening and closing pressures and SRVs 3 through 6 have higher closing pressures for their first time operation. These two different sets of pressure set points are provided to ensure that no more than one SRV reopens following the first SRV opening. The low-pressure set points, also called "low-low set relief" points, override the normal set points of the first time operation following the initial opening of any SRV.

Table 3.1. Set pressures for "power-actuated relief" mode of operation of the SRVs

Number of SRVs	First time operation				After first-time operation low-low set relief				Cumulative number of SRVs
	Open		Close		Open		Close		
	[psig	(MPa)]	[psig	(MPa)]	[psig	(MPa)]	[psig	(MPa)]	
1	1,103	(7.605)	1,003	(6.915)	1,033	(7.122)	926	(6.385)	1
1	1,113	(7.674)	1,013	(6.984)	1,073	(7.398)	936	(6.454)	2
4	1,113	(7.674)	1,013	(6.984)	1,113	(7.674)	946	(6.522)	6
5	1,113	(7.674)	1,013	(6.984)	1,113[a]	(7.674)	1,013	(6.984)	11
9	1,123	(7.743)	1,023	(7.053)	1,123	(7.743)	1,023	(7.053)	20

[a] When modeling the SRVs in the MELCOR input, an intermediate opening pressure of 1,118 psig (7.708 MPa) instead of 1,113 psig was used for these 5 SRVs to allow for a step between the 4 SRVs at 1,113 psig and the 9 SRVs at 1,123 psig.

Comments received from the Grand Gulf plant staff with respect to the draft of this report indicated that the closing pressures of the "first time" operation mode of the SRVs are the same closing pressures of the "low-low set relief" mode. Table 3.1 shows six SRVs with higher closing pressures during the "first time" operation than during the "low-low set relief" mode. The effect of these different closing pressures during the first SRV cycle is deemed to be insignificant on the overall station blackout transient. Therefore, the complete MELCOR transient with the correct (lower) closing pressures was not rerun.

The SRVs can also be opened and closed manually under the "power-actuated relief" mode of operation at any pressure below the automatic set pressures of Table 3.1. Normally, opening of one SRV is sufficient to control reactor vessel pressure. The SRV that cycles automatically to relieve steam will be the one opening at the lowest pressure (number 1 of Table 3.1). If this automatic procedure is left undisturbed, the same SRV will repeatedly cycle, releasing steam to the *same point* of the pressure suppression pool and causing *unequal heating* of the suppression pool water. Therefore, manual operation of the SRVs to open a *different* SRV at lower pressure settings than the automatic settings listed in Table 3.1 is recommended and will result in a more even heating of the wetwell water. The "manual" pressure settings are 900 psig (6.205 MPa) for opening and 800 psig (5.516 MPa) for closing, as indicated by the Grand Gulf plant staff.[13]

The flow through each SRV is a function of the pressure differential across the valve. It varies between 868,000 lb/h (110 kg/s) at 1,130 psig (7.791 MPa) and 925,000 lb/h (117 kg/s) at 1,205 psig (8.31 MPa).

Depressurization of the reactor by manually opening the eight SRVs of the ADS is very important in BWR accident mitigation. For this operation, dc power is required and would remain available from the station batteries for several hours after a station blackout is initiated. The ADS valves are manually opened to depressurize the reactor vessel and to delay fuel heatup by "steam cooling" uncovered portions of the hot core. The steam is produced by vaporization of some of the reactor water coolant as it is depressurized.

The timing of this depressurization is very important in the accident progression. If the depressurization is initiated while the core is still covered with water or when the core is uncovered but the exposed portion of the fuel is not very hot, the water lost by vaporization will not provide any significant beneficial effects of steam cooling. On the other hand, if the depressurization is delayed too long and the exposed portion of the core has reached the runaway steam oxidation temperature, the flow of steam from the depressurization will increase the Zircaloy oxidation, increasing the fuel and cladding temperatures instead of providing cooling.

Currently, the Grand Gulf Nuclear Station follows the EPGs Rev. 4 (Ref. 4) that calls for depressurization when the collapsed water level in the core is at two-thirds of the ACH. Previous studies[7, 14–16] on depressurization timing for cores with high burnup fuel concluded that depressurization per EPGs Rev. 3 (Ref. 3) delays the accident progression relative to the case following EPGs Rev. 4. Revision 3 of the EPGs calls for depressurization when the collapsed water level in the core is at about one-third of the ACH.

3.3 CONTAINMENT

The Grand Gulf plant consists of the Mark-III primary containment, the enclosure building, the auxiliary building, and the turbine building as shown in Fig. 3.1. The Mark-III containment is a reinforced concrete structure consisting of a flat circular foundation mat, a right circular cylinder, and a hemispherical dome on top of the cylinder, as shown in Fig. 3.3 (taken from Ref. 12). The base mat is about 9-1/2 ft (2.9 m) thick with an outside diameter of 134 ft (40.84 m). The containment wall of the circular cylinder is 3-1/2 ft (1.07 m) thick, with an internal diameter of 124 ft (37.8 m) and a height of 144-3/4 ft (44.12 m). The containment dome is a hemispherical shell 2-1/2 ft (0.762 m) thick, with the same internal diameter as the circular cylinder.

The internal surface of the containment is completely lined with a welded steel plate that forms a leakage barrier. The suppression pool is a 360° annular pool of water located at the bottom inner periphery of the containment. The volume inside the containment can be divided into drywell, wetwell, and outer containment. The drywell and the outer containment are separated by the vertical cylindrical wall with the vent pipes and by the drywell head and the bottom wall of the upper pool. The 28-in.-diam. (0.78-m) vents are located in three horizontal rows (Fig. 3.3). The total number of vents is 135.

The reactor vessel is centrally located inside the drywell. Some of the water of the suppression pool is located in the drywell volume. The maximum volume of water in the suppression pool is 138,700 ft^3 (3,927 m^3). The outer containment also has the upper refueling pool on top of the drywell with a water volume of 73,000 ft^3 (2,067 m^3). This water can be dumped into the suppression pool, if needed.

The outer containment provides support for different platforms at different levels and also supports the 125-ton polar bridge crane that is located inside the dome. Two personnel access locks with double interlocked doors and one equipment hatch are provided to access the containment.

There are 90 ignitors inside the containment, 72 in the outer containment, and 18 in the drywell. The ignitors are not operational under station blackout conditions.

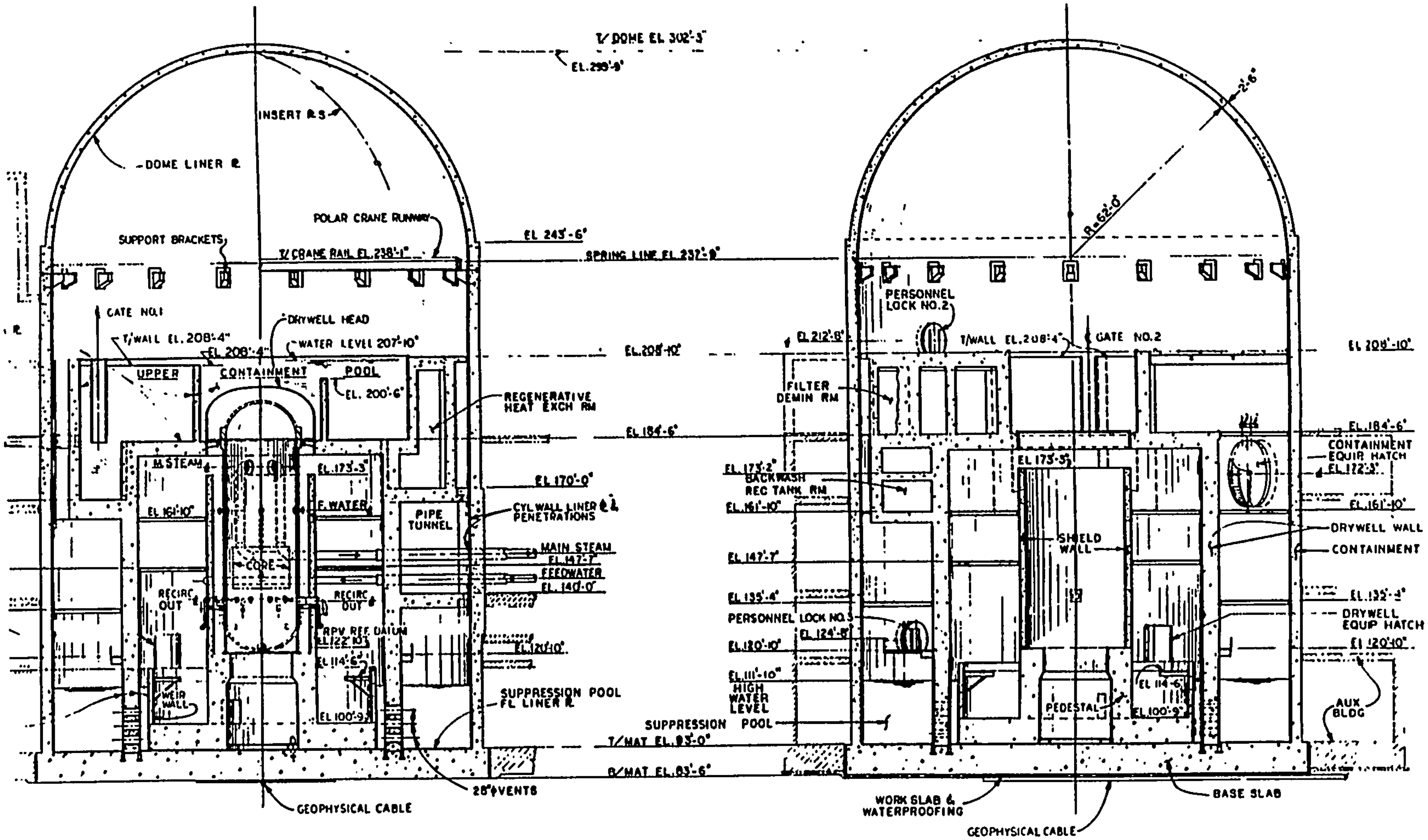

Fig. 3.3 Grand Gulf Nuclear Station containment

Normally, the drywell pressure is higher than the outer containment pressure. Three vacuum relief systems equalize the pressure between the drywell and the outer containment for those cases when the drywell pressure is lower than the outer containment pressure. These vacuum relief systems are: the Normal Drywell Vacuum Relief System, the Drywell Purge System, and the Post-LOCA Vacuum Relief System. Under station blackout conditions, these vacuum relief systems are not operational.

The internal design pressures of the drywell and outer containment are 30 and 15 psig (0.2 and 0.1 MPa), respectively. The external design pressures are -21 and -3 psig (-0.15 and -0.02 MPa), respectively. The ultimate failure pressure of the containment is 56 psig (0.385 MPa) as reported in the Grand Gulf Final Safety Analysis Report (FSAR),[12] in Ref. 7, and confirmed by the Grand Gulf plant staff.[13] This failure pressure is about 3.7 times the design pressure.

The location of the containment failure caused by internal overpressurization has been considered to be in the upper region of the outer containment, at the junction of the cylindrical wall and hemispherical dome as documented in Ref. 7. This junction is surrounded by the enclosure building (Fig. 3.1). Therefore, after containment failure, leakage will enter the enclosure building and from there it would enter the environment. The failure pressure of the enclosure building is only 45 psfd (0.31 psig or 2.15 kPa).

It should be noted that comments received from the Grand Gulf Nuclear Station staff as a result of their review of the draft of this report indicate that recently completed studies have identified nine potential containment failure modes at different pressures and locations. None of the newly identified failure pressures is below the 56-psig (0.385-MPa) failure pressure considered here. However, the Grand Gulf studies indicate a failure pressure of 64 psig (0. 44 MPa) at the junction of the containment dome and cylindrical wall. Some of the failures leak into the auxiliary building.

Containment failures into the auxiliary building need to consider the auxiliary building in the plant model (Sect. 4). These types of containment failures have not been considered in this study.

A summary of the containment design characteristics is given in Table 3.2.

Table 3.2. Grand Gulf containment design characteristics

	Containment		
	Drywell	Outer containment	Enclosure building
Internal design pressure, psig (MPa)	30 (0.2)	15 (0.1)	0.31 (0.002)
External design pressure, psid (MPa)	-21 (-0.15)	-3 (-0.02)	
Failure pressure, psig (MPa)		56 (0.385)	0.31 (0.002)
Design temperature, °F (K)	330 (439)	185 (358)	
Free volume, ft^3 (m^3)	270,000 (7,650)	1,400,000 (40,000)	600,000 (16,990)
Suppression pool water volume, ft^3 (m^3)	13,000 (368)	125,700 (3,560)	
Upper-pool water volume, ft^3 (m^3)		73,000 (2,067)	

4. DESCRIPTION OF THE FULLY QUALIFIED BEST-ESTIMATE MELCOR DECK

The fully qualified best-estimate MELCOR deck has been prepared using information from Refs. 6, 7, 12, 13, 17–21. The model can be divided into the reactor vessel, the containment (drywell, wetwell, and outer containment), the enclosure building, and the environment. The auxiliary building is not modeled since fission products do not travel through the auxiliary building for the containment failure location analyzed. The containment fails into the enclosure building, and from the enclosure building the fission products are released into the environment (Sect. 3.3)

The MELCOR model employs a total of 35 control volumes, 6 for the vessel, 9 for the drywell, 18 for the wetwell or outer containment, 1 for the enclosure building, and 1 for the environment. These 35 control volumes are linked by a total of 58 flowpaths, 16 originating in the reactor vessel, 16 originating in the drywell, and the remaining 26 originating in the wetwell or in the outer containment. Eight flowpaths are valves operated by control functions. A total of 76 heat slabs, 136 control functions, and 21 tabular functions are used.

The core region is divided into 13 axial levels and 4 radial rings. Of the 13 axial levels, 6 model the lower plenum and core plate, while the remaining 7 axial levels model the core itself. Five of these seven axial levels model the active fuel length of 150 in. (3.81 m).

The MELGEN input for this model is reproduced in Appendixes A and B. Appendix B is a listing of the BH Package[2] input. The MELCOR input to run the station blackout transient is provided as Appendix C.

A modification of this best-estimate deck without the BH Package input was also prepared (Sect. 4.4). The results from this run have been helpful in explaining the differences observed between the results of the "complete" best-estimate deck and the NUREG-1150 deck.

4.1 INITIAL CONDITIONS

The MELCOR calculation is initiated with the reactor at full power [3,833 MW(t)] and with normal plant operating values for the reactor vessel and containment. These initial conditions include water level in reactor vessel at 569.7 in. (14.471 m) above the bottom of the vessel and the pressures and temperatures given in Tables 4.1 and 4.2. The main steam lines supply 16.5 x 10^6 lb/h (2,079 kg/s) of steam at 549°F (580 K) to the turbine, and the same mass flow rate of water at 420°F (489 K) is injected into the vessel by the feedwater pumps. The recirculation pumps provide a total flow of water (driven plus induced) of 112.5 x 10^6 lb/h (14,175 kg/s) to the core. The average initial temperatures of the fuel and cladding are 1,768°F (1,237 K) and 610°F (595 K), respectively.

At time zero, the station blackout is initiated, and the reactor is scrammed. The main steam isolation valves (MSIVs) start closing 1 s after scram and are fully closed 2 s afterward (3 s after scram). The feedwater pumps coastdown to zero flow in 5 s. The recirculation pumps coastdown to zero flow in 40 s. Modeling of the SRV operation is described in Sect. 4.2.

4.2 REACTOR VESSEL MODEL

The reactor vessel is modeled with 6 control volumes and 16 flowpaths as shown in Fig. 4.1. Some of the flowpaths of Fig. 4.1 are valves. These valves are normally closed; they open or close by control functions. The control volumes as well as the initial conditions used are described in Table 4.1. The 16 reactor vessel flowpaths are listed as the first 16 entries of Table 4.3 with information concerning flow areas and open fractions.

Three flowpaths (Nos. 100, 101, and 102 as listed on Table 4.3) model the operation of the SRVs. Flowpath 100 represents the operation of the SRVs in the "automatic" mode of the "power-actuated relief" mode. For first time operation, the SRVs have higher opening and closing pressures than for subsequent cycles ("low-low set relief" mode) as described in Sect. 3.2 and Table 3.1. At 5 min after scram, manual operation of the SRVs is represented as being started by the control room operators with opening and closing pressures of 900 and 800 psig (6.205 and 5.516 MPa), respectively. Flowpath 102 represents this manual mode of operation. Finally, flowpath 101 models manual operation of the ADS SRVs, which opens simultaneously eight SRVs when the water level in the core drops to one-third of the ACH.

Two of the reactor vessel flowpaths model the recirculation pumps. Flowpath 17 represents the recirculation pump coastdown during the first 40 s of the transient. Flowpath 16 represents the jet pumps after the recirculation pumps have stopped.

Table 4.1. Reactor vessel volumes and initial conditions (best-estimate deck)

Volume No.	Name	Volume [ft^3	(m^3)]	Water level [in. (m)]	Temperature [°F	(K)]	Pressure psia	(MPa)
100	Lower plenum	3,838	(108.677)	Full	533	(551)	1,074	(7.405)
101	Core	1,094	(30.976)	Full	550	(561)	1,047	(7.218)
102	Bypass	971	(27.498)	Full	550	(561)	1,047	(7.218)
103	Separators	2,300	(65.129)	569.7 (51.91)[a]	549	(560.6)	1,040	(7.17)
104	Dome-dryers	7,340	(207.846)	Empty	549	(560.6)	1,040	(7.17)
105	Downcomer	7,661	(216.936)	569.7 (51.91)[a]	477	(520)	1,040	(7.17)

[a] The water level in inches is measured from the bottom of the vessel, which is at elevation 122-10 ft (37.44 m) over the absolute zero of the plant.
The water level in meters is referred to the absolute zero of the plant. MELCOR input values are in SI units and use the absolute zero of the plant.

Table 4.2. Volumes used in the containment, enclosure building, and environment (best-estimate deck)

Volume No.	Volume name	Total volume [ft^3	(m^3)]	Volume water [ft^3	(m^3)]	Temperature [°F	(K)]	Pressure [psia	(MPa)]
201	DRY-HEAD-SEAL	4,700	(133.1)	0	0	135	(331)	14.7	(0.101)
202	PEDESTAL-CAVITY	9,162	(259.5)	5.3	(0.15)	135	(331)	14.7	(0.101)
203	WEIR-WALL-ANN.	16,347	(462.9)	12,494	(353.8)	135	(331)	14.7	(0.101)
204	DRYWELL-ANN-4	62,754	(1,777)	0	0	135	(331)	14.7	(0.101)
205	SHIELD-WALL-ANN.	13,423	(380.1)	0	0	135	(331)	14.7	(0.101)
206	DRYWELL-ANN.-3	46,580	(1,319)	0	0	135	(331)	14.7	(0.101)
207	DRYWELL-ANN.-2	101,247	(2,867)	0	0	135	(331)	14.7	(0.101)
208	DRYWELL-ANN.-1	41,142	(1,165)	0	0	135	(331)	14.7	(0.101)
209	DRYWELL-HEAD	5,703	(161.5)	0	0	135	(331)	14.7	(0.101)
310	SUPPRESSION-POOL	278,880	(7,987)	123,919	(3,509)	95	(308)	14.7	(0.101)
311	WETWELL-ANN-1	131,088	(3,712)	0	0	95	(308)	14.7	(0.101)
312	UPPER-POOL-ANN-1	57,386	(1,625)	0	0	95	(308)	14.7	(0.101)
313	REFUELPOOL	76,068	(2,154)	72,995	(2,067)	95	(308)	14.7	(0.101)
314	UPPER-CTMT-REG1	124,837	(3,535)	0	0	95	(308)	14.7	(0.101)
315	UPPER-CTMT-REG2	124,837	(3,535)	0	0	95	(308)	14.7	(0.101)
316	DOME-HEMISPHERE	372,923	(10,560)	0	0	95	(308)	14.7	(0.101)
317	WW-ANN.-LOWER	84,473	(2,392)	0	0	95	(308)	14.7	(0.101)
318	WW-ANN.-UPPER	84,473	(2,392)	0	0	95	(308)	14.7	(0.101)
319	UPPER-POOL-ANN.-2	60,282	(1,707)	0	0	95	(308)	14.7	(0.101)
320	PUMP-SAMPLING	12,526	(354.7)	0	0	135	(331)	14.7	(0.101)
321	MAIN-STEAM-ROOM	16,800	(475.7)	0	0	95	(308)	14.7	(0.101)

Table 4.2. (Continued)

Volume No.	Volume name	Total volume [ft^3	(m^3)]	Volume water [ft^3	(m^3)]	Temperature [°F	(K)]	Pressure [psia	(MPa)]
322	RWCU-HX-ROOM	10,500	(297.3)	0	0	95	(308)	14.7	(0.101)
323	VALVE-NEST-ROOM	3,207	(90.8)	0	0	95	(308)	14.7	(0.101)
324	RCWU-FILTER-DEM	4,573	(129.5)	0	0	95	(308)	14.7	(0.101)
325	RWCU-PUMP-ROOM	772	(21.8)	0	0	95	(308)	14.7	(0.101)
326	RCWU-TANK-ROOM	3,447	(97.6)	0	0	95	(308)	14.7	(0.101)
327	EQUIP-HATCH	55,868	(1,582)	0	0	95	(308)	14.7	(0.101)
399	ENCLOSURE	600,000	(16,990)	0	0	80	(300)	14.7	(0.101)
400	ENVIRONMENT	3.5×10^8	(10^7)	0	0	80	(300)	14.7	(0.101)

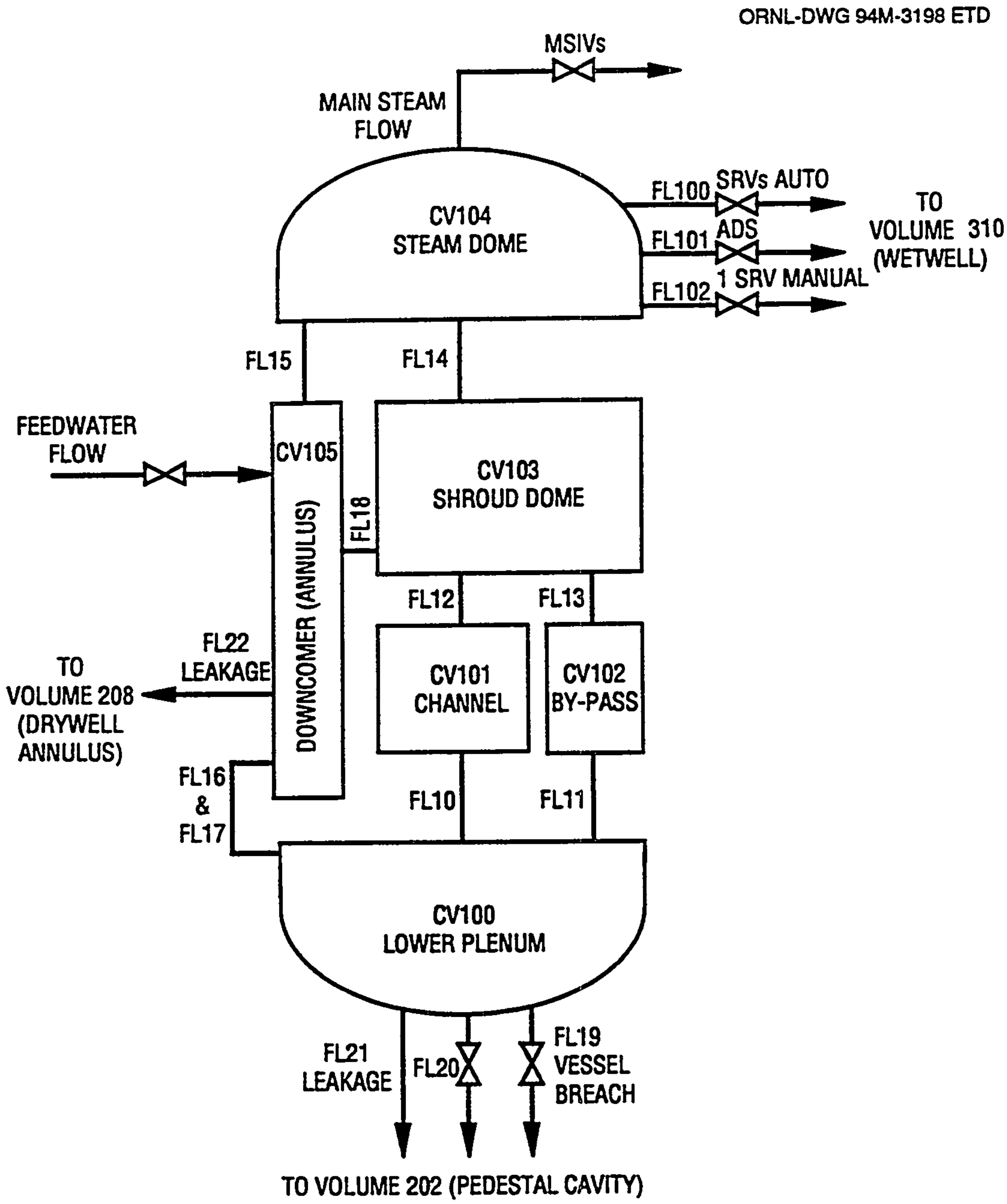

Fig. 4.1 MELCOR model of the vessel

Table 4.3. Flowpaths used in the MELCOR model of Grand Gulf (best-estimate deck)

Flowpath No.	From volume	To volume	Flowpath name	Area [ft^2	(m^2)]	Fraction open initially	Control Function
10	100	101	LP-CORE	82	(7.62)	0.61	Yes
11	100	102	LP-BYPASS	73	(6.76)	0.01	
12	101	103	CORE-UPLENUM	82	(7.62)	1.0	
13	102	103	BYP-UPLENUM	73	(6.76)	1.0	
14	103	104	SEP-DRYERS	142	(13.23)	1.0	
15	104	105	DOME-DOWNC	173	(16.0)	1.0	
16	105	100	JET-PUMPS	18	(1.65)	0.0	Yes
17	105	100	RCPUMPS	18	(1.65)	1.0	
18	103	105	SEP-DOWNC	978	(90.86)	1.0	
19	100	202	BH-VES-BREACH	1.0	(0.1)	0.0	Yes
20	100	202	VESSEL-BREACH	0.1	(0.01)	0.0	Yes
21	100	202	LEAK-CRDS	3.7×10^{-5}	(3.4×10^{-6})	1.0	
22	105	208	LEAK-RCPS	3.0×10^{-5}	(2.8×10^{-6})	1.0	
100	104	310	SRVS-AUTO	2.6	(0.24)	0.0	Yes
101	104	310	ADS	1.0	(0.095)	0.0	Yes
102	104	310	MANUAL-SRV	0.1	(0.012)	0.0	Yes
201	208	207	FL201	1,682	(156.24)	1.0	
202	207	206	FL202	2,357	(218.95)	1.0	
203	206	204	FL203	2,355	(218.77)	1.0	
204	204	201	FL204	688	(63.9)	1.0	
205	205	201	FL205	250	(23.25)	1.0	

Table 4.3. (Continued)

Flowpath No.	From volume	To volume	Flowpath name	Area [ft^2	(m^2)]	Fraction open initially	Control function
206	209	201	FL206	4.4	(0.4)	1.0	
207	202	205	FL207	20	(1.82)	1.0	
208	208	202	FL208	21	(1.95)	1.0	
209	208	202	FL209	0.7	(0.06)	1.0	
210	204	319	VACUUM BREAKER	0.6	(0.05)	0.0	
211	203	310	TOP-ROW-VENTS	4.1	(0.38)	1.0	
212	203	310	MID-ROW-VENTS	4.1	(0.38)	1.0	
213	203	310	BOTTOM-ROW-VENTS	4.1	(0.38)	1.0	
214	207	203	FL214	554	(51.44)	1.0	
215	207	310	FL215	0.05	(0.005)	1.0	
216	209	201	FL216	4.4	(0.4)	1.0	
301	310	311	FL301	2,123	(197.2)	0.73	
302	311	312	FL302	2,494	(231.7)	0.73	
303	319	317	FL303	2,987	(277.5)	1.0	
304	317	318	FL304	4,874	(452.8)	1.0	
305	317	314	FL305	5,215	(484.5)	1.0	
306	318	315	FL306	5,215	(484.5)	1.0	
307	318	316	FL307	4,874	(452.8)	1.0	
308	315	316	FL308	7,202	(669.1)	1.0	
309	314	315	FL309	7,202	(669.1)	1.0	
310	313	314	FL310	7,202	(669.1)	1.0	

Table 4.3. (Continued)

Flowpath No.	From volume	To volume	Flowpath name	Area [ft²	(m²)]	Fraction open initially	Control function
311	312	319	FL311	1,640	(152.3)	1.0	
312	399	400	ENCL-FAIL	1.1	(0.1)	1.0	
313	319	320	FL313	28	(2.6)	1.0	
314	322	321	FL314	34	(3.14)	1.0	
315	319	322	FL315	21	(1.95)	1.0	
316	313	310	UPPER POOL DUMP	5	(0.46)	0.0	
317	312	323	FL317	20	(1.9)	1.0	
318	319	324	FL318	9	(0.85)	1.0	
319	312	325	FL319	21	(1.95)	1.0	
320	325	326	FL320	21	(1.95)	1.0	
321	310	327	HATCH-WW	760	(70.62)	1.0	
322	327	311	HATCH-LOWANN	1,478	(137.35)	1.0	
323	327	312	HATCH-UPPANN	1,300	(120.73)	1.0	
324	327	319	HATCH-UPPANN	1,375	(127.73)	1.0	
325	327	317	HATCH-DOME	760	(70.62)	1.0	
399	318	399	CONT-FAIL	1.1	(0.1)	0.0	Yes

Two flowpaths (Nos. 21 and 22) model leakage from the reactor vessel, the first from the control rod drives and the second from the recirculation pump seals. The steam leaving the dome before the MSIVs close and the water injected into the downcomer by the feedwater pumps during the first seconds of the transient are modeled with tables of flow vs time.

4.3 CONTAINMENT MODEL

The containment is modeled with 9 control volumes for the drywell (Fig. 4.2) and 18 control volumes for the wetwell and outer containment (Fig. 4.3). One volume models the enclosure building (volume 399), and one volume models the environment (volume 400). These control volumes are described in Table 4.2 together with the initial values for temperature and pressure. The control volumes of the drywell are numbered in the 200s; the control volumes of the wetwell and outer containment are numbered in the 300s. The water of the suppression pool is distributed between volumes 203 and 310, with the majority of the water in volume 310. The total amount of water in both volumes is 136,413 ft^3 (3,863 m^3). The upper pool is modeled by volume 313. It contains 72,995 ft^3 (2,067 m^3) of water. A small amount of water is in the pedestal sump (volume 202). Control volumes 320 through 327 listed in Table 4.2 are not represented in Fig. 4.3. These control volumes model small rooms located inside the containment such as the pump sampling room, the valve rooms, filters and pumps room, equipment hatch, etc.

The flowpaths linking the containment volumes are described in Table 4.3. Flowpath 210 models the vacuum breaker between drywell and outer containment; it is always closed during the station blackout accident sequence. Flowpath 316 models the line provided for dumping water from the upper refueling pool to the suppression pool. This flowpath also remains closed during this accident sequence. Flowpath 399 models containment failure at a pressure of 56 psig (0.385 MPa), and flowpath 312 models the leakage from the enclosure building into the environment. The open area for the containment failure flowpath (399) is assumed to be 1 ft^2 (0.1 m^2), based on the most probable value of estimates used for the NUREG-1150 study.[1,6] For flowpath 312, from the enclosure building to the environment, a

ORNL-DWG 94M-3199R ETD

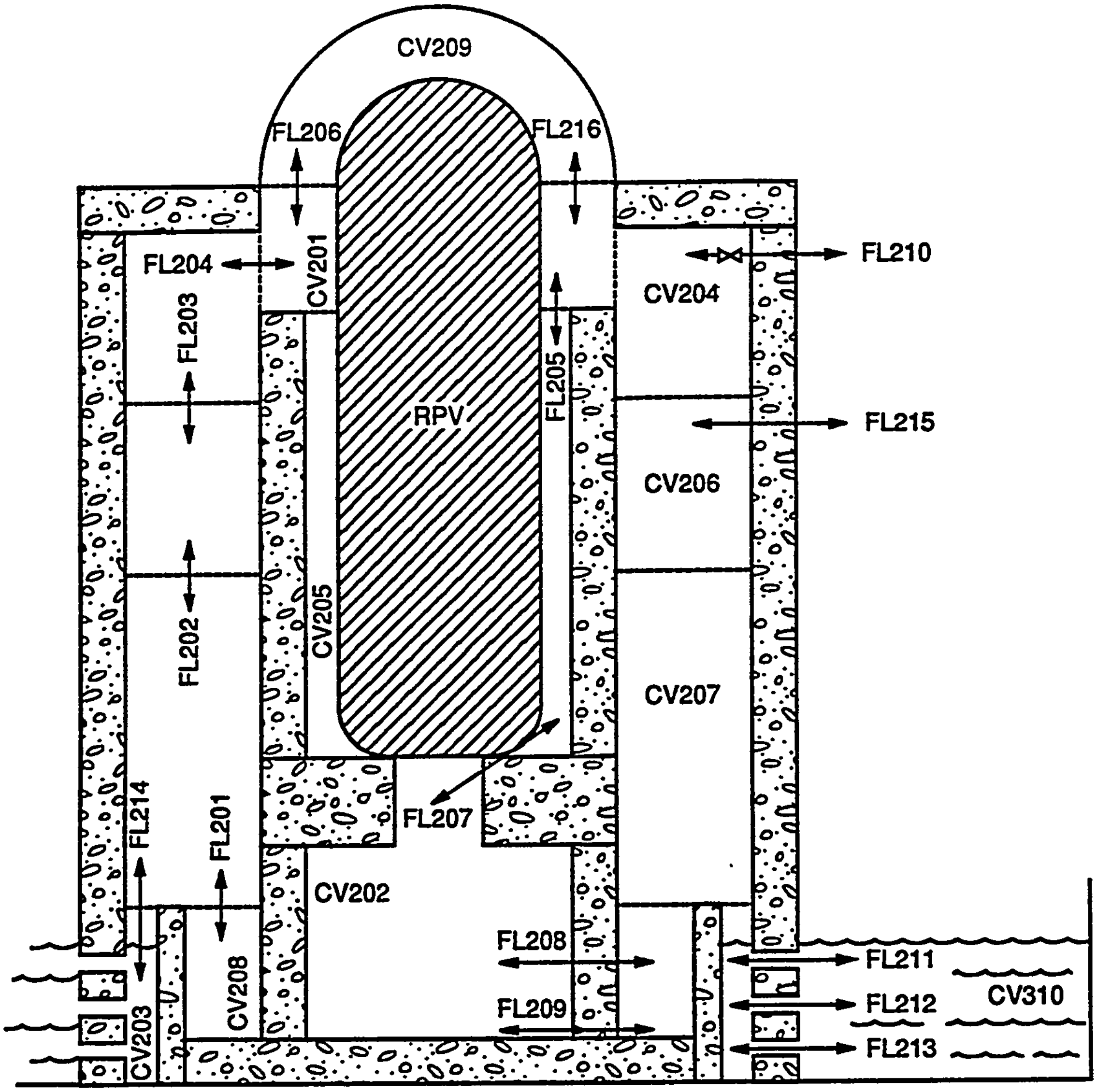

Fig. 4.2 MELCOR model of the drywell

ORNL-DWG 94M-2435R ETD

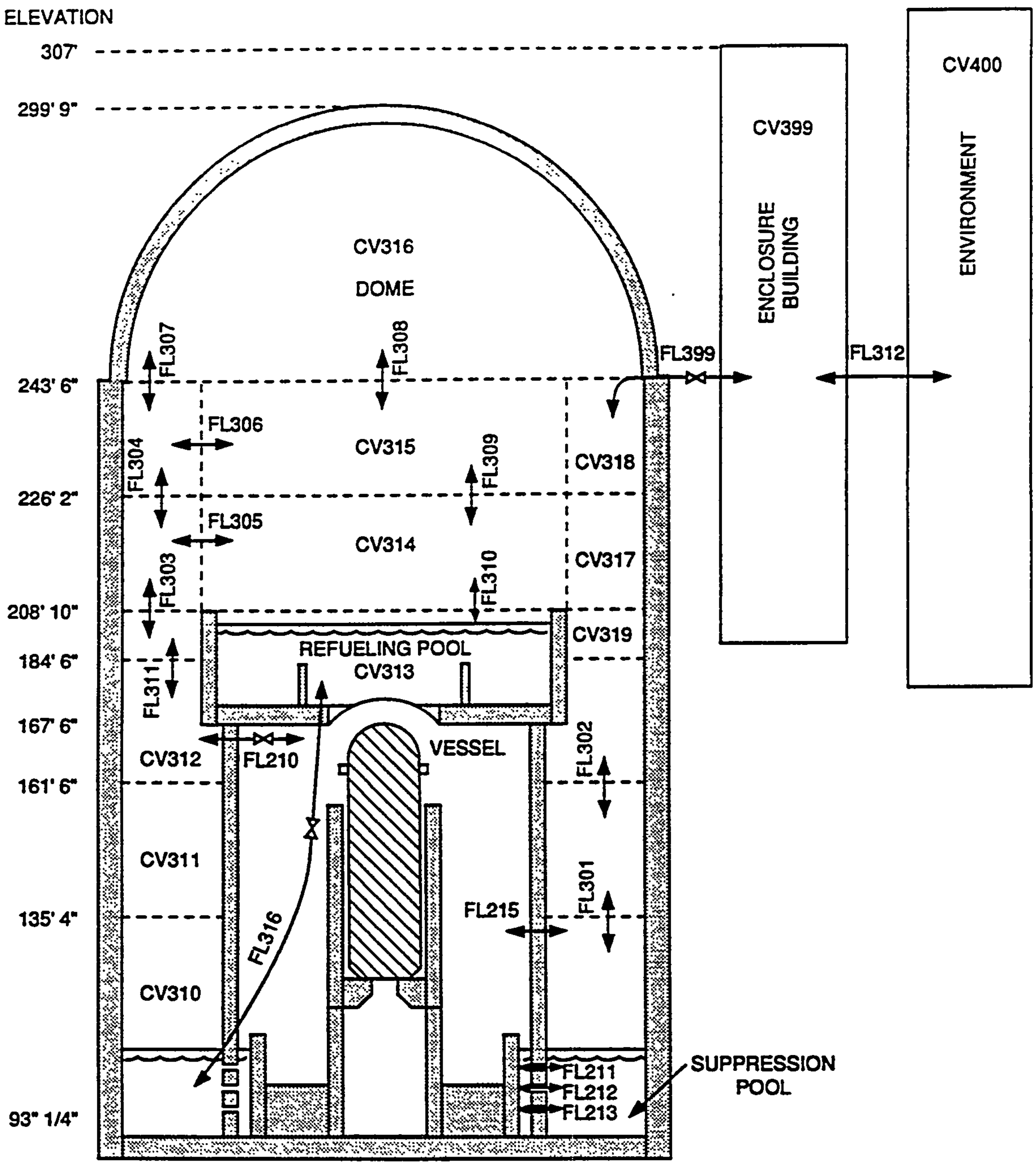

Fig. 4.3 MELCOR model of the wetwell and other containment

flowpath area of 10 ft^2 (1 m^2) was used, ten times the area used for flowpath 399. The design leakage area for the enclosure building under normal conditions is only 0.2 ft^2 (0.02 m^2), one-fiftieth of the area assumed here for accident conditions.

4.4 CORE MODEL

The core and lower plenum are nodalized with 4 radial rings and 13 axial levels, with a total of 52 nodes (Fig. 4.4). The lower plenum is modeled with the first five axial levels, the core plate is the sixth axial level, while the remaining seven levels model the core. Five of these seven levels represent the active fuel. The elevations for all axial levels are shown in Fig. 4.4.

The four radial rings comprise volume fractions of 0.5657, 0.2043, 0.1139, and 0.1161 of the total core volume from center (ring 1) to periphery (ring 4), respectively.

The total masses in the core are: fuel as UO_2, 353,070 lb (160,150 kg); Zircaloy as cladding, 95,681 lb (43,000 kg); Zircaloy as cans, 79,415 lb (36,022 kg); steel from the fuel assemblies, 26,382 lb (11,967 kg); steel from the control blades, 40,180 lb (18,225 kg); Inconel from grids, 2,531 lb (1,148 kg); and poison from control blades, 2,759 lb (1,252 kg). Other steel masses represented are: the core plate, 36,676 lb (16,636 kg) and the lower plenum structural steel, 205,054 lb (93,011 kg). The total amount of steel in the core and lower plenum is 308,292 lb (139,839 kg). Four penetrations are represented in the core package input corresponding to each radial ring, with a total mass of 6,058 lb (2,748 kg). The MELGEN input is listed in Appendix A. MELCOR 1.8.3 (1.8 PN) allows quenching of the core debris with the water in the lower plenum. A heat transfer coefficient of 132 Btu/h•ft^2•°F (750 W/m^2•K) between the debris and the water was used for this purpose with a velocity of the falling debris of 0.33 ft/s (0.1 m/s). Separate input for the Lower Plenum Debris Bed (BH) Package,[2] was also required for the calculations reported here. The input for the BH Package is in Appendix B.

A modification of this best-estimate deck was prepared <u>without</u> quenching of the core debris in the lower plenum <u>and without</u> the BH Package input. This deck, designated the "best-estimate without BH" deck was also run with MELCOR 1.8.3 (1.8 PN). Its results are reported in Sect. 6.2.

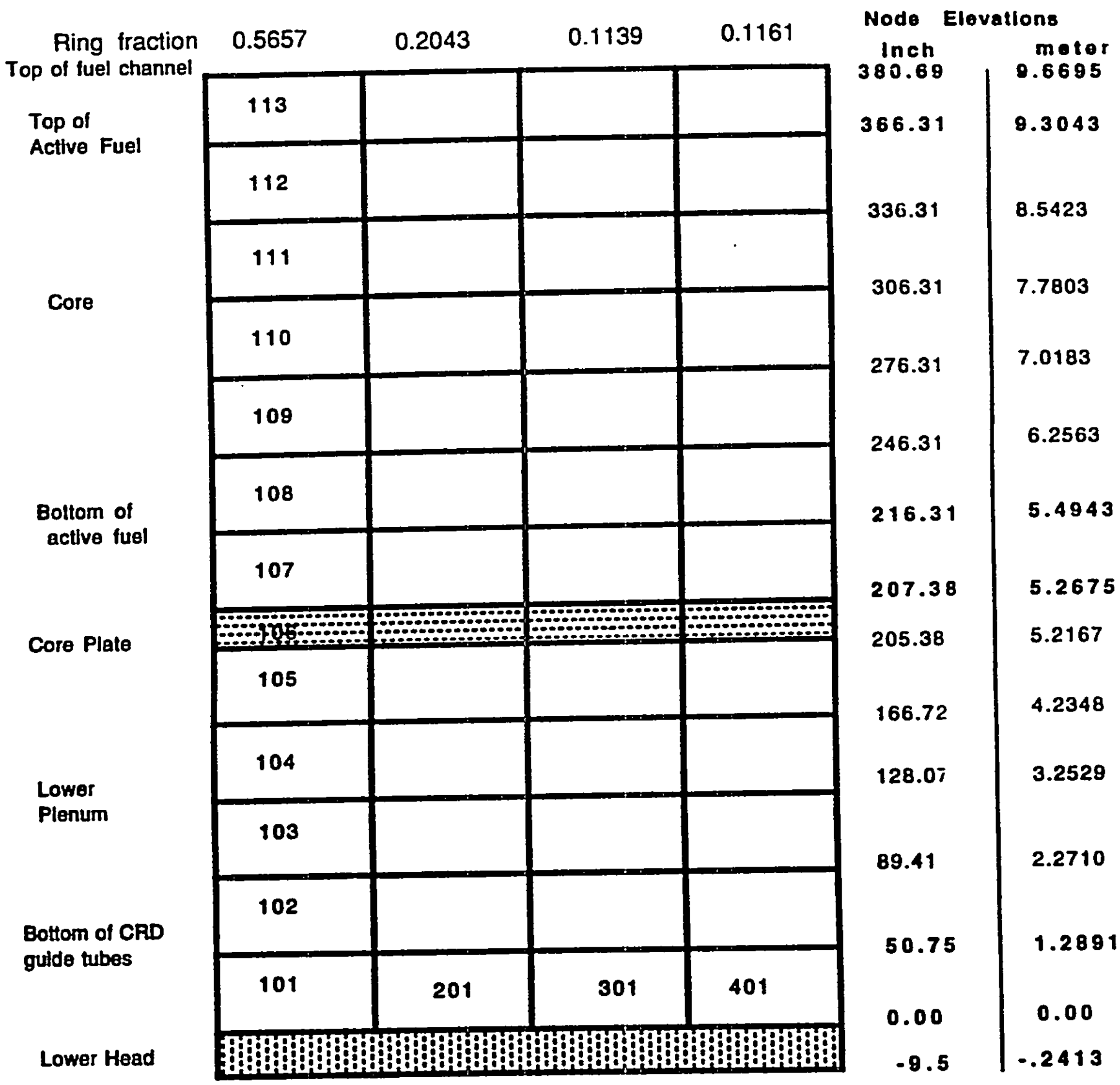

Fig. 4.4 MELCOR model of the core and lower plenum

The shroud around the core and lower plenum is modeled with 10 heat slabs. Other slabs represent the downcomer region baffle plate, the dryers, the steam generators, and the vessel itself. The total number of heat slabs related to the vessel is 27.

The decay heat of the fuel is calculated by MELCOR using results obtained by use of a version of the ORIGEN code[22] maintained at SNL. A correction factor of 1.07123, the ratio of the Grand Gulf power [3,833 MW(t)] to the default power assigned by MELCOR [3,578 MW(t)], is applied. Axial and radial power distributions in the core were calculated based on data[19] supplied by the Grand Gulf plant for end-of-life fuel.

4.5 CAVITY MODEL

The cavity is located under the reactor vessel, inside the pedestal region of the drywell (Fig. 3.3). The cavity is represented as a cylindrical opening 10 ft 7 in. (3.2258 m) in radius and 9 ft 7 in. (2.921 m) in depth inside a solid cylinder with an outside radius of 16 ft 4 in. (4.9784 m) and a total height of 20 ft 7 in. (6.2738 m). Figure 4.5 shows this cavity geometry. The upper limit of the cavity walls has been taken at elevation 104 ft 1 in. (31.7246 m) because of openings in the pedestal walls at this elevation. Otherwise, the pedestal walls continue up to the reactor vessel skirt (Fig. 3.3). The thickness of the radial pedestal wall is 5.75 ft (1.753 m), while the thickness (depth) of the floor is 11 ft (3.353 m). This radial thickness is intended to represent the minimum thickness of the pedestal wall as shown in Fig. 3.3. There is, however, more concrete outside the radial boundaries of this cavity model below elevation 100 ft 9 in. (30.71 m), as can be seen in Fig. 3.3. A total of 55 rays are used by the CORCON-MOD3 model input for MELCOR to model the cavity.

4.6 FISSION PRODUCT MODEL

MELCOR employs a total of 16 different groups or classes of fission products. The first 15 classes are standard in MELCOR and are listed in Table 4.4. The last three classes of this table, boron, water, and concrete are not radioactive materials.

Class 16 is a user-defined class to model the formation of CsI, which is formed by the combination of cesium from class 2 and iodine from class 4. All the iodine released from class 4 is assumed to be combined with cesium and to form CsI. In fact, all the material

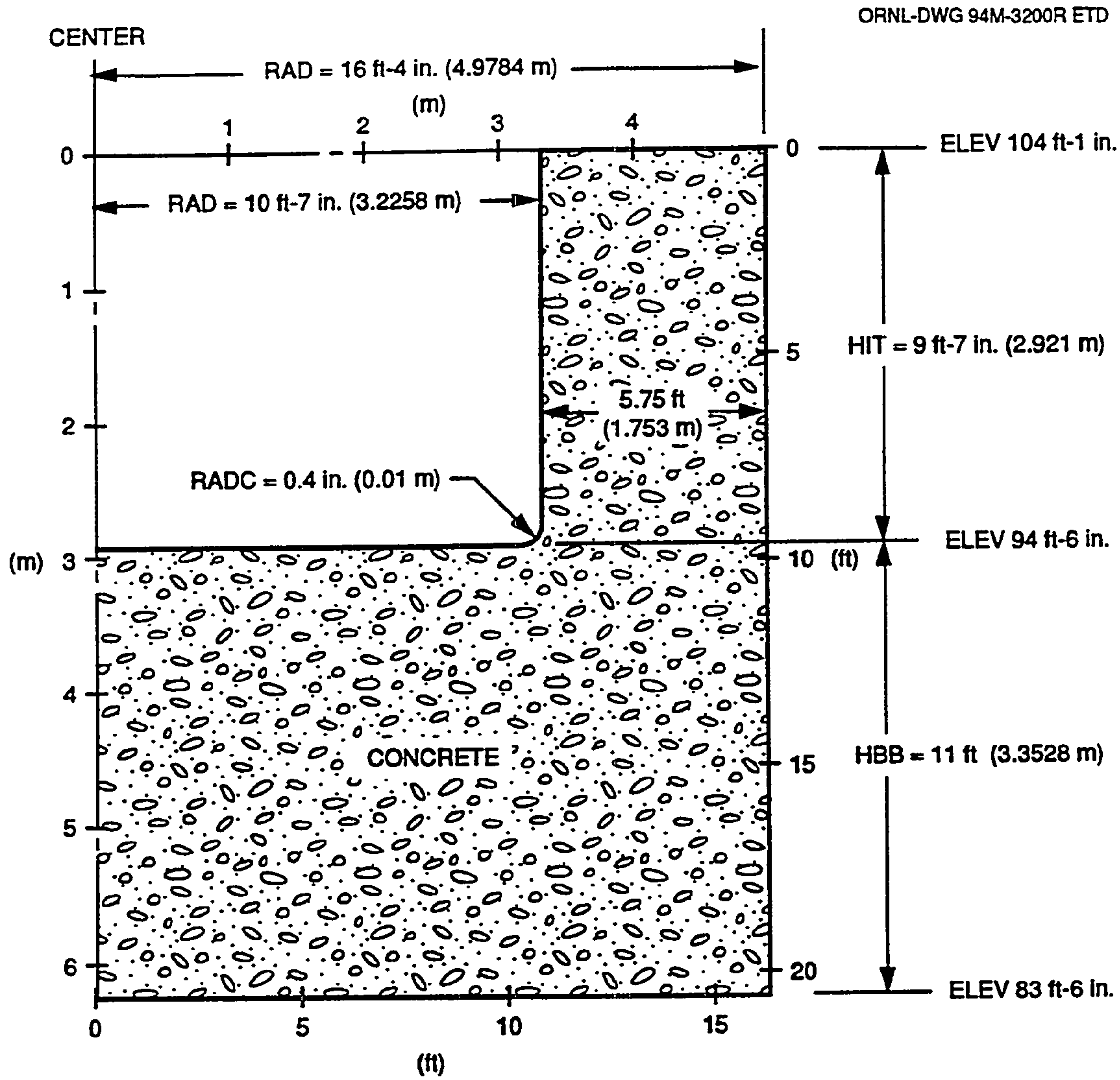

Fig. 4.5 MELCOR model of the cavity (best-estimate deck)

Table 4.4. MELCOR fission product material classes

Class number and name	Representative element	Other member elements
1. Noble gases	**Xe**	**Kr**, Rn, He, Ne, Ar, H, N
2. Alkali metals	**Cs**	**Rb**, Li, Na, K, Fr, Cu
3. Alkaline earths	**Ba**	**Sr**, Be, Mg, Ca, Ra, Es, Fm
4. Halogens	**I**	**Br**, F, Cl, At
5. Chalcogens	**Te**	**Se**, S, O, Po
6. Platinoids	**Ru**	**Pd**, **Rh**, Ni, Re, Os, Ir, Pt, Au
7. Transition metals	**Mo**	**Tc**, **Nb**, Fe, Cr, Mn, B, Co, Ta, W
8. Tetravalents	**Ce**	**Zr**, Th, **Np**, Ti, Hf, Pa, Pu, C
9. Trivalents	**La**	**Pm**, Sm, **Y**, **Pr**, **Nd**, Al, Sc, Ac, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Am, Cm, Bk, Cf
10. Uranium	**U**	**U**
11. More volatile main group metals	Cd	Hg, Pb, Zn, **As**, **Sb**, Tl, Bi
12. Less volatile main group metals	**Sn**	**Ag**, In, Ga, Ge
13. Boron	B	Si, P
14. Water	H_2O	
15. Concrete		

NOTE: The 29 ORIGEN elements used in MELCOR decay heat tabulations are shown in **boldface**.

released from class 4 which includes bromine and other halogens in addition to iodine, is assumed to form CsI. No free iodine (or any free halogen) exists in the released fission products because there is always an excess of cesium to combine with any free class 4 fission products.

This CsI formation modeling agrees with the findings of recent studies on the chemical form of iodine released into containments. Reference 23 indicates that more than 95% of the iodine released into containment is in the form of CsI.

The initial inventories used for these 16 classes are given in Table 4.5. The amounts for the first nine classes and classes 11 and 12 are the MELCOR default values. The inventory of class 10, uranium, is 138,300 kg and is calculated from the total amount of UO_2 input in the core (160,150 kg). The mass of UO_2 is converted to mass of uranium by

Table 4.5. Initial inventory of fission products

Class No.	Name	Element	Amount (kg)	Class total (kg)
1	Noble gases	Xe	429.36	463.7
		Kr	34.34	
2	Alkali metals	Cs	236.15	268.35
		Rb	32.20	
3	Alkaline earths	Ba	121.65	207.52
		Sr	85.87	
4	Halogens	I	18.96	20.93
		Br	1.97	
5	Chalcogens	Te	35.78	40.78
		Se	5.00	
6	Platinoids	Ru	182.48	306.99
		Rh	35.06	
		Pd	89.45	
7	Early transition	Mo	275.51	350.64
		Tc	71.15	
		Nb	3.58	
8	Tetravalents	Ce	243.30	593.65
		Zr	311.0	
		Np	39.35	
9	Trivalents	La	107.34	571.03
		Pr	93.02	
		Nd	314.86	
		Pm	12.88	
		Y	42.93	
10	Uranium	U	138,300	138,300
11	More volatile main group	Sb	1.40	1.41
		As	0.01	
12	Less volatile main group	Sn	3.94	8.59
		Ag	4.65	
13	Boron	B	0	0
14	Water	H_2O	0	0
15	Concrete		0	0
16	New class, cesium iodide	CsI	0	0

multiplying by the ratio 238/(238 + 32), and then the mass of the other 15 classes combined (2,833.6 kg) is subtracted.

The initial inventories of class 14 (water) and 15 (concrete) are zero. The initial inventory of class 16 (CsI) employed in the model is also zero because it is assumed that there is no CsI at the beginning of the calculation. The maximum final inventory of CsI that can be produced is 42.85 kg. This amount results from converting all the material of class 4 into CsI. The molecular weight of CsI is 259.8, and the atomic weight of iodine is 126.9. Consequently, 20.93 kg of class 4 inventory (Table 4.5) will be converted into 20.93 x (259.8/126.9) = 42.85 kg of CsI. The MELCOR-calculated final inventories of CsI are close to this maximum theoretical amount.

Likewise, to produce 42.85 kg of CsI with 20.93 kg of iodine, 42.85 – 20.93 = 21.92 kg of cesium need to react with the 20.93 kg of iodine. Therefore, the amount of class 2 material available for release at the end of the transient will be 268.35 – 21.92 = 246.43 kg.

The source terms are reported as fractions of the fission product inventories. The MELCOR code calculates the release fractions for each class as a fraction of the *actual* inventory of that class. The initial and the actual inventories of fission products for all classes are the same because the fission product inventory does not change (or decay) during the calculation with the exception of classes 2 and 16. The class 2 inventory (Cs) decreases over time from 268.35 to 246.43 kg because part of the Cs is converted into CsI.

The class 16 inventory increases over time from zero initial inventory to a maximum final inventory of about 42.85 kg. Therefore, the release fractions of class 16 early in the calculation when the inventory of CsI is small are relative to a different inventory than the fractions late in the calculation with a large inventory of CsI.

A similar problem occurs with class 2. To avoid these problems, the fractions of both classes 2 and 16 have been converted from fractions of the *actual* inventory (a variable amount) to fractions of the *final* inventory (a fixed amount). These inventories are approximately 246.43 kg for class 2 and 42.85 kg for class 16 (MELCOR calculates slightly different amounts).

To obtain the total fraction of Cs released, including the amounts in class 2 and class 16 (as CsI), the fractions from classes 2 and 16 need to be combined using the following expression:

$$f_{CS,\,TOTAL} = [246.43\, f_2 + 42.85\, (21.92\, /42.85)\, f_{16}]/\, 268.35 = 0.918\, f_2 + 0.082\, f_{16}\, .$$

This expression indicates that the total fraction of Cs lies between the fractions of classes 2 and 16 and very close to the fraction of class 2.

Similarly, the fraction of total I (in CsI) is equal to the fraction of CsI (class 16) as all the iodine released is converted into CsI, therefore:

$$f_{I,\,TOTAL} = f_{16}\, .$$

The release model used for the radionuclides is the modified CORSOR with surface-to-volume ratio option.

5. NUREG-1150 MELCOR DECK

The MELCOR 1.8.1 deck that was used for the Grand Gulf calculations in the NUREG-1150 study was received from SNL via the NRC. Some minor input changes and additions were implemented as necessary to make the deck compatible with MELCOR Version 1.8.3 (1.8 PN). These changes and additions did not modify the basic structural model. Some new models were implemented to make the accident sequence represented by the deck more comparable to the accident sequence calculated by use of the best-estimate deck. The models added are (1) ADS SRVs manual actuation (depressurization) at core water level of one-third of the ACH as per Rev. 3 of the EPGs and (2) containment failure to occur at 55 psig (0.378 MPa) as reported in Ref. 6 (as per NUREG-1150 study[1]), and at the intersection of the cylindrical and hemispherical portion of the containment with a failure area of 1 ft^2 (0.1 m^2). These two models were not in the original NUREG-1150 MELCOR deck.

The depressurization model implemented is exactly the same model used in the fully qualified best-estimate MELCOR deck (Sect. 4.2). The containment failure model implemented is very similar to the one used in the best-estimate MELCOR deck (Sect 4.3). The best-estimate MELCOR deck uses a failure pressure of 56 psia (0.385 MPa), 1 psi higher than the value used in the NUREG-1150 deck. The containment failure area for both decks is 1 ft^2 (0.1 m^2). Finally, both decks do not consider hydrogen burns and detonations.

The NUREG-1150 deck employs a total of 15 control volumes: 6 for the vessel, 3 for the drywell, 5 for the wetwell and outer containment, and 1 for the environment. (The enclosure building is not modeled.) These 15 control volumes are linked by a total of 31 flowpaths: 14 originating in the reactor vessel, 7 originating in the drywell, and the remaining 10 originating in the wetwell or outer containment. Of the 31 flowpaths, 10 are valves operated by control functions.

The core is divided into 13 axial levels and 4 radial rings. Five of these axial levels model the lower plenum and the core plate, eight levels model the core, and six levels model the active fuel length.

A total of 44 heat slabs, 52 control functions, and 16 tabular functions are used in the model.

The MELGEN input for this model is in Appendix D. The MELCOR input to run the station blackout transient is in Appendix E.

5.1 INITIAL CONDITIONS

The MELCOR calculations in this deck are initiated 1,720 s after the station blackout began. (The initial conditions were obtained from a BWR-LTAS code[10] run.) Therefore, the initial conditions in this deck are different from those in the best-estimate deck. The water level in the reactor vessel is only 366 in. (9.3 m) above vessel zero, lower than in the best-estimate deck (Sect. 4.1), since some water has been vaporized during the first 1,720 s of the transient. The initial pressures and temperatures for all the control volumes are given in Table 5.1.

5.2 REACTOR VESSEL MODEL

The reactor vessel's 6 control volumes and 14 flowpaths are given in Tables 5.1 and 5.2 together with the control volumes and flowpaths used in the containment. The model of the reactor vessel is very similar to the model used in the fully qualified deck (Sect. 4.2). The NUREG-1150 deck has only one flowpath for the SRV actuation vs two flowpaths (automatic and manual operation) in the best-estimate deck. Flowpath 22, manual depressurization, was added to the original deck.

5.3 CONTAINMENT MODEL

The containment control volumes and flowpaths are given in Tables 5.1 and 5.2. This model is less detailed than the fully qualified best-estimate MELCOR deck (Sect. 4.3). The enclosure building, modeled in the best-estimate deck, is not modeled in this deck. As the best-estimate deck, the auxiliary building is not modeled. Flowpath 100, containment failure, was added to the original deck. The total amount of water in the suppression pool, added from control volumes 202 (weir wall) and 305 (wetwell), is 141,339 ft^3 (4,002 m^3) which is slightly larger than the amount used in the best-estimate deck (136,413 ft^3 or 3,863 m^3), and also larger than the design maximum amount of water (138,700 ft^3 or 3,927 m^3) given in the

Table 5.1. Control volumes used in the NUREG-1150 deck

Volume No.	Volume name	Total volume [ft^3	(m^3)]	Volume water [ft^3	(m^3)]	Temperature [°F	(K)]	Pressure [psia	(MPa)]
100	LOWER-PLENUM	3,535	(100.1)	Full	Full	544	(558)	1013	(6.96)
101	CHANNEL	1,352	(38.3)	1,243[a]	(35.2)	544	(558)	1005	(6.93)
102	BYPASS	893	(25.3)	821[a]	(23.3)[a]	544	(558)	1005	(6.93)
103	UPPER-PLENUM/SEP	2,299	(65.1)	0	(0)	544	(558)	1005	(6.93)
104	DRYER/STEAM-DOME	6,759	(191.4)	0	(0)	544	(558)	1005	(6.93)
105	DOWN/RECIRC-2	8,058	(228.2)	3,835[a]	(108.6)[a]	544	(558)	1005	(6.93)
201	DRYWELL	231,452	(6,554)	0	(0)	158	(344)	15.5	(0.107)
202	WEIR WALL	51,648	(1,462.5)	13,677	(387.3)	117	(321)	15.5	(0.107)
204	PEDESTAL	8,634	(244.5)	0	(0)	158	(344)	15.5	(0.107)
301	DOME	899,217	(25,463)	61,130	(1,731)	93	(308)	15.5	(0.107)
302	EQUIP HATCH	58,410	(1,654)	0	(0)	93	(308)	15.5	(0.107)
303	UPPER ANN.	158,210	(4,480)	0	(0)	93	(308)	15.5	(0.107)
304	LOWER ANN.	115,761	(3,278)	0	(0)	93	(308)	15.5	(0.107)
305	WETWELL	274,854	(7,783)	127,662	(3,615)	117	(321)	15.5	(0.107)
400	ENVIRONMENT	3.5×10^8	(10^7)	0	(0)	80	(300)	14.7	(0.101

[a] This volume of water corresponds to a water level of 366 in. (9.3 m) above the vessel bottom.

Table 5.2. Flowpaths used in the NUREG-1150 deck

Flowpath No.	From volume	To volume	Flowpath name	Area [ft^2	(m^2)]	Fraction open initially	Control function
11	100	101	CHAN-IN	85.6	(7.9)	0.618	Yes
12	100	102	BYPASS-INLET	65.1	(6.0)	0.013	
13	101	103	CORE-OUTLET	85.6	(7.9)	0.676	
14	102	103	BYPASS-OUTLET	66.9	(6.2)	1.0	
15	103	104	UPPER-PLENUM-OUT	45.1	(4.2)	1.0	
16	104	105	DOME-DOWNCOMER	149.6	(13.9)	1.0	
17	103	105	SEP-DRAIN	113.4	(10.5)	0.0	Yes
18	105	100	JET-PUMP-SUCTION	3.6	(0.33)	1.0	Yes
19	105	201	VES-BRCH-DC	1.1	(0.1)	0.0	Yes
21	104	305	STEAM-LINE-SRV	11.9	(1.1)	0.0	Yes
22	104	305	ADS	1.0	(0.09)	0.0	Yes
31	100	204	VESSEL BREACH	1.1	(0.1)	0.0	Yes
100	301	400	CONT-FAIL	1.1	(0.1)	0.0	Yes
201	301	201	WW-DW-VB	0.6	(0.05)	0.0	Yes
202	302	201	WW-DW-LEAK	1.0	(0.09)	0.017	Yes
203	201	202	DW-WEIR-WAT	553.3	(51.4)	1.0	
204	201	202	DW-WEIR-GAS	553.3	(51.4)	1.0	
205	201	204	DW-PED-GAS	21.0	(1.9)	1.0	
206	201	204	DW-PED-DRAIN	53.8	(5.0)	1.0	
211	202	305	TOP-SP-VENTS	192.7	(17.9)	1.0	
212	202	305	MID-SP-VENTS	192.7	(17.9)	1.0	

Table 5.2. (Continued)

Flowpath No.	From volume	To volume	Flowpath name	Area [ft^2	(m^2)]	Fraction open initially	Control function
213	202	305	BOT-SP-VENTS	192.7	(17.9)	1.0	
301	301	302	DOME-HATCH	799.8	(74.3)	1.0	
302	301	303	DOME-UPPERANN	1,637.2	(152.1)	1.0	
303	302	303	HATCH-UPPERANN	1,460.0	(135.6)	1.0	
304	302	304	HATCH-LOWANN	1,690.0	(157.0)	1.0	
305	302	305	HATCH-WW	671.7	(62.4)	1.0	
306	303	304	UPP-LOW-ANN	2,462.8	(228.8)	1.0	
307	304	305	LOWANN-WW	1,554.3	(144.4)	1.0	
370	105	201	LEAKAGE-DOWN	3.0×10^{-5}	(2.8×10^{-6})	1.0	
371	100	204	LEAKAGE-LP	3.7×10^{-5}	(3.4×10^{-6})	1.0	

Grand Gulf FSAR.[12] The amount of water in the refueling pool above the drywell (volume 301, dome) is 61,130 ft^3 (1,731 m^3) which is smaller than the amount used in the best-estimate deck (72,995 ft^3 or 2,067 m^3).

5.4 CORE MODEL

This model is very similar to the one used in the fully qualified best-estimate deck (Sect. 4.4) with the same number of radial rings (4) and axial levels (13). The NUREG-1150 deck, however, employs eight levels for the core, one more than the best-estimate deck. Because the total number of axial levels is the same for both decks (13), it is evident that the lower plenum is represented by one fewer level in the NUREG-1150 deck as compared to the best-estimate deck. Table 5.3 shows a comparison of the important parameters employed by the core models.

The volume fractions for the four radial rings are 0.603, 0.162, 0.115, and 0.120. The total masses in the core are: fuel as UO_2, 366,408 lb (166,200 kg); Zircaloy as cladding, 96,950 lb (43,975.8 kg); Zircaloy as cans, 66,361 lb (30,100.8 kg); steel in the control blades and fuel assemblies, 52,620 lb (23,868 kg); and control blade poison, 2,020 lb (916.4 kg). Other steel masses are the core plate, 24,607 lb (11,162 kg) and the lower plenum structural steel, 72,624 lb (32,942 kg). This model has much less structural steel in the lower plenum than does the best-estimate deck (Sect. 5.4). Other differences in masses may be due to the fact that the best-estimate deck is based upon the current 9 x 9-5 fuel assemblies, while the NUREG-1150 deck appears to be based upon the 8 x 8 fuel assemblies in use when that study was conducted.

Four penetrations are represented in the NUREG-1150 deck, with a total mass of 87 lb (39.5 kg). This is much less than the penetration mass represented in the best-estimate deck (6,058 lb or 2,748 kg).

No quenching between the core debris and the lower plenum water is provided in the NUREG-1150 input deck. This input was prepared for MELCOR 1.8.1, which does not have a debris quenching model. The NUREG-1150 deck does not have a detailed representation of the lower plenum volumes and steel structures, as required for use of the BH Package.[2]

Table 5.3. Comparison of the core models

Input Variable	Best-estimate model	NUREG-1150 model
Radial rings	4	4
Axial levels, LP	5	4
Core plate	1	1
Core region	7	8
Active core	(5)	(6)
Total	13	13
Fuel	9 x 9-5	8 x 8
UO_2, kg	160,150	166,200
Zr, cladding, kg	43,000	43,976
Zr, cans, kg	36,022	30,101
Steel, fuel, kg	11,967 } 29,192	23,868
Steel, control blades, kg	18,225 } 29,192	
Inconel, kg	1,148	---
B_4C, kg	1,252	916
Core plate, kg	16,636	11,162
LP steel, kg	93,011	32,942
Penetrations, kg	2,748	39
Quench model	Yes[a]	No
BH input	Yes[a]	No
Decay heat model	ORIGEN	Input table

[a]Both the quench model for debris in the lower plenum and the BH input were turned off in the best-estimate model without the BH Package.

The decay heat of the fuel is calculated by tabular input of the current fraction of the initial thermal power vs time. The difference between the decay heat calculated by this table and by the ORIGEN code in the best-estimate model (Sect. 4.4) is small (< 5%), with the tabular values always larger than the ORIGEN values.

The fission product masses used are identical to those used in the best-estimate deck (Sect. 4.6) except that class 10, uranium, has a larger mass (143,700 kg vs 138,300 kg). This larger mass is a result of the larger total inventory of UO_2 in the core for the NUREG-1150 deck (166,200 kg) as opposed to the best-estimate deck (160,150 kg).

The NUREG-1150 deck employs the same modified CORSOR with surface-to-volume ratio radionuclides release model as does the best-estimate deck.

5.5 CAVITY

The cavity model is very similar to that of the best-estimate deck (Sect. 4.5 and Fig. 4.5), with the same internal dimensions (10-ft 7-in. radius and 9-ft 7-in. depth) and the same outside radius (16 ft 4 in.). The radial wall thickness is 5.75 ft (1.75 m). The only difference with respect to the best-estimate model is in the thickness (depth) of the floor, which is 6.56 ft (2 m) vs the 11-ft (3.35-m) thickness represented in the cavity of the best-estimate deck (Sect. 4.5). [In reality, there is more concrete in both the radial and the axial (depth) directions of this cavity model as can be seen in Fig. 3.3.] The NUREG-1150 cavity model employs 55 rays for CORCON-MOD 3, the same number of rays as employed by the best-estimate model.

5.6 COMPARISON OF BEST-ESTIMATE AND NUREG-1150 MODELS

Tables 5.3 and 5.4 show the important differences between the best-estimate and the NUREG-1150 models. To summarize, the best-estimate model has a more detailed representation of the lower plenum and bottom head (BH Package model) and containment (including the enclosure building). The best-estimate model has more steel in the core, core plate, and lower plenum structures than the NUREG-1150 model. The best-estimate model without BH has neither the detailed representation of the lower plenum required for the BH Package nor quench between the debris and the water in the lower plenum (Table 5.3).

Table 5.4. Comparison between Grand Gulf models

Input Variable	Best-estimate model	NUREG-1150 model
Initial conditions at time, s	0	1,720
Control volumes, vessel	6	6
Drywell	9	3
Outer containment	18	5
Auxiliary building	Not modeled	Not modeled
Enclosure	1	Not modeled
Environment	1	1
Total	35	15
Flowpaths, vessel	16	14
Drywell	16	7
Outer Containment	26	10
Total	58	31
Heat slabs	76	44
Control functions	136	52
Tabular functions	21	16
Vessel volume, m^3	657.1	648.4
Containment volume, m^3	51,169	50,919
Water suppression pool volume, m^3	3,863	4,002
Water refueling pool, m^3	2,067	1,731
Cavity, depth, m (ft)	2.921 (9.58)	2.921 (9.58)
Radius, m (ft)	3.225 (10.58)	3.225 (10.58)
Radial wall, m (ft)	1.75 (5.75)	1.75 (5.75)
Bottom wall, m (ft)	3.35 (11)	2 (6.56)
Number of rays	55	55

6. STATION BLACKOUT RESULTS

This chapter describes and compares the results of the short-term station blackout calculations performed with three different MELCOR decks: the best-estimate deck described in Sect. 4, the best-estimate deck without the BH Package input also described in Sect. 4, and the NUREG-1150 deck described in Sect. 5. All of the calculations have been performed with MELCOR Version 1.8.3 (1.8 PN). Section 6.1 provides the results with the best-estimate deck. Section 6.2 gives the results with the best-estimate deck without the BH Package. Section 6.3 addresses the results with the NUREG-1150 deck. Finally, Sect. 6.4 compares the results from the three decks.

6.1 BEST-ESTIMATE DECK RESULTS

The timing of the important events and significant results obtained with the best-estimate deck are presented in Sect. 6.1.1. The associated in-containment source terms are described in Sect. 6.1.2. The corresponding environmental source terms are discussed in Sect. 6.1.3.

6.1.1 Timing of Important Events and Significant Results

The best-estimate times for the important events of this short-term station blackout sequence are summarized in Table 6.1. The core becomes uncovered at about 31 min after transient initiation. The vessel is manually depressurized (per Rev. 3 of the EPGs) at 59 min (1 h) after transient initiation, vessel penetration failures are predicted to occur at 288 min (almost 5 h afterward), and gross failure of the lower head by ablation follows about 465 min (7.8 h) after transient initiation. Containment failure is predicted to occur 43 h after transient initiation.

Some graphical results are also presented. Figure 6.1 shows the pressure inside the reactor vessel during the first 400 s of the transient. The SRVs open and close at a higher pressure the first time than for subsequent cycles, as described in Sect. 3.2 (Table 3.1). At 300 s, one SRV was still open in the automatic mode when another SRV is opened manually.

Table 6.1. Calculated times for the events of the station blackout with the best-estimate deck

Event	Time (s)	Time (min)	Time (h)
Station blackout initiation (MELCOR calculation started)	0	0	0
Core uncovering	1,850	31	0.5
Manual vessel depressurization	3,541	59	1.0
First gap release (Ring 1)	4,860	81	1.4
Second ring gap release	5,368	89	1.5
Third ring gap release	6,171	103	1.7
Core relocation starts	6,850	114	1.9
Last gap release (Ring 4)	7,183	120	2.0
Gap release phase duration	2,323	39	
First core plate failure	11,017	184	3.1
Core plate 2 failure	11,565	193	3.2
Core plate 3 failure	16,096	268	4.5
Vessel failure (penetration failure)	17,272	288	4.8
Early in-vessel release phase duration	10,089	168	
Core plate 4 failure	20,707	345	5.8
Lower head failure	27,922	465	7.8
Radial rupture of cavity	114,344	1,906	31.8
Containment failure	154,827	2,580	43.0
Calculation ended	170,000	2,833	47.2

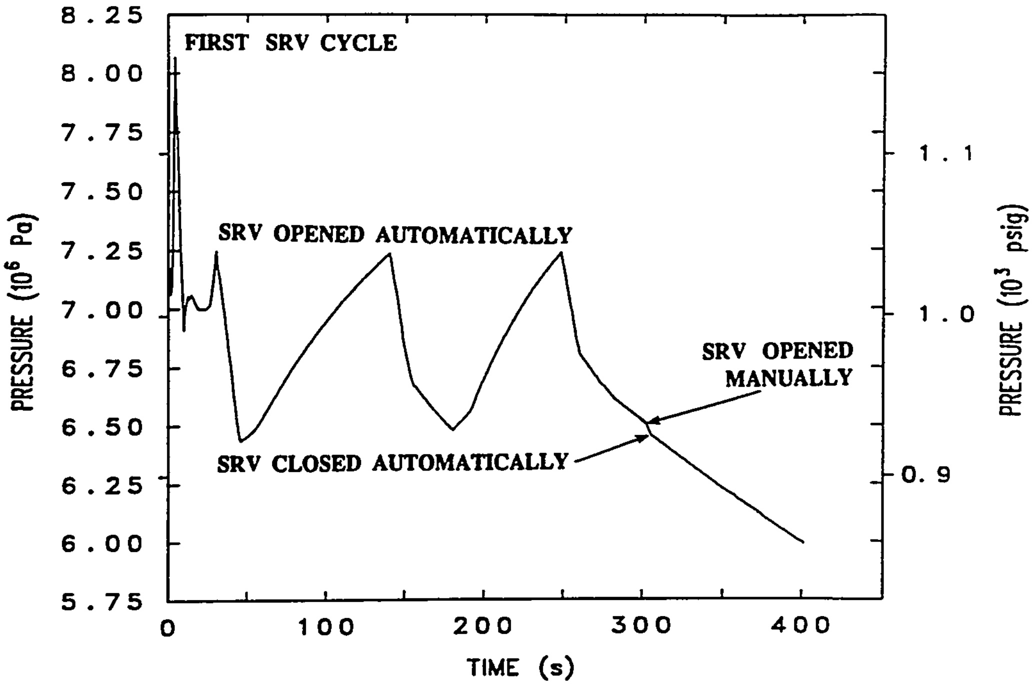

Fig. 6.1 Reactor vessel pressure during the first 400 s of transient (best-estimate deck)

Figure 6.2 shows the reactor vessel pressure on an expanded scale, during the first 4,000 s of the transient. Manual operation of the SRVs between 800 and 900 psig (5.6 and 6.28 MPa) occurs from 300 s until 3,541 s when the ADS SRVs are manually opened as the water level in the core drops to one-third ACH. SRV actuation (open or close) occurs a total of eight times in the automatic mode and 48 times in the manual mode. When the vessel is depressurized at 3,541 s, the temperature of the suppression pool is 140°F (333 K), below the 148°F (338 K) limit associated with EPGs Rev. 3 (Sect. 2.1).

Figure 6.3 shows the steam flows through the SRVs during the first 4,000 s of the transient. For the first SRV cycle, 11 SRVs are opened simultaneously. Subsequently, one SRV is opened either in the automatic or manual mode of operation. At 3,541 s, the eight SRVs of the ADS are opened manually.

Figure 6.4 shows the pressures in different control volumes of the containment during the entire transient. The pressures in the wetwell (control volume 310 of Fig. 4.3) and the containment dome (control volume 316) are the same. Before vessel failure, the pressure in the wetwell or in the outer containment is higher than the pressure in the drywell due to the

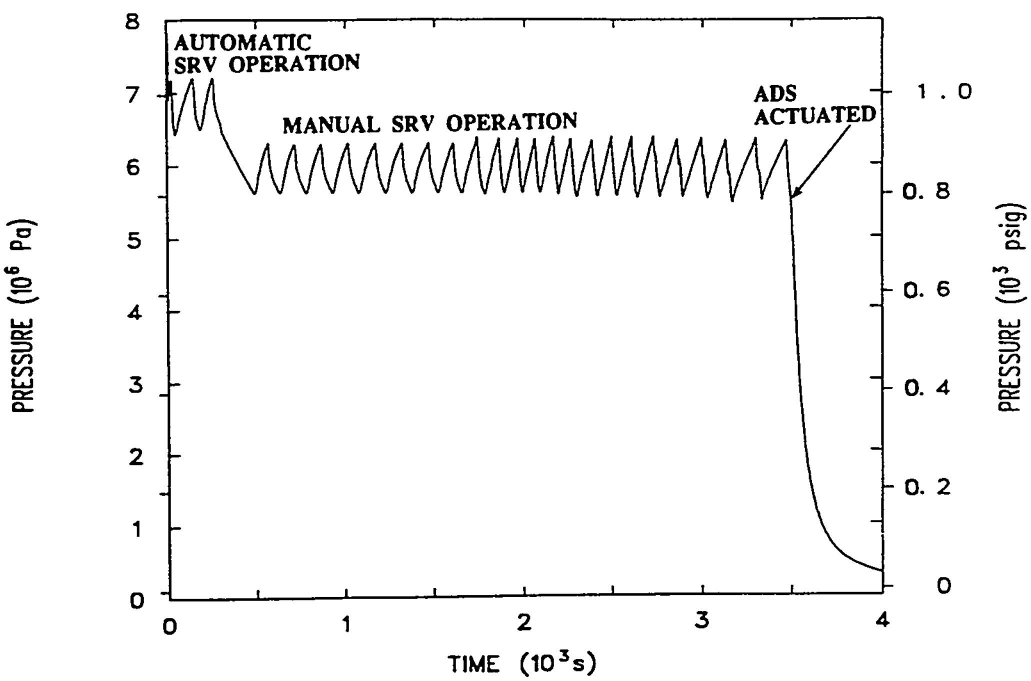

Fig. 6.2 Reactor vessel pressure during the first 4,000 s of transient (best-estimate deck)

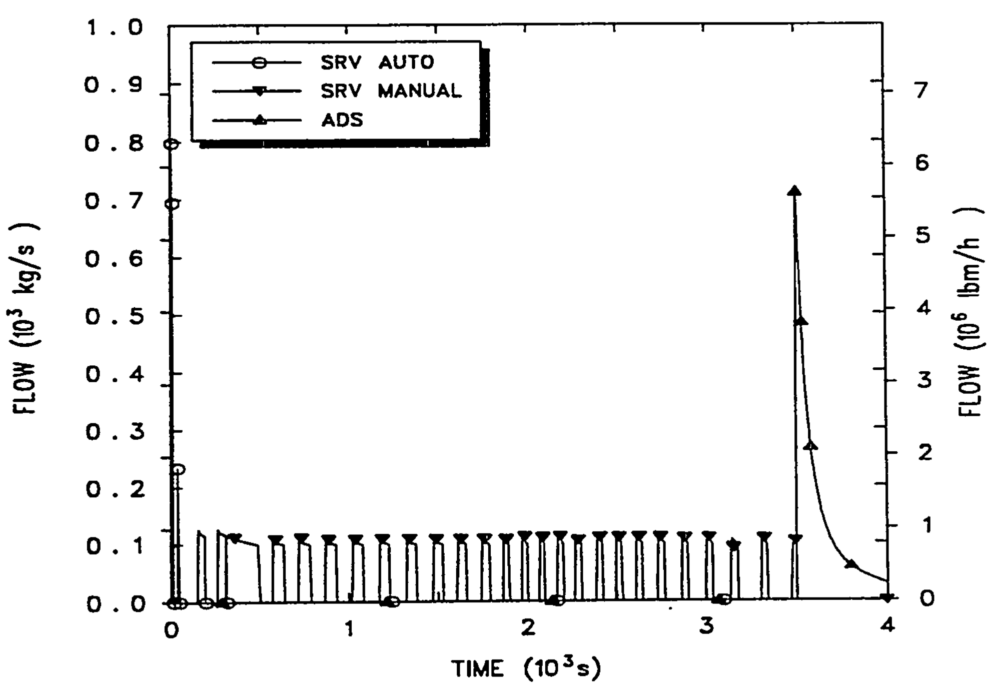

Fig. 6.3 Steam flows through SRVs (best-estimate deck)

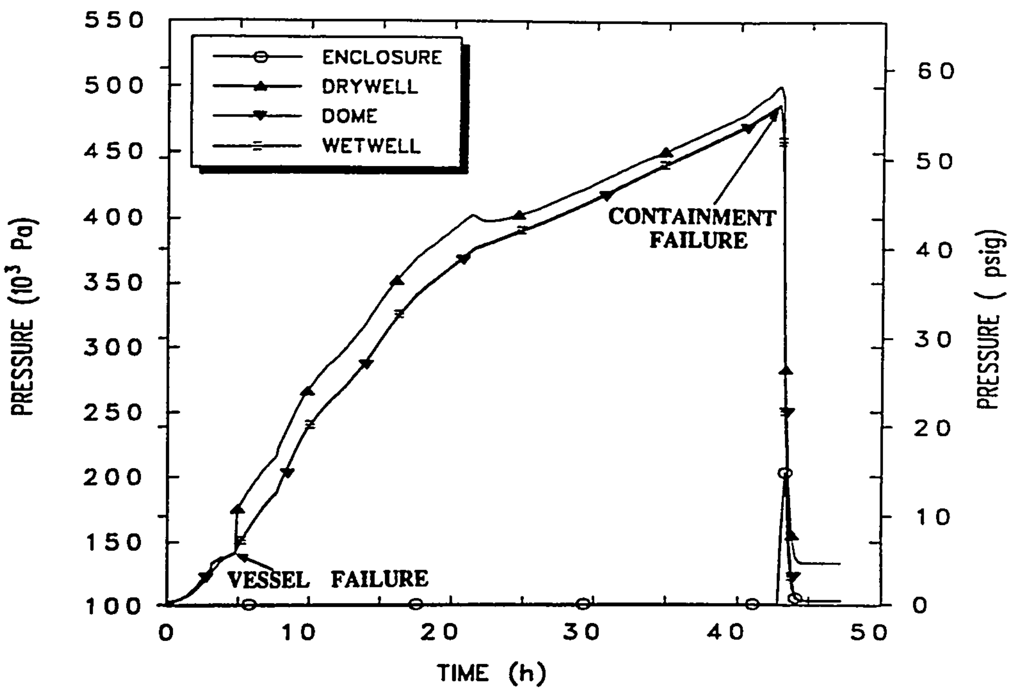

Fig. 6.4 Containment pressures (best-estimate deck)

collection of noncondensables discharged into the suppression pool water via the SRVs. After vessel failure (at 4.8 h), the pressure in the drywell is higher than in the outer containment. The containment is predicted to fail at 43 h by a pressure differential of 56 psig (0.486 MPa) between the dome and the enclosure building.

Figure 6.5 shows the water levels (relative to mean sea level) in drywell and wetwell portions of the suppression pool and in the pedestal control volume. The bottom level of the pedestal sump is at elevation 91.5 ft (27.89 m). The floor of the pedestal is at elevation 94.5 ft (28.8 m). Before vessel failure, the water level in the drywell portion of the pool is higher than the portion in the wetwell due to the higher pressure of the wetwell atmosphere. After vessel failure, the opposite is true. After vessel failure, the water present in the sump of the pedestal is vaporized by the hot debris discharged from the vessel. Water from the suppression pool never spills into the pedestal region.

Figure 6.6 illustrates the calculated ablation of the reactor cavity concrete. At 114,344 s (31.8 h) into the transient, radial rupture of the cavity is predicted as the core-concrete reaction ablates the complete radial thickness of the cavity model (5.75 ft or 1.753 m). However, there is additional concrete (the pedestal mat) beyond the radial thickness of the cavity model at the location (below elevation 100 ft 9 in.) where the radial

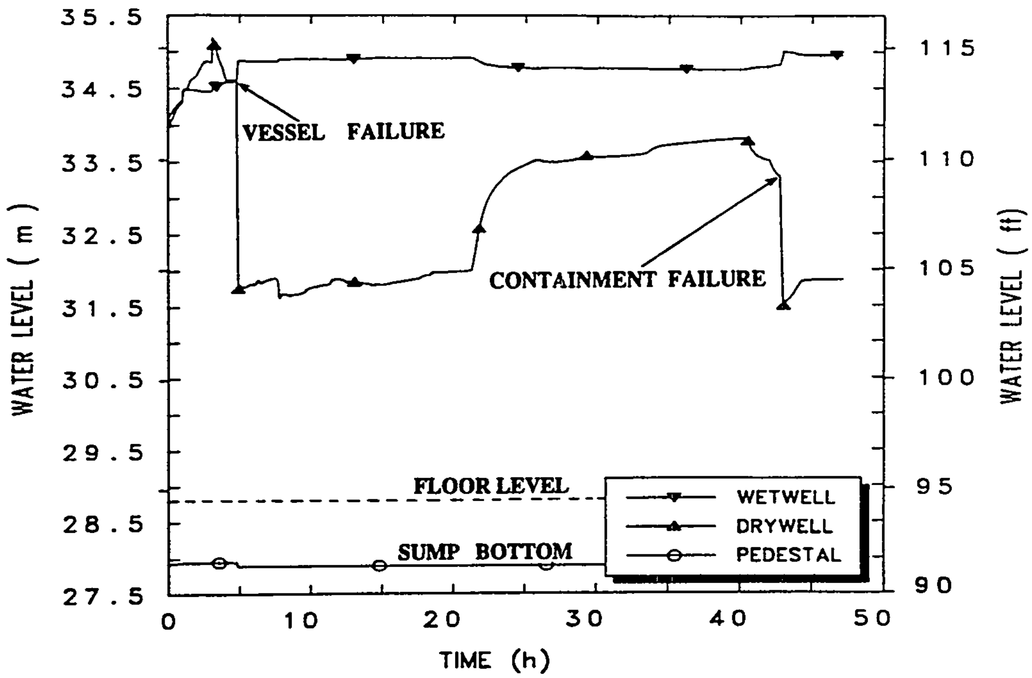

Fig. 6.5 Water levels in pedestal and suppression pool (best estimate deck)

rupture is predicted to occur. Therefore, this predicted cavity rupture is not realistic, and the core-concrete reaction was allowed to continue. Axial rupture of the cavity floor is never predicted to occur, because the core-concrete reaction never ablated the complete depth of the cavity floor (which is 11 ft or 3.353 m). The predicted cavity/debris configuration at the end of the calculation (47.2 h) is as labeled in Fig. 6.6. The total calculated ablation in the radial direction is 7.1 ft (2.2 m) and in the axial direction is 6.84 ft (2.1 m) with a remaining concrete thickness for the floor of 4.2 ft (1.3m). All the Zr in the cavity was completely oxidized at the end of the calculation.

The total hydrogen produced in-vessel at the end of the calculation (47.2 h) was 1,521 lb (690 kg). Of this total, 650 lb (295 kg) was calculated by the BH Package after lower plenum dryout; the remainder was predicted by the core routines of MELCOR. At the end of the calculations, the amount of fuel left in the core region was 4,402 lb (1,997 kg), about 1.3% of the total initial fuel inventory of 353,070 lb (160,150 kg).

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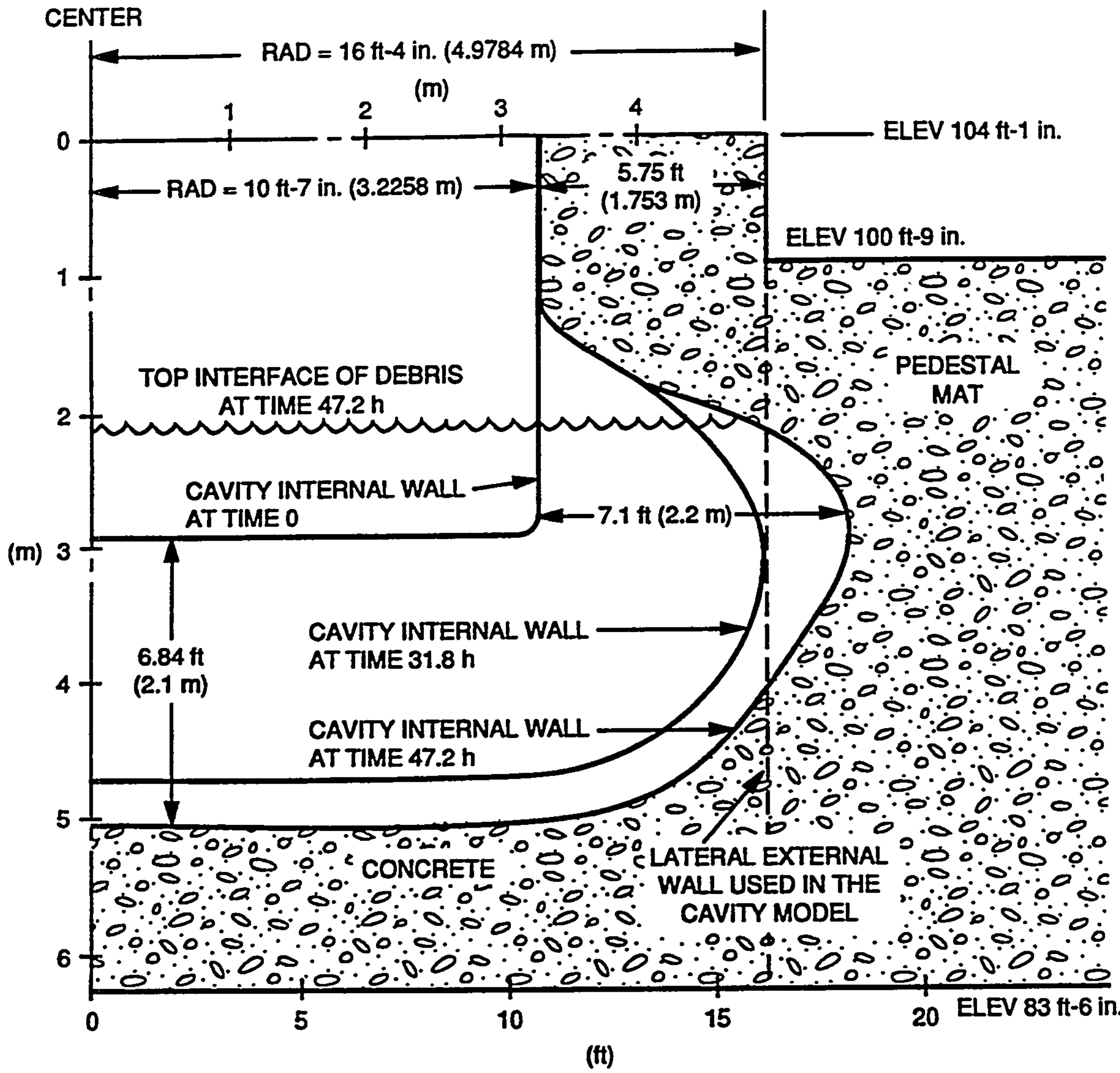

Fig. 6.6 Cavity wall ablation (best-estimate deck)

6.1.2 Source Terms Into Containment

The source terms into containment comprise all those fission products released from the fuel and the vessel. The unreleased fission products inside the fuel (either fuel inside the vessel or in the cavity) and the released fission products remaining inside the vessel **are not** part of the source terms into containment.

Table 6.2 lists the in-containment source terms divided into four release phases: "gap;" "early in-vessel;" "ex-vessel;" and "late in-vessel;" together with the duration of each phase. (These release phases are described in Refs. 16 and 24.) In this study, the "gap" release phase starts when the cladding of the hottest fuel rod fails releasing the first fission products at 81 min into the transient (Table 6.1) and ends when the cladding of all the fuel rods failed (at 120 min into the transient). The second release phase, the "early in-vessel" release phase, starts at the end of the "gap" release phase and ends when the vessel fails at 288 min. The last two release phases, the "ex-vessel" and the "late-in-vessel" start when the vessel fails and end when the calculations are terminated at 2,833 min. The "ex-vessel" release phase accounts for the fission products released into containment from the fuel in the cavity during the core-concrete interaction.

Finally, the "late-in-vessel" release phase accounts for the fission products released from the vessel into containment after vessel failure. Part of these fission products are late releases from the peripheral fuel that remains within the core region. Other portions of these "late-in-vessel" releases arise from the predicted revaporization of fission products previously deposited on the vessel internals. The "total" releases are the summation of the previously discussed four release phases.

The largest "total" releases are for class 1 (noble gases), with almost 100%, class 2 (Cs) with 86%, class 5 (Te) with 66%, class 12 (Sn) with 22%, and class 16 (CsI) with 89%. Some "late in-vessel" releases due to revaporization are predicted for classes 1, 2, 5, and 16. Very small "total" releases (< 1%) were calculated for classes 6–10. The results of Table 6.2 are similar (despite some differences) to the results obtained for the Peach Bottom plant (Ref. 16, Table 5.5). The calculations described in Ref. 16 used a different version of MELCOR (version 1.8.1) and a different radionuclide release model (the CORSOR with S/V ratio vs the CORSOR with the <u>modified</u> S/V ratio that was used in the present calculation).

Table 6.2. Source terms released into containment for the station blackout with the best-estimate deck

		Phase	Gap release	Early in-vessel	Ex-vessel	Late in-vessel	Total
	Duration	(min)	39	168	2,545	2,545	2,752
		(h)	0.7	2.8	42.4	42.4	45.9
Class	Element	Inventory (kg)	Fraction	Fraction	Fraction	Fraction	Fraction
1	Noble gases	463.7	0.1442	0.8315	0.0236	0.0006	0.9999
2	Cs	246.4	0.1422	0.4800	0.0224	0.2182	0.8628
3	Ba, Sr	207.5	0	0.0026	0.1154	0	0.1180
4	I	20.93	-	-	-	-	-
5	Te	40.79	0.0368	0.5592	0.0248	0.0363	0.6571
6	Ru	307.0	0	0	0.0001	0	0.0001
7	Mo	350.6	0	0	0	0	0
8	Ce	593.9	0	0	0.0017	0	0.0017
9	La	571.0	0	0	0.0001	0	0.0001
10	U	138,300	0	0	0.0034	0	0.0034
11	Cd	1.41	0	0	0.0149	0	0.0149
12	Sn	8.59	0.0007	0.0304	0.1892	0	0.2203
16	CsI	42.85	0.1138	0.4977	0.0236	0.2513	0.8864

Notes: All fractions are from the initial inventories of fission products, except for class 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted. Class 4 (I) releases are combined with class 2 (Cs) to form class 16 (CsI).

A total of 6,272 lb (2,845 kg) of nonradioactive aerosols is predicted to be produced from the core-concrete interactions at the end of the calculation. From this total, 5,516 lb (2,502 kg) was deposited, 741 lb (336 kg) was mixed with water from condensation, and only 15 lb (7 kg) was suspended in the containment atmosphere.

6.1.3 Source Terms into Environment

Table 6.3 shows the source terms released from the containment into the environment at different times after containment failure. At the end of the calculation (4.2 h after

Table 6.3. Cumulative source terms released into the environment for the station blackout with the best-estimate deck

Time after containment failure						
	(s)	2,365	3,365	7,775	11,774	15,173
	(min)	3.9	56	130	196	253
	(h)	0.7	0.9	2.2	3.3	4.2
Class	**Element**	**Fraction**	**Fraction**	**Fraction**	**Fraction**	**Fraction**
1	Noble gases	0.6374	0.7465	0.8001	0.8264	0.8460
2	Cs	0.0034	0.0067	0.0087	0.0095	0.0100
3	Ba, Sr	8×10^{-7}	9.8×10^{-7}	1.1×10^{-6}	1.2×10^{-6}	1.2×10^{-6}
4	I	-	-	-	-	-
5	Te	0.0009	0.0018	0.0024	0.0026	0.0028
6	Ru	1.4×10^{-10}	1.5×10^{-10}	1.6×10^{-10}	1.6×10^{-10}	1.6×10^{-10}
7	Mo	1.6×10^{-10}	2.0×10^{-10}	2.4×10^{-10}	2.6×10^{-10}	2.9×10^{-10}
8	Ce	4.6×10^{-8}	5.8×10^{-8}	6.7×10^{-8}	7.4×10^{-8}	8.2×10^{-8}
9	La	4.6×10^{-8}	5.7×10^{-8}	6.6×10^{-8}	7.3×10^{-8}	8.2×10^{-8}
10	U	5.1×10^{-8}	6.3×10^{-8}	7.2×10^{-8}	8.0×10^{-8}	8.8×10^{-8}
11	Cd	2.8×10^{-5}	3.5×10^{-5}	4.1×10^{-5}	4.5×10^{-5}	5.1×10^{-5}
12	Sn	2.2×10^{-6}	2.8×10^{-6}	3.3×10^{-6}	3.6×10^{-6}	4.1×10^{-6}
16	CsI	0.0048	0.0091	0.0118	0.0129	0.0135

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted. All class 4 (I) releases are combined with class 2 (Cs) to form class 16 (CsI).

containment failure), 84.6% of the noble gases, 1% of the Cs and CsI and < 0.1% of the other fission product classes were released.

Table 6.4 shows the fractional distribution of fission products by class and location at the end of the MELCOR calculation (2.7 h after containment failure). The majority of the noble gases (84.6%) escaped to the environment, with 8% in the wetwell atmosphere and 7% in the enclosure building. The wetwell suppression pool retained most of classes 2 (Cs), 5 (Te), and 16 (CsI). The majority of classes 3 (Ba), 6 (Ru), 7 (Mo), 8 (Ce), 9 (La), 10 (U), and 11 (Cd) are in the cavity debris. Elemental iodine, which did not react with Cs, remains

Table 6.4. Fractional distribution of fission products by class and location at the end of the MELCOR calculation (47.2 h after transient initiation) with the best-estimate deck

Class	Element	Core fuel	Cavity debris	Reactor coolant system	Drywell	Wetwell	Enclosure building	Environment
1	Noble gases	0.111×10^{-3}	0	0.583×10^{-7}	0.786×10^{-4}	0.0837	0.0701	0.8460
2	Cs	0.118×10^{-3}	0.106×10^{-8}	0.1371	0.1509	0.6954	0.0065	0.0100
3	Ba, Sr	0.0069	0.6258	0.2493	0.0330	0.0850	0.634×10^{-6}	0.122×10^{-5}
4	I	1.0	0	0	0	0	0	0
5	Te	0.117×10^{-3}	0.0001	0.3427	0.0599	0.5923	0.0021	0.0028
6	Ru	0.0069	0.9928	0.0002	0.173×10^{-4}	0.607×10^{-4}	0.171×10^{-10}	0.159×10^{-9}
7	Mo	0.0069	0.9931	0.140×10^{-11}	0.750×10^{-8}	0	0.234×10^{-9}	0.286×10^{-9}
8	Ce	0.0069	0.9913	0.961×10^{-4}	0.0013	0.0004	0.739×10^{-7}	0.823×10^{-7}
9	La	0.0069	0.9930	0.455×10^{-9}	0.0001	0.191×10^{-4}	0.738×10^{-7}	0.819×10^{-7}
10	U	0.0126	0.9736	0.0104	0.0007	0.0027	0.742×10^{-7}	0.882×10^{-7}
11	Cd	0.0069	0.9782	0.276×10^{-6}	0.0121	0.0028	0.491×10^{-4}	0.511×10^{-4}
12	Sn	0.0067	0.3694	0.4036	0.0179	0.2024	0.381×10^{-5}	0.408×10^{-5}
16	CsI	0.160×10^{-9}	0.591×10^{-5}	0.1136	0.1754	0.6891	0.0084	0.0135

Note: All fractions are from the initial inventories of fission products except for classes 2, 4, and 16 that are from the final inventories.

only in the core fuel. Finally, about 1.3% of class 10 (U) is still in the core fuel; this result agrees with the amount of fuel predicted to remain in the core (1.3% in Sect. 6.1.1).

6.2 BEST-ESTIMATE DECK WITHOUT THE BH PACKAGE RESULTS

The timing of the important events and some significant results obtained when the BH Package is not used are presented in Sect. 6.2.1. The calculated in-containment source terms for this deck are described in Sect. 6.2.2. The environmental source terms are described in Sect. 6.2.3.

6.2.1 Timing of Important Events and Significant Results

The MELCOR calculated times for the station blackout sequence are summarized in Table 6.5. This MELCOR deck is a modification of the best-estimate deck but without the BH Package input and without the debris/lower plenum water quench model. Vessel depressurization is predicted at 59 min after transient initiation (only 16 s earlier than the results of Table 6.1), vessel penetration failure at 184.4 min [much earlier than the equivalent result (288 min) of Table 6.1], and containment failure at 42.2 h (vs 43 h in Table 6.1). The results of this run are almost identical to the results of the best-estimate deck of Sect. 6.1 up to the first core plate failure. Gross failure of the lower head was not calculated because this failure model of the lower head is only available with the BH Package.

Graphical results up to core plate failure are identical to the results presented in Sect. 6.1. Figure 6.7 shows the pressures in the containment. Although vessel penetration failure occurred in this run earlier than in the best-estimate run of Sect. 6.1 (Fig. 6.4), the containment was predicted to fail at about the same time in both runs.

Figure 6.8 shows the water levels (relative to mean sea level) in the pedestal and in the drywell and wetwell portions of the suppression pool. When the vessel fails at 3.1 h, a lot of water in the vessel lower plenum is ejected to the pedestal cavity together with debris. This water is completely evaporated by the debris decay heat (and core-concrete interaction) at about 5 h (accident time).

Table 6.5. Calculated times for the events of the station blackout with the best-estimate deck without BH

Event	Time (s)	Time (min)	Time (h)
Station blackout initiation (MELCOR calculation started)	0	0	0
Core uncovering	1,850	31	0.5
Vessel depressurization	3,525	59	1.0
First gap release (Ring 1)	4,861	81	1.4
Second ring gap release	5,370	89	1.5
Third ring gap release	6,171	103	1.7
Core relocation starts	6,850	114	1.9
Last gap release (Ring 4)	7,192	120	2.0
Gap release phase duration	2,331	39	
First core plate failure	11,046	184	3.1
Vessel failure (penetration failure)	11,065	184.4	3.1
Early in-vessel release phase duration	3,873	64.4	
Core plate 2 failure	11,558	193	3.2
Core plate 3 failure	17,006	283	4.7
Core plate 4 failure	a	a	a
Lower head failure	b	b	b
Radial rupture of cavity	108,085	1,801	30.0
Containment failure	152,020	2,534	42.2
Calculation ended	168,000	2,800	46.7

Notes: [a]This core plate did not fail
[b]This model was not available in this run

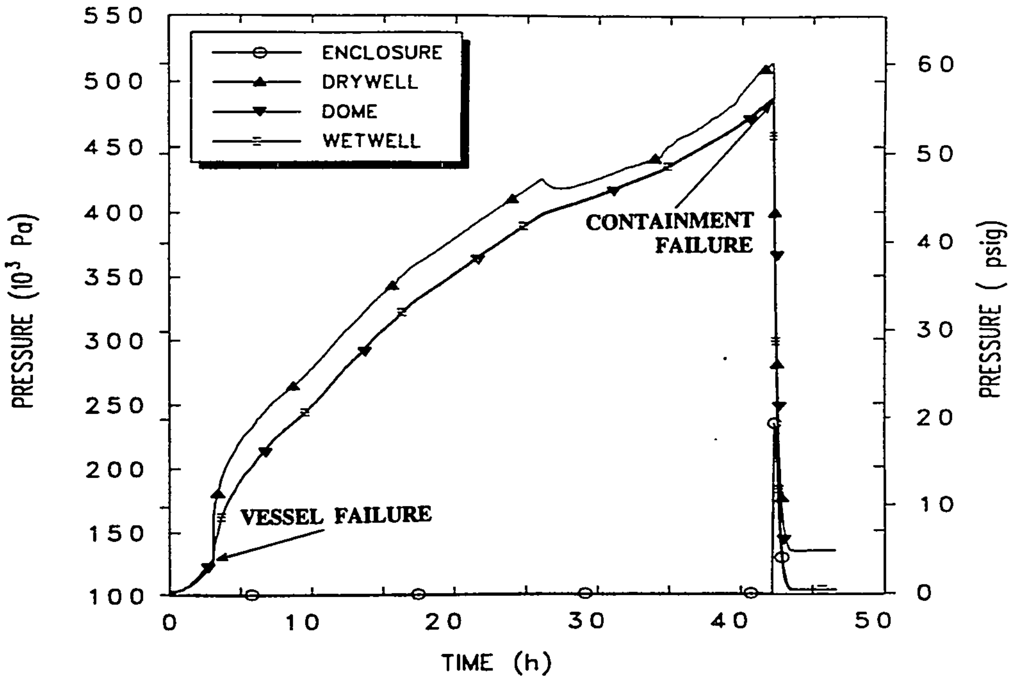

Fig. 6.7 Containment pressures (best-estimate deck without BH)

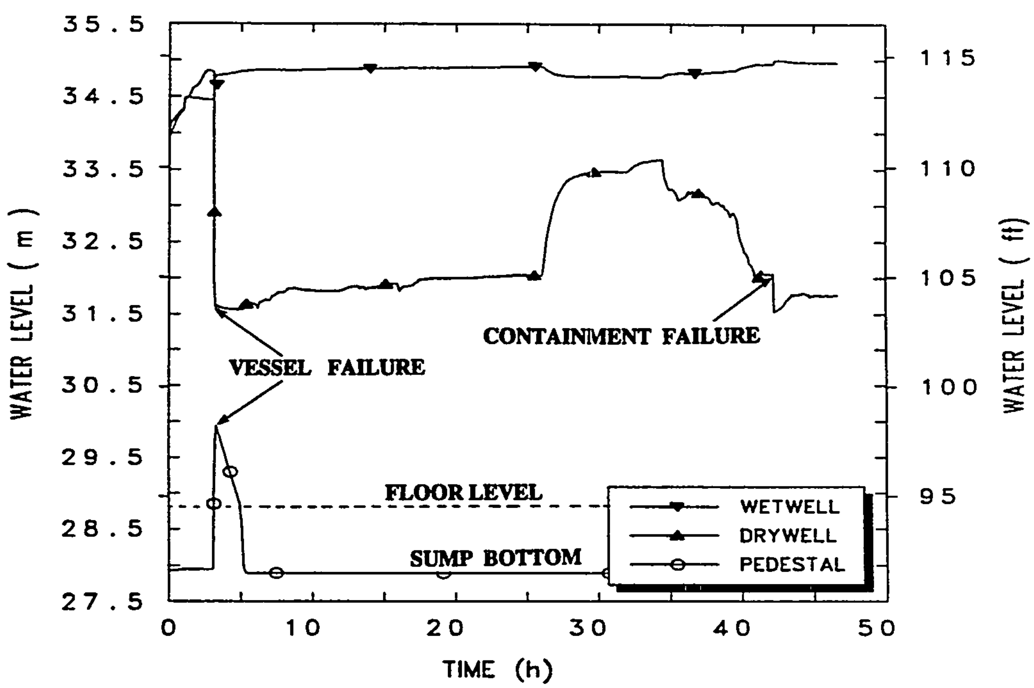

Fig. 6.8 Water levels in pedestal and suppression pool (best-estimate deck without BH)

At the end of the calculation (46.7 h) the total amount of the hydrogen produced in-vessel was 714 lb (324 kg). At the same time, the amount of fuel left in the core region was 48,235 lb (21,879 kg), about 13.7% of the total initial core inventory. All the Zr in the cavity was oxidized at the end of the calculation.

An additional run was performed with this deck, keeping the BH Package input inactive but with the debris/lower plenum water quenching model active. The results of this run were very similar to those shown in Table 6.5. The only differences were: vessel failure occurred at 195.5 min (only 11.1 min later than in the previous run of Table 6.5), and containment failure occurred at 40.9 h (1.3 h earlier than in the case of Table 6.5). The later vessel failure time was due to the delay caused by debris cooling during quenching while falling into the lower head.

6.2.2 Source Terms into Containment

Table 6.6 shows the source terms released into containment divided into the four release phases: "gap;" "early in-vessel;" "ex-vessel;" and "late in-vessel." These release phases were defined in Section 6.1.2. Large "total" releases were calculated for classes 1, 2, 5, 7, 11, 12, and 16. "Late in-vessel" releases were calculated for classes 1, 2, 3, 5, and 16. At the end of the calculations (46.7 h), a total of 11,206 lb (5,083 kg) of nonradioactive aerosols was produced from the core-concrete interaction. From this total, 9,209 lb (4,177 kg) was deposited, 1,989 lb (902.1 kg) were mixed with water and the remaining 9.5 lb (4.3 kg) was suspended in the containment atmosphere.

6.2.3 Source Terms into Environment

Table 6.7 shows the source terms released into the environment at two different times after containment failure. At the end of the calculation (4.4 h after containment failure), 84.6% of the noble gases are predicted to escape to the environment. For the rest of the classes, all releases are < 1%.

Table 6.8 shows the fractional distribution of fission products by class and location at the end of the MELCOR calculation. The majority of the noble gases (84.6%) escaped to the environment. The majority of classes 2 (Cs), 5 (Te), and 16 (CsI) are in the suppression

Table 6.6. **Source terms released into containment for the station blackout with the best-estimate deck without BH**

		Phase	Gap release	Early in-vessel	Ex-vessel	Late in-vessel	Total
	Duration	(min)	39	65	2,615	2,615	2,719
		(h)	0.7	1.1	43.6	43.6	45.3
Class	Element	Inventory (kg)	Fraction	Fraction	Fraction	Fraction	Fraction
1	Noble gases	463.7	0.1456	0.7733	0.0615	0.0173	0.9977
2	Cs	246.3	0.1453	0.4203	0.0593	0.2249	0.8480
3	Ba, Sr	207.5	0	0.0018	0.3252	0.0002	0.3272
4	I	20.93	-	-	-	-	-
5	Te	40.79	0.0400	0.5098	0.0660	0.0809	0.6967
6	Ru	307.0	0	0	0	0	0
7	Mo	350.6	0	0	0.9335	0	0.9335
8	Ce	593.9	0	0	0.0440	0	0.0440
9	La	571.0	0	0	0.0013	0	0.0013
10	U	138,300	0	0	0.0003	0	0.0003
11	Cd	1.41	0	0	0.9336	0	0.9336
12	Sn	8.59	0.0007	0.0216	0.8868	0	0.9091
16	CsI	42.75	0.1155	0.4356	0.0619	0.2736	0.8866

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted. Class 4 (I) releases are combined with class 2 (Cs) to form class 16 (CsI).

Table 6.7. Cumulative source term released into the environment for the station blackout with the best-estimate deck without BH

Time after containment failure	(s)	7,981	15,981
	(min)	133	266
	(h)	2.2	4.4
Class	**Element**	**Fraction**	**Fraction**
1	Noble gases	0.7845	0.8456
2	Cs	0.0039	0.0047
3	Ba, Sr	1.1×10^{-5}	1.2×10^{-5}
4	I	-	-
5	Te	0.0018	0.0022
6	Ru	3.3×10^{-8}	4.7×10^{-8}
7	Mo	0.0010	0.0011
8	Ce	9.4×10^{-8}	1.3×10^{-7}
9	La	9.8×10^{-8}	1.4×10^{-7}
10	U	7.1×10^{-6}	8.6×10^{-6}
11	Cd	0.0083	0.0086
12	Sn	0.0019	0.0019
13-15			
16	CsI	0.0052	0.0063

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No release of class 4 (I) are predicted since this class 4 combines with Cs of class 2 to form class 16 (CsI).

Table 6.8. Fractional distribution of fission products by class and location at the end of the MELCOR calculation (46.7 h after transient initiation) with the best-estimate deck without BH

Class	Element	Core fuel	Cavity debris	Reactor coolant system	Drywell	Wetwell	Enclosure building	Environment
1	Noble gases	0.0019	0	0.0004	0.0001	0.0798	0.0722	0.8456
2	Cs	0.0020	0.108×10^{-8}	0.1500	0.1859	0.6540	0.0033	0.0047
3	Ba, Sr	0.0655	0.6051	0.0022	0.1978	0.1294	0.737×10^{-5}	0.0001
4	I	1.0	0	0	0	0	0	0
5	Te	0.0020	0.313×10^{-8}	0.142×10^{-6}	0.1013	0.5918	0.0015	0.0022
6	Ru	0.0656	0.9344	0.3012	0.151×10^{-5}	0.554×10^{-6}	0.524×10^{-7}	0.472×10^{-7}
7	Mo	0.0656	0.273×10^{-9}	0.0009	0.8969	0.0354	0.0001	0.0010
8	Ce	0.0656	0.8895	0.162×10^{-6}	0.0293	0.0157	0.137×10^{-6}	0.133×10^{-6}
9	La	0.0656	0.9331	0.785×10^{-8}	0.0009	0.0004	0.143×10^{-6}	0.138×10^{-6}
10	U	0.1380	0.8616	0.859×10^{-5}	0.0003	0.0001	0.568×10^{-5}	0.863×10^{-5}
11	Cd	0.0656	0.283×10^{-4}	0.0006	0.8367	0.0871	0.0014	0.0086
12	Sn	0.0641	0.138×10^{-7}	0.0268	0.8363	0.0706	0.0002	0.0019
16	CsI	0.153×10^{-8}	0.780×10^{-4}	0.1133	0.2200	0.6559	0.0044	0.0063

Note: All fractions are from the initial inventories of fission products, except for classes 2, 4, and 16 that are of the final inventories.

pool. The majority of classes 3 (Ba), 6 (Ru), 8 (Ce), 9 (La), and 10 (U) are in the cavity debris. Elemental iodine (class 4) exits only in the core fuel (unreleased). The majority of classes 7 (Mo), 11 (Cd), and 12 (Sn) are in the drywell. The amount of uranium (class 10) left in the core fuel is 13.8% of the initial inventory, in agreement with the amount of fuel calculated by the MELCOR core package to remain in the core region (Sect. 6.2.1).

6.3 NUREG-1150 DECK RESULTS

The timing of important events and significant results are presented in Sect. 6.3.1 for this deck. The associated in-containment source terms are described in Sect. 6.3.2. The corresponding environmental source terms are discussed in Sect. 6.3.3.

6.3.1 Timing of Important Events and Significant Results

Table 6.9 summarizes the timing of the most important events calculated for the station blackout accident using the NUREG-1150 deck. The times listed in Table 6.9 have been adjusted to add 1,720 s, the time when the MELCOR calculation started (Sect. 5.1). The core is uncovered immediately after the calculation starts (0.5 h of transient time). Manual depressurization was calculated to occur at about 0.8 h, vessel failure at about 2 h, and containment failure at 36.7 h after transient initiation.

Figure 6.9 shows the pressure inside the reactor vessel during the first 8,000 s of the calculation. The ADS SRVs are actuated at 1,112 s calculation time or 2,832 s transient time (with the 1,720 s added). Vessel failure was predicted to occur at 5,602 s calculation time or 7,322 s transient time. One SRV is operated at the "low-low set" of the automatic mode of operation (Sect. 3.2). Manual operation (at lower pressures than the automatic operation) of the SRVs is not considered in this deck. The SRV cycles 18 times (open or close) before the ADS SRVs activation at 1,112 s (calculation time). If the calculations had been started at time zero of the transient (1,720 s prior to zero time of calculations), the SRVs would have cycled 46 times.

Figure 6.10 shows the pressure inside the containment. The pressure in the drywell is higher than in the wetwell or outer containment after vessel failure.

Table 6.9. Calculated times for the events of the station blackout with the NUREG-1150 deck

Event	Time (s)	Time (min)	Time (h)
Station blackout initiation	0	0	0
MELCOR calculation started	1,720	29	0.5
Core uncovery starts	1,720	29	0.5
Vessel depressurization	2,832	48	0.8
First gap release (Ring 1)	3,915	65	1.1
Second ring gap release	4,008	67	1.1
Third ring gap release	4,353	73	1.2
Last gap release (Ring 4)	6,512	109	1.8
Gap release phase duration	2,597	43	
Core relocation starts	6,670	111	1.9
First core plate failure	7,267	121	2.0
Vessel failure (penetration 2 failed)	7,322	122	2.0
Early in-vessel release phase duration	810	14	
Core plate 2 failure	8,046	134	2.2
Core plate 3 failure	8,125	135	2.3
Core plate 4 failure	9,987	166	2.8
Cavity radial rupture	90,033	1,500	25.0
Containment failure	131,933	2,199	36.7
Calculation ended	158,528	2,642	44.0

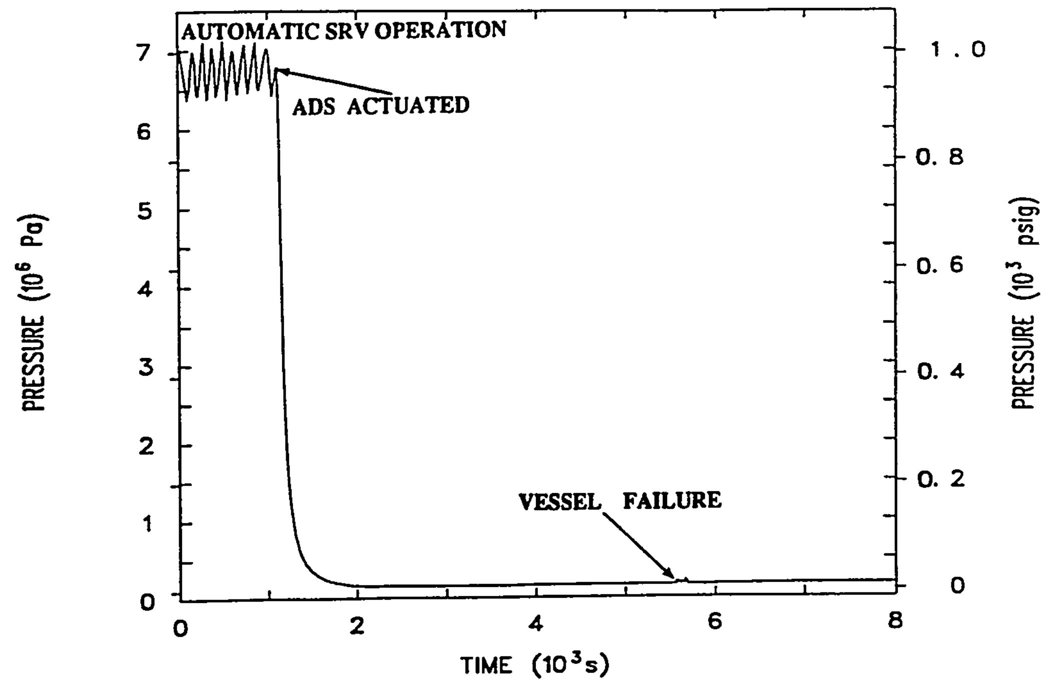

Fig. 6.9 Reactor vessel pressure during the first 8,000 s of transient (NUREG-1150 deck)

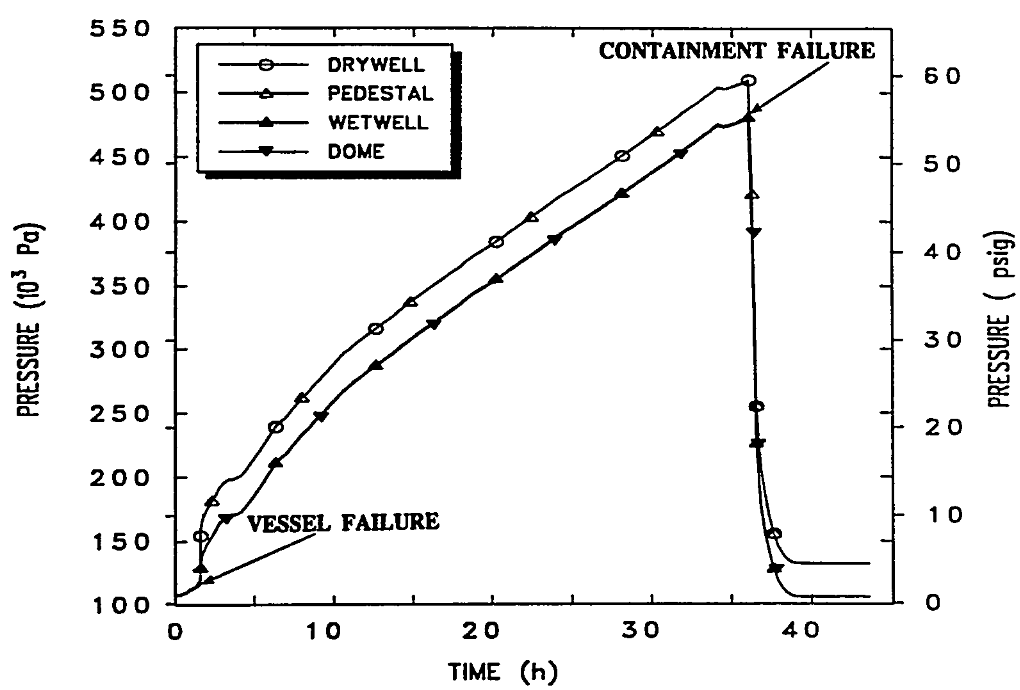

Fig. 6.10 Containment pressure (NUREG-1150 deck)

Figure 6.11 shows the water level in the drywell and wetwell portions of the suppression pool and in the pedestal. In this model, elevation zero is the bottom of the reactor vessel. Consequently, the listed elevations of the pedestal are negative. The floor of the pedestal is at elevation -28.35 ft (-8.64 m). After vessel failure, the water level in the wetwell portion of the pool is higher than that of the pool surface within the drywell due to the higher pressure of the drywell (Fig. 6.10). The water added to the pedestal at vessel failure is from the lower plenum. This water vaporizes later by the heat from the core debris and from the core-concrete interaction.

With the cavity geometry used in this deck (radial thickness of 1.752 m and axial depth 2 m as described in Sect. 5.5), radial rupture of the cavity was calculated to occur at 25 h (90,033 s) and axial rupture at 44 h (158,528 s). This cavity geometry of this deck is not realistic, because additional concrete exists in the actual plant beyond both the radial and axial limits of the cavity as modeled. Consequently, the core-concrete reaction was allowed to continue. (Cavity ruptures would not occur if the actual extent of the concrete boundaries in the cavity region were appropriately represented). All the Zr in the cavity was oxidized at the end of the calculation.

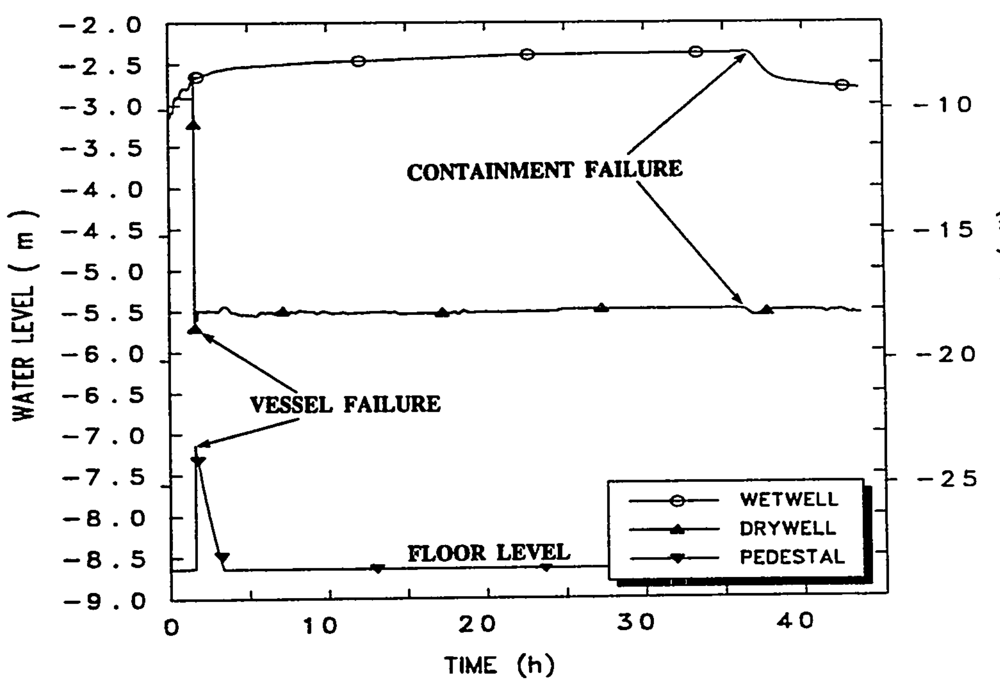

Fig. 6.11 Water levels in pedestal and suppression pool (NUREG-1150 deck)

At the end of the calculation (44 h), a total of 727 lb (330 kg) of hydrogen was predicted to be produced in-vessel. At this time, only 1,726 lb (783 kg) of fuel is predicted to remain in the core; this is < 1% of the initial fuel inventory (366,428 lb or 166,200 kg). Thus, MELCOR predicts that almost all of the fuel has been ejected into the cavity.

6.3.2 Source Terms into Containment

Table 6.10 shows the source terms released into containment divided into the four release phases: "gap;" "early in-vessel;" "ex-vessel;" and "late in-vessel." These release phases were defined in Sect. 6.1.2.

Large "total" releases were calculated for classes 1, 2, 3, 5, 7, 11, 12, and 16. "Late in-vessel" releases were calculated for classes 1, 2, 3, 5, 12, and 16.

At the end of the calculation, a total of 17,926 lb (8,131 kg) nonradioactive aerosols was produced from the core-concrete interaction. From this total, 10,617 lb (4,816 kg) was deposited, 7,282 lb (3,303 kg) was mixed with water from condensation, and the remaining 27 lb (12 kg) was suspended in the containment atmosphere.

6.3.3 Source Terms into Environment

Table 6.11 shows the source terms released from the containment into the environment for four different times after containment failure. At the end of the calculation, 7.4 h after containment failure, 99.8% of the noble gases are predicted to escape into the environment. Releases more than 1% are predicted for classes 5, 7, 11, and 12.

Table 6.12 shows the fractional distribution of fission products by class and location at the end of the MELCOR calculation, 7.4 h after containment failure. As indicated before, most of the noble gases (99.8%) have been released to the environment. The wetwell suppression pool was predicted to retain most of classes 2, 5, and 16. The majority of classes 3, 6, 8, 9, and 10 are in the cavity debris. The majority of classes 7, 11, and 12 are in the drywell. Finally, all the elemental iodine remains in the core fuel (unreleased).

Table 6.10. Source terms released into containment for the station blackout with the NUREG-1150 deck

		Phase	Gap release	Early in-vessel	Ex-vessel	Late in-vessel	Total
	Duration	(min)	43	14	2,520	2,520	2,577
		(h)	0.7	0.2	42	42	42.9
Class	Element	Inventory (kg)	Fraction	Fraction	Fraction	Fraction	Fraction
1	Noble gases	463.2	0.3871	0.4405	0.1228	0.0493	0.9997
2	Cs	245.9	0.2517	0.2203	0.1192	0.1024	0.6936
3	Ba, Sr	207.3	0.0002	0.0058	0.6050	0.0007	0.6117
4	I	20.91	-	-	-	-	-
5	Te	40.75	0.0100	0.3263	0.3238	0.0682	0.7283
6	Ru	306.7	0	0	0	0	0
7	Mo	350.3	0	0	0.9970	0	0.9970
8	Ce	593.4	0	0	0.1372	0	0.1372
9	La	570.5	0	0	0.0040	0	0.0040
10	U	143,700	0	0	0.0004	0	0.0004
11	Cd	1.41	0	0	0.9967	0	0.9967
12	Sn	8.58	0.0025	0.0423	0.9173	0.0065	0.9686
16	CsI	42.78	0.2283	0.2262	0.1237	0.1199	0.6981

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted. Class 4 (I) releases are combined with class 2 (Cs) to form class 16 (CsI).

Table 6.11. Cumulative source term released into the environment for the station blackout with the NUREG-1150 deck

Time after containment failure					
	(s)	7,790	14,989	22,188	26,595
	(min)	130	250	370	443
	(h)	2.2	4.2	6.2	7.4
Class	Element	Fraction	Fraction	Fraction	Fraction
1	Noble gases	0.9939	0.9967	0.9975	0.9977
2	Cs	0.0041	0.0043	0.0046	0.0049
3	Ba, Sr	2.9×10^{-5}	3.3×10^{-5}	3.7×10^{-5}	4.0×10^{-5}
4	I	-	-	-	-
5	Te	0.0120	0.0136	0.0142	0.0143
6	Ru	9.2×10^{-8}	1.2×10^{-7}	1.7×10^{-7}	2×10^{-7}
7	Mo	0.0258	0.0259	0.0259	0.0259
8	Ce	2.4×10^{-6}	2.5×10^{-6}	2.6×10^{-6}	2.7×10^{-6}
9	La	5.3×10^{-7}	6.4×10^{-7}	8.3×10^{-7}	9.5×10^{-7}
10	U	2.2×10^{-5}	2.6×10^{-5}	3.3×10^{-5}	3.7×10^{-5}
11	Cd	0.0764	0.0800	0.0827	0.0836
12	Sn	0.0314	0.0316	0.0316	0.0316
13-15					
16	CsI	0.0046	0.0049	0.0053	0.0056

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No release of class 4 (I) are predicted. All class 4 released forms class 16 (CsI).

Table 6.12. Fractional distribution of fission products by class and location at the end of the MELCOR calculation (44 h after transient initiation) with the NUREG-1150 deck

Class	Element	Core fuel	Cavity debris	Reactor coolant system	Drywell	Wetwell	Environment
1	Noble gases	0.0003	0	0.372×10^{-8}	0.143×10^{-8}	0.0020	0.9977
2	Cs	0.0003	0.264×10^{-6}	0.3061	0.0928	0.5959	0.0049
3	Ba, Sr	0.0030	0.3814	0.0038	0.2481	0.3637	0.400×10^{-4}
4	I	1.0	0	0	0	0	0
5	Te	0.0007	0.313×10^{-8}	0.2710	0.0747	0.6393	0.0143
6	Ru	0.0030	0.9970	0.469×10^{-6}	0.818×10^{-6}	0.186×10^{-5}	0.203×10^{-6}
7	Mo	0.0030	0.271×10^{-9}	0.388×10^{-7}	0.6586	0.3125	0.0259
8	Ce	0.0030	0.8597	0.286×10^{-4}	0.0674	0.0699	0.274×10^{-5}
9	La	0.0030	0.9930	0.607×10^{-6}	0.0022	0.0018	0.947×10^{-6}
10	U	0.0048	0.9948	0.258×10^{-4}	0.0002	0.0002	0.366×10^{-4}
11	Cd	0.0030	0.0002	0.0001	0.5453	0.3678	0.0836
12	Sn	0.0029	0.138×10^{-7}	0.0285	0.5835	0.3535	0.0316
16	CsI	0.701×10^{-10}	0.823×10^{-4}	0.3018	0.1004	0.5921	0.0056

Note: All fractions are from the initial inventories of fission products, except for classes 2, 4, and 16 that are of the final inventories.

6.4 COMPARISON OF MODELS AND RESULTS

6.4.1 General

The three MELCOR models used in these calculations, the best-estimate deck (Sect. 4), the best-estimate deck without the BH Package (Sect. 4), and the NUREG-1150 deck (Sect. 5) have differences in modeling the Grand Gulf plant. The differences between the best-estimate deck and the best-estimate deck without the BH Package are only in the use of the BH Package[2] of MELCOR; it includes a detailed model of the lower plenum and reactor vessel lower head and quenching of the debris with the lower plenum water. The differences between the two best-estimate decks and the NUREG-1150 deck are more extensive. In particular, SRV operation is different (Sects. 4.2 and 5.2). Different inventories of the core materials are represented (Sects. 4.4 and 5.4). The NUREG-1150 deck does not use the BH Package or the quenching model of the core debris by the water in the lower plenum. These options were not available with previous versions of MELCOR, at the time when the NUREG-1150 deck was originally prepared.

The best-estimate deck model of the containment (Sect. 4.3) is more detailed than the NUREG-1150 deck model (Sect. 5.3). Importantly, the best-estimate decks recognize the existence of the enclosure building whereas the NUREG-1150 deck does not.

The best-estimate decks start calculations at time zero (when the station blackout is initiated, Sect. 4.1) while the NUREG-1150 deck starts calculations at 1,720 s after transient initiation, using initial conditions appropriate to that time (Sect. 5.1). However, the initial conditions of the NUREG-1150 deck are different than the corresponding conditions calculated by the best-estimate decks at 1,720 s after transient initiation. The best-estimate decks have a lower pressure in the vessel (between 800 and 900 psig or 5.6 and 6.28 MPa) due to the SRVs manual operation at this time (Fig. 6.2) than does the NUREG-1150 deck at time zero (Fig. 6.9). The NUREG-1150 deck initial pressure is 998 psig (6.96 MPa), which is between the values of 910 and 1020 psig (6.358 and 7.114 MPa) of the automatic operation of the SRVs. The lower vessel pressures of the best-estimate decks correspond to lower saturation temperatures inside the vessel control volumes and also to lower fuel and structural temperatures than do the values of the NUREG-1150 deck.

On the other hand, the three decks have identical models or options for many important phenomena. Hydrogen burns or detonations are not allowed in either model.

Depressurization is at the same water level (one-third ACH, as per EPGs Rev. 3) for the three models. The radionuclide release model of MELCOR is the same (modified CORSOR with the Surface-to-Volume Ratio) for all of the decks. Finally, the containment failure pressure is about the same in all the models (56 psig in the best-estimate deck and 55 psig in the NUREG-1150 deck), at the same location in the containment (the intersection of the spherical and cylindrical portions of the containment), and with the same failure area (1 ft^2). The NUREG-1150 deck, however, does not consider the enclosure building around the containment.

The best-estimate results for this station blackout accident are the values calculated by the "complete" best-estimate deck (that includes the BH Package) given in Sect. 6.1. The best-estimate deck without the BH Package is not a "complete" best-estimate model of the plant because the BH model of the lower plenum and bottom head is not included. However, the results of this best-estimate deck without the BH Package are helpful in comparing and explaining the differences between the results of the "complete" best-estimate deck and the NUREG-1150 deck.

6.4.2 Comparison of Timing of Important Events

The times of the most significant events of this transient are given in Tables 6.1 (for the best-estimate deck), 6.5 (for the best-estimate deck without the BH Package), and 6.9 (for the NUREG-1150 deck). These tables have been consolidated into Table 6.13, which reveals substantial differences between the calculated results. Both best-estimate decks predict later times than the NUREG-1150 deck for every event with the exception of the "gap release" phase duration, which is slightly longer (by 4 min) for the NUREG-1150 deck. The most significant difference is in the vessel failure time, which is predicted to occur at a later time in the best-estimate deck (with the BH model). This is a direct consequence of the BH model that delays vessel failure until all the water in the lower plenum is vaporized. The vessel failure time of the best-estimate deck is more than twice as long (288 min) when compared to the NUREG-1150 deck (122 min). Comparing the vessel failure times of the two runs without the BH Package model, it can be noticed that the time calculated by the NUREG-1150 deck (122 min) is considerably shorter than the time calculated by the best-estimate deck without BH (184.4 min). Both runs resulted in vessel penetration failure almost

Table 6.13. Comparison of the times of events for the station blackout at Grand Gulf using three different models

Event	Time with best-estimate deck		Time with best-estimate deck without BH		Time with NUREG-1150 deck	
	(min)	(h)	(min)	(h)	(min)	(h)
Core uncovering	31	0.5	31	0.5	29	0.5
Vessel depressurization	59	1.0	59	1.0	48	0.8
Gap release initiation	81	1.4	81	1.4	65	1.1
Gap release ended	120	2.0	120	2.0	109	1.8
Gap release phase duration	39	0.7	39	0.7	43	0.7
Core relocation started	114	1.9	114	1.9	111	1.9
First core plate failure	184	3.1	184	3.1	121	2.0
Vessel failure	288	4.8	184.4	3.1	122	2.0
Early in-vessel release phase duration	168	2.8	64.4	1.1	14	0.2
Containment failure	2,580	43.0	2,534	42.2	2,199	36.7
Time between vessel and containment failures	2,292	38.2	2,349	39.1	2,077	34.6
Calculation ended	2,833	47.2	2,800	46.7	2,642	44.0
Ex-vessel release phase duration	2,545	42.4	2,615	43.6	2,520	42.0

immediately (within 1 min) after core plate failure. While the time of initiation of core relocation is very similar for both runs (114 and 111 min) the times of core plate failure are very different (184 and 121 min for the best-estimate without BH and the NUREG-1150 deck, respectively). Thus, the core plate of the NUREG-1150 deck fails earlier than in the best-estimate decks. This earlier core plate failure is a consequence of the reduced heat capacity of the core plate and the lower plenum steel in contact with the core plate of the NUREG-1150 deck. The steel mass of the core plate is 36,676 lb (16,636 kg) in the best-estimate deck and only 24,608 lb (11,162 kg) in the NUREG-1150 deck. The lower plenum steel is 205,054 lb (93,011 kg) in the best-estimate deck and only 72,625 lb (32,942 kg) in the NUREG-1150 deck. There is also less steel in the core of the NUREG-1150 deck and reduced penetration masses. Table 5.3 compared these values. Therefore, the *shorter time to vessel failure* calculated by the NUREG-1150 deck is a consequence of the absence of the *BH Package model* and the *reduced steel inventory* in the core, core plate, and lower plenum. Because of the earlier predicted vessel failure, the "early in-vessel" release phase calculated for the NUREG-1150 deck is very short, only 14 min, compared to 64.4 min for the best-estimate deck without BH and 168 min for the best-estimate deck.

Results from the Grand Gulf short-term station blackout study documented in Ref. 7, which were obtained using the BWRSAR[8,9] and the BWR-LTAS[10] codes, are presented in Table 6.14 and compared to the results obtained with the best-estimate deck (Sect. 6.1) and the NUREG-1150 deck (Sect. 6.3). The BWRSAR/BWR-LTAS results are closer to the results obtained by MELCOR with the best-estimate deck. The best-estimate deck predicts a shorter time for core uncovery (31 min) and ADS depressurization (61.2 min) than Ref. 7 (42 and 75 min) but longer times for the other events.

The differences in the calculated containment failure times for the three runs of Table 6.13 are not significant. The NUREG-1150 calculated containment failure time is shorter (by about 3 h) than the time calculated by the two best-estimate decks. This shorter time may be a consequence of the more detailed model of the containment in the best-estimate decks. The calculated containment failure time for the NUREG-1150 deck is conservative, because it occurs earlier than in the best-estimate decks.

6.4.3 Comparison of Source Terms

The in-containment source terms are presented in Table 6.2 for the best-estimate deck, in Table 6.6 for the best-estimate deck without BH, and in Table 6.10 for the NUREG-

Table 6.14. Comparison of the time of events for the station blackout with two MELCOR decks and results from Ref. 7

	Time with best-estimate deck		Time with NUREG-1150 deck		Results from Ref. 7	
Event	(min)	(h)	(min)	(h)	(min)	(h)
Core uncovering	31	0.5	29	0.5	42.0	0.7
Vessel depressurization	59	1.0	48	0.8	75.0	1.25
Gap release initiation	81	1.4	65	1.1		
Gap release ended	120	2.0	109	1.8		
Gap release phase duration	39	0.7	43	0.7		
Core relocation started	114	1.9	111	1.9	106.9	1.8
First core plate failure	184	3.1	121	2.0	111.0	1.85
Vessel failure	288	4.8	122	2.0	218.2	3.6
Early in-vessel release phase duration	168	2.8	14	0.2		
Containment failure	2,580	43.0	2,199	36.7		
Time between vessel and containment failures	2,292	38.2	2,077	34.6		
Calculation ended	2,833	47.2	2,642	44.0		
Ex-vessel release phase duration	2,545	42.4	2,520	42.0		

1150 deck. There are substantial differences in these results. The "total" in-containment source terms calculated by the three models are compared in Table 6.15. The values calculated by the NUREG-1150 deck are larger than the values calculated by the best-estimate deck for all classes except for Class 1 (noble gases), class 2 (Cs), class 6 (Ru), class 10 (U), and class 16 (CsI). The differences for classes 1 and 6 are minimal, the difference for class 2 is 24%; for class 10, 850%; and for class 16, 27%; all are larger in the best-estimate deck than in the NUREG-1150 deck.

Very large release "total" fractions (almost 100%) are predicted in the NUREG-1150 deck for classes 7 (Mo), 11 (Cd), and 12 (Sn). These releases occur in the "ex-vessel" release phase (Table 6.10). Also, significant "total" releases are predicted for class 3 (with 61%), and for class 8 (with 14%) in the NUREG-1150 deck. The best-estimate deck does not predict these large releases for classes 3, 7, 8, 11, and 12. However, the best-estimate deck without BH also predicts these large releases which seems to be a consequence of use the BH Package. The "total" in-containment source terms for classes 2 (Cs) and 16 (CsI) are very similar for the two best-estimate decks. Thus, the discrepancies between the best-estimate and the NUREG-1150 deck results for classes 2 and 16 are not due to use of the BH Package but to other model differences. Large discrepancies between the results of the best-estimate and the NUREG-1150 decks appear for classes 3, 7–12.

The NUREG-1150 deck predicts larger releases (by a factor of 3) of nonradioactive aerosols into containment than does the best-estimate deck. The amount of aerosols released by the best-estimate deck without BH is a value in between the amounts calculated by the other two models (Table 6.15).

The results are compared now by release phase. Table 6.16 compares the "gap" in-containment source terms. Most of the "gap" releases of the NUREG-1150 deck are larger than the corresponding releases of the best-estimate decks (except for class 5). The longer duration of this phase for the NUREG-1150 model is the main cause of these larger source terms.

The "early in-vessel" in-containment source terms are compared in Table 6.17. As expected, because the "early in-vessel" release phase of the NUREG-1150 model is very short (14 min) compared to the same release phase for the best-estimate deck (178 min) or for the best-estimate deck without BH (64.4 min), smaller "early in-vessel" releases are predicted for the NUREG-1150 deck. However, for two classes (3 and 12) the NUREG-1150

Table 6.15. Total in-containment source terms calculated by MELCOR using three different models for Grand Gulf station blackout

Class	Element	Best-estimate	Best-estimate without BH	NUREG-1150
		Fraction	Fraction	Fraction
1	Noble gases	0.9999	0.9977	0.9997
2	Cs	0.8628	0.8480	0.6936
3	Ba, Sr	0.1180	0.3272	0.6117
4	I	-	-	-
5	Te	0.6571	0.6967	0.7283
6	Ru	0.0001	0	0
7	Mo	0	0.9335	0.9970
8	Ce	0.0017	0.0440	0.1372
9	La	0.0001	0.0013	0.0040
10	U	0.0034	0.0003	0.0004
11	Cd	0.0149	0.9936	0.9967
12	Sn	0.2203	0.9091	0.9686
15	Concrete Aerosols (kg)	2,845	5,083	8,131
16	CsI	0.8864	0.8866	0.6981

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories of fission products.
Class 15 releases are in kg.
No releases of class 4 (I) are predicted since class 4 combines with class 2 (Cs) to form class 16 (CsI).

Table 6.16. Gap release in-containment source terms calculated by MELCOR using three different models

Model		Best-estimate	Best-estimate without BH	NUREG-1150
Duration	(min)	39	39	43
	(h)	0.7	0.7	0.7
Class	Element	Fraction	Fraction	Fraction
1	noble gases	0.1442	0.1456	0.3871
2	Cs	0.1422	0.1453	0.2517
3	Ba, Sr	0	0	0.0002
4	I	-	-	-
5	Te	0.0368	0.0400	0.0100
6	Ru	0	0	0
7	Mo	0	0	0
8	Ce	0	0	0
9	La	0	0	0
10	U	0	0	0
11	Cd	0	0	0
12	Sn	0.0007	0.0007	0.0025
16	CsI	0.1138	0.1155	0.2283

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted. Class 4 (I) releases are combined with class 2 (Cs) to form class 16 (CsI).

Table 6.17. Early in-vessel in-containment source terms calculated by MELCOR using three different models

Model		Best-estimate	Best-estimate without BH	NUREG-1150
Duration	(min)	168	64.4	14
	(h)	2.8	1.1	0.2
Class	**Element**	**Fraction**	**Fraction**	**Fraction**
1	noble gases	0.8315	0.7733	0.4405
2	Cs	0.4800	0.4203	0.2203
3	Ba, Sr	0.0026	0.0018	0.0058
4	I	-	-	-
5	Te	0.5592	0.5098	0.3263
6	Ru	0	0	0
7	Mo	0	0	0
8	Ce	0	0	0
9	La	0	0	0
10	U	0	0	0
11	Cd	0	0	0
12	Sn	0.0304	0.0216	0.0423
16	CsI	0.4977	0.4356	0.2262

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted. Class 4 (I) releases are combined with class 2 (Cs) to form class 16 (CsI).

deck predicts larger releases than the best-estimate decks. The "early in-vessel" source terms of the best-estimate deck without BH are values in between the results of the other two models in accordance to the duration of this phase for the three models.

The "ex-vessel" source terms are compared in Table 6.18. The "ex-vessel" releases are larger for the NUREG-1150 deck, except for classes 6 and 10.

When comparing the two models without the BH input, it is apparent that very similar results are calculated for classes 7, 10–12. Therefore, use of the BH Package (or the lack of it) appears to cause large discrepancies between the "ex-vessel" source terms for these classes between the best-estimate and the NUREG-1150 models.

Finally, the "late in-vessel" releases are compared in Table 6.19. The "late in-vessel" source terms for classes, 1, 3, and 12 are larger for the NUREG-1150 deck results than for the other decks. The source terms for the remaining classes are larger for the best-estimate deck without BH. When comparing the best-estimate and the NUREG-1150 deck results, classes 2 and 16 releases are larger for the best-estimate deck, and the remaining class (1, 3, 5, and 12) releases are larger for the NUREG-1150 deck.

Overall, the majority of the source terms calculated by the NUREG-1150 deck are larger than their equivalent source terms calculated by the best-estimate deck. Therefore, the majority of the NUREG-1150 deck calculated source terms are conservative. However, some source terms calculated by the best-estimate deck are larger than their corresponding source terms of the NUREG-1150 deck. The larger source terms for the best-estimate deck are the following: "total" source terms of classes 2, 10, and 15; "gap" source terms of class 5; "early in-vessel" source terms of classes 1, 2, 5, and 16; "ex-vessel" source terms of class 10; and, "late in-vessel" source terms of classes 2 and 16.

Table 6.20 presents some values calculated by the three models at the end of the calculation. The best-estimate deck without BH has a larger inventory of fuel remaining in the core (about 13.7%) than the other two models. This model did not predict failure of core plate 4; the other two models did. Consequently, the fuel of radial ring 4 remained in the core in the best-estimate deck without BH. The reason for this different result is not known. Finally, the amount of in-vessel hydrogen calculated by the best-estimate model is larger than that calculated by the other models because the BH model kept the fuel longer in the lower plenum (with water) producing more hydrogen.

Table 6.18. Ex-vessel in-containment source terms calculated by MELCOR using three different models

Model		Best-estimate	Best-estimate without BH	NUREG-1150
Duration	(min)	2,545	2,615	2,520
	(h)	42.2	43.6	42
Class	Element	Fraction	Fraction	Fraction
1	noble gases	0.0236	0.0615	0.1228
2	Cs	0.0224	0.0593	0.1192
3	Ba, Sr	0.1154	0.3252	0.6050
4	I	-	-	-
5	Te	0.0248	0.0660	0.3238
6	Ru	0.0001	0	0
7	Mo	0	0.9335	0.9970
8	Ce	0.0017	0.0440	0.1372
9	La	0.0001	0.0013	0.0040
10	U	0.0034	0.0003	0.0004
11	Cd	0.0149	0.9336	0.9967
12	Sn	0.1892	0.8868	0.9173
16	CsI	0.0236	0.0619	0.1237

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted. Class 4 (I) releases are combined with class 2 (Cs) to form class 16 (CsI).

Table 6.19. Late in-vessel in-containment source terms calculated by MELCOR using three different models

Model		Best-estimate	Best-estimate without BH	NUREG-1150
Duration	(min)	2,545	2,615	2,520
	(h)	42.4	43.6	42
Class	Element	Fraction	Fraction	Fraction
1	noble gases	0.0006	0.0173	0.0493
2	Cs	0.2182	0.2249	0.1024
3	Ba, Sr	0	0.0002	0.0007
4	I	-	-	-
5	Te	0.0363	0.0809	0.0682
6	Ru	0	0	0
7	Mo	0	0	0
8	Ce	0	0	0
9	La	0	0	0
10	U	0	0	0
11	Cd	0	0	0
12	Sn	0	0	0.0065
16	CsI	0.2513	0.2736	0.1199

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted. Class 4 (I) releases are combined with class 2 (Cs) to form class 16 (CsI).

Table 6.20. Values calculated by the three models at the end of the calculation

Variable	Best-estimate	Best-estimate without BH	NUREG-1150
Total calculation time, h	47.2	46.7	44.0
Fuel left in core region, kg	1,997	21,879	783
Initial inventory, %	1.3	13.7	0.5
In-vessel hydrogen produced			
Core, kg	295	324	330
BH, kg	395	-	-
Total, kg	660	324	330

The source terms released into the environment are presented in Table 6.3 for the best-estimate deck, in Table 6.7 for the best-estimate deck without BH and in Table 6.11 for the NUREG-1150 deck. Comparison of the environmental source terms from the three models at about the same time after containment failure is presented in Table 6.21. The NUREG-1150 deck predicts larger releases than the best-estimate decks except for classes 2 and 16. At least two reasons account for these differences. First, the NUREG-1150 deck predicts larger "total" in-containment source terms (except for classes 2 and 16). Second, the NUREG-1150 deck does not model the enclosure building, which retains about 7% of the noble gases (Table 6.4). Perhaps the presence of the enclosure building also serves to retain 8.4% of the noble gases inside the wetwell of the best-estimate deck (Table 6.4) vs only 0.2% in the wetwell of the NUREG-1150 deck (Table 6.12).

The environmental releases of classes 1 and 5 are very similar for the two best-estimate decks which indicates that these releases are independent of the use of BH model.

Table 6.21. Source term calculated by MELCOR released into environment for Grand Gulf using three different models

Model		Best-estimate	Best-estimate without BH	NUREG-1150
Duration	(s)	15,173	15,981	14,989
	(min)	253	266	250
	(h)	4.2	4.4	4.2
Class	Element	Fraction	Fraction	Fraction
1	Noble gases	0.8460	0.8456	0.9967
2	Cs	0.0100	0.0047	0.0043
3	Ba, Sr	1.2×10^{-6}	1.2×10^{-5}	3.3×10^{-5}
4	I	-	-	-
5	Te	0.0028	0.0022	0.0136
6	Ru	1.6×10^{-10}	4.7×10^{-8}	1.2×10^{-7}
7	Mo	2.9×10^{-10}	0.0011	0.0259
8	Ce	8.2×10^{-8}	1.3×10^{-7}	2.5×10^{-6}
9	La	8.2×10^{-8}	1.4×10^{-7}	6.4×10^{-7}
10	U	8.8×10^{-8}	8.6×10^{-6}	2.6×10^{-5}
11	Cd	5.1×10^{-5}	0.0086	0.0800
12	Sn	4.1×10^{-6}	0.0019	0.0316
16	CsI	0.0135	0.0063	0.0049

Notes: All fractions are from the initial inventories of fission products, except for classes 2 and 16 that are from the final inventories.
No releases of class 4 (I) are predicted since this class combines with class 2 (Cs) to form class 16 (CsI).

However, the releases for classes 2, 3, 7, 11, 12, and 16 are very similar for the two decks without the BH Package, which indicates these releases are dependent on the BH Package. A similar trend was found for the "total" in-containment source terms of Table 6.15.

6.4.4 Summary of Results Comparison

Substantial differences have been found between the station blackout results of the best-estimate deck and the NUREG-1150 deck. The NUREG-1150 deck predicts shorter times for almost all of the important events and larger source terms (with some exceptions) than does the best-estimate deck. The best-estimate deck predicts substantially larger "total" in-containment source terms for classes 2 (Cs), 10 (U), and 16 (CsI); larger "gap" release for class 5 (Te); larger "early in-vessel" releases for classes 1 (noble gases), 2 (Cs), 5 (Te), and 16 (CsI); larger "ex-vessel" releases for class 10 (U); and larger "late in-vessel" releases for classes 2 (Cs) and 16 (CsI) than the NUREG-1150 deck. The environmental source terms of class 2 (Cs) and 16 (CsI) are also larger for the best-estimate deck. Therefore, if shorter times and larger source terms are considered "conservative," the NUREG-1150 deck results are in general "conservative," with the exceptions mentioned.

The main causes of these different results have been identified in the following NUREG-1150 deck deficiencies: absence of the BH model, reduced inventory of steel in the core and lower plenum, and absence of detail in the containment model, in particular, absence of the enclosure building.

7. INJECTION RECOVERY SEQUENCES

7.1 GENERAL

Several injection recovery sequences have been run with the MELCOR code using the best-estimate deck to investigate the effects of water injection into the reactor vessel, assuming that power is recovered after the onset of core degradation during the station blackout accident sequence. All of the injection recovery sequences were initiated after core relocation occurred (at about 6,850 s into the transient). At this time, the vessel is depressurized (that occurred at 3,541 s) to a pressure slightly above containment pressure, about 25 psia (0.17 MPa).

The Grand Gulf Nuclear Station has several ECCSs and other systems capable of injecting water into the vessel. The injection characteristics for these systems are listed in Table 7.1. For the purposes of this study, it is assumed that the control room operators will take action to manually control the vessel injection rate once ac power is restored. Specifically, it is assumed that one residual hat removal (RHR) pump in the low-pressure coolant injection (LPCI) mode is selected to inject water into the core up to a rate of 7,450 gal/min (470 L/s) for the injection recovery sequences considered here. The injection is initiated when the vessel is at low pressure, about 25 psia (0.17 MPa). The injection time has been varied to investigate when (after core relocation) the core can be recovered so that vessel failure is avoided.

A low mass flow rate of water injection (between 10 and 15 kg/s) was simulated using the control rod drive hydraulic system pumps (Table 7.1).

Section 7.2 presents the results calculated by MELCOR for these injection recovery sequences. Section 7.3 investigates the possibility of a pressure spike inside the vessel during the water injection phase due to large steam production. Section 7.4 investigates the possibility of achieving recriticality in the core when unborated water is injected. Finally, Sect. 7.5 summarizes all the results.

7.2 RESULTS

A total of 21 water injection recovery cases have been run and their results are presented in Table 7.2. The *first two columns* and the *last line* of Table 7.2 show the events and

Table 7.1. ECCS and other injection systems of the Grand Gulf Nuclear Station

System	Pressure	Flow	Runout Flow
High-pressure core spray (HPCS)	1,147 - 200 psia (7.89 - 1.5 MPa)	1,650 - 7,115 gal/min (104 - 449 L/s)	9,100 gal/min (574 L/s)
Low-pressure core spray (LPCS)	128 psia (0.98 MPa)	7,115 gal/min (449 L/s)	
Standby liquid control system (SLCS)	1,280 psia (8.9 MPa)	86 gal/min (5.5 L/s)	
Reactor core isolation cooling (RCIC)	1,200 psia (8.4 MPa)	800 gal/min (50.5 L/s)	
Residual heat removal (RHR)	25 psia	3 x 7,450 gal/min	3 x 8,940 gal/min
Low-pressure coolant injection (LPCI)	(0.27 MPa)	(3 x 470 L/s)	(3 x 564 L/s)
Control rod (CR) pumps	1,280 psia (8.9 MPa)	2 x 96 gal/min (2 x 6 L/s)	

Note: The CR pumps and the RCIC System are not part of the ECCS but they may be used for water injection into the reactor vessel.

Table 7.2. Injection recovery sequences run with MELCOR for the Grand Gulf plant

Base case event	Occurred at time (min)	Water injection at (min)	Mass flow rate (kg/s)	Injected into	Pressure spike (MPa)	Pressure spike (psia)	H_2 generated (kg)	Accident terminated
Control blade relocation	92							
Fuel rod relocation	114							
		117	467.6	Core	-		120	Yes[a]
		183	467.6	Core	4.8	(700)	264	Yes[b]
Core plate 1 failure	184							
		184.1	467.6	Core	4.8	(700)	265	Yes[c]
Core plate 2 failure	192.8							
		193	467.6	Core	1.0	(150)	298	Yes[d]
Core plate 3 failure	268							
		268.3	467.6	Core	0.34	(50)	378	Yes[e]
		283	15	Core	-		610	No[c,f,g]
		283	467.6	Core	-		388	No[c,g,h]
LP dryout and penetration failure	288							
		342	15	LP by BH	-		752	No[c,g]
		342	467.6	LP by BH	-		868	No[c,g]
		345	15	LP by BH	-		724	No[c,g]
		344.8	467.6	LP by BH	-		789	No[e,g]

Table 7.2. (Continued)

Base case event	Occurred at time (min)	Water injection at (min)	Mass flow rate (kg/s)	Injected into	Pressure spike (MPa)	Pressure spike (psia)	H_2 generated (kg)	Accident terminated
		345	467.6	LP by BH	-		975	No[g,i]
Core plate 4 failure	345.1							
		345.2	467.6	LP by BH	-		972	No[g]
		346.3	15	LP by BH	-		858	No[g]
		450	10	LP by BH	-		710	No[g]
		450	467.6	LP by BH	-		750	No[g]
		452	10	LP by BH	-		691	No[j]
		452	467.6	LP by BH	-		690	No[k]
		458.3	10	LP by BH	0.7	(100)	640	No[l]
		458.3	467.6	LP by BH	1.37	(200)	652	No[m]
Lower head failure	465							
Calculation ended	500	**Base case**	0	-	-		689	No

NOTES
LP: Lower plenum
BH: Lower Plenum Bebris Bead Package of MELCOR

[a]None of the four core plates failed
[b]Only core plate 1 failed at 184 min
[c]Core plates 2, 3, and 4 did not fail
[d]Core plates 3 and 4 did not fail
[e]Core plate 4 did not fail
[f]Penetration failed at 289 min
[g]Lower head did not fail
[h]Penetration failed at 291 min
[i]Core plate 4 failed at 345 min
[j]Lower head failed at 473 min
[k]Lower head failed at 458.5 min
[l] Lower head failed at 497.7 min
[m]Lower head failed at 467 min

timing of the *base case* station blackout without water injection. (These are the times of Table 6.1.) These *two columns* provide reference for key events against which the water injection times of the recovery cases can be compared. The third column shows the timing of water injection for the recovery cases. The fourth column shows the mass flow rate of water injected. The fifth column provides the location where the water is injected. The sixth column indicates the pressure spike in the vessel calculated from the water injection. The seventh column shows the amount of in-vessel hydrogen generated, and finally, the last column indicates the success of the water injection recovery in terminating the accident. All of the water injection cases were started after fuel relocation [(that occurred at 114 min (6,850 s)] but before lower head failure [(that occurred at 465 min (27,918 s)]. After lower head failure, all the debris in the lower plenum is transferred to the cavity below. Water injected into the vessel after lower head failure is also transferred directly to the cavity without providing any cooling to the vessel. On the other hand, a large portion of the water injected into the vessel after penetration failure [(that occurred at 288 min (17,272 s)] but before lower head failure remains in the vessel (the water leaving through the failed penetrations is a function of the size and number of penetrations failed.)

For the first injection recovery case, water was injected at 117 min, about 3 min after fuel relocation started but before the first core plate failure. Although some core degradation had already occurred at 117 min, no debris had entered the vessel lower plenum. The mass flow of water injected, 7,450 gal/min (equivalent to 470 L/s or 467.6 kg/s) at a temperature of 80° F (300 K) was kept constant until the vessel was filled to the normal water level. Afterward, the mass flow rate was reduced to about 160 gal/min (10 kg/s) to replace the water boiled off by the decay heat of the fuel. The water inside the vessel cooled the fuel to saturation temperature at about 167 min, accident time, (50 min after water injection initiation), precluding both core plate and vessel failure and terminating the accident sequence.

The second injection recovery case considered the same mass flow of injected water (7,450 gal/min or 467.6 kg/s) as the first recovery case, but it was started at a later time. For the base case without water injection, the central ring of the core plate is predicted to fail at 184 min (11,017 s). For the second injection recovery case, water injection was started at 183 min (11,000 s).

As a result of the water injection in this second recovery case, the initial core plate failure occurred 13 s later than in the base case without water injection. The core was completely cooled at 250 min, accident time (67 min after the injection was initiated). The core plate of the remaining three rings never failed, the vessel did not fail, and the accident was terminated. There was, however, fuel debris in the lower plenum after failure of the central core plate region. In the previous case, with water injected at 117 min (7,000 s) debris never fell to the lower plenum. For both cases, fuel melting occurred, with a larger extent of fuel melting in the case with the later water injection.

When water injection is initiated after 269 min, vessel failure (via penetration failure) cannot be prevented. When the water injection is initiated on or before 268.3 min (16,100 s), vessel failure is prevented and the accident is terminated.

Lower plenum dryout is predicted to occur at 288 min (17,272 s) for the base case without water injection. At this time, the BH Package of MELCOR becomes active to represent the lower plenum debris bed and its interaction with the reactor vessel bottom head. For injection recovery sequences with water injected after this time, the injection characteristics were specified as part of the BH Package input.

The injection characteristics are specified separately when the BH Package is used because the debris bed response models address only the lower plenum debris bed. There are no core package debris response models to address the effects of reflood water on the debris in the core region. Thus, it is important to recognize that if the postulated water injection rate is sufficient to cool the lower plenum debris bed, fill the remainder of the lower plenum, and ultimately cause the water level to rise into the core region, the effects of this water in the core region will not be calculated by MELCOR.

Another important point is that the temperature of the lower plenum debris at the time of dryout is sufficiently high that penetration failures are predicted to occur immediately. Although the predicted failure of the instrument guide tube structure within the bed is straightforward, real question arises as to the fate of the guide tube walls ex-vessel.

For the BH Package of MELCOR, the question of penetration failures as a viable escape pathway for the debris liquids is to be determined by user input. For the calculations reported here, it has been assumed that ex-vessel tube wall failures would occur. In other words, debris liquids have an escape pathway before there is gross failure of the bottom head wall.

The results listed in Table 7.2 show the following trends:

1. Vessel failure can be prevented if water is injected into the vessel on or before 268.3 min (16,100 s). This is about 2 1/2 h after fuel relocation began. Although there will be significant core damage with significant portions of the fuel melted and relocated, the injected water provides stable core cooling, and vessel failure is prevented. Lower plenum dryout does not occur, and the BH Package is never called. Once the core is completely cooled, the severe accident sequence is terminated.
2. If water is injected after lower plenum dryout and penetration failure (at 288 min or 17,272 s) but before 452 min (27,100 s), the water injection will prevent lower head gross failure (predicted to occur in the base case without injection at 465 min or 27,918 s). However, the vessel has already failed via penetration failures.
3. The earlier water injection is initiated, the less core damage before the accident is recovered, and, consequently, the less hydrogen is produced in the sequence. When different mass flow rates of water are used, less hydrogen is produced when larger mass flow rates of water are injected into the vessel (Table 7.2) if the injection is initiated before 283 min. For later water injection, after 342 min, MELCOR results indicate that more hydrogen is produced in those cases with larger mass flow rates. All of the calculations of Table 7.2 were terminated at 500 min; the amount of hydrogen generated in all the cases, including the base case without injection, was computed at that time. For comparison, the base case without injection, generated 689 kg of hydrogen at 500 min. This amount is larger than that generated for cases with water injection initiated on or before 283 min, but is smaller than that generated in most of the cases with water injection initiated after 342 min.
4. The source terms released into containment for the cases with complete recovery are smaller than in the station blackout base case without injection. Once the core is flooded and cooled, the release of fission products stops. The in-containment source terms for the case with water injection at 183 min are presented in Table 7.3. Only two release phases occurred in this sequence: "gap" and "early-in-vessel". The "gap" release phase is identical to the base case presented in Table 6.2; it started at 81 min (4,860 s) and ended at 120 min (7,183 s) with a duration of 39 min (2,323 s). Water injection was initiated after the "gap" release phase was ended. Therefore, the "gap" release phase is the same for the water injected or noninjected cases. The "early-in-

Table 7.3 Source terms released into containment for the case with water injection at 183 min

	Phase	Gap release	Early in-vessel	Total	Total releases for the base station blackout without water injection
	Duration (min)	39	380	419	2,752
	(h)	0.7	6.3	7.0	45.9
Class	Element	Fraction	Fraction	Fraction	Fraction
1	Noble gases	0.1442	0.7937	0.9379	0.9999
2	Cs	0.1422	0.4472	0.5894	0.8628
3	Ba-Sr	0	0.0024	0.0024	0.1180
4	I	-	-	-	-
5	Te	0.0368	0.5329	0.5697	0.6571
6	Rn	0	0	0	0.0001
7	Mo	0	0	0	0
8	Ce	0	0	0	0.0017
9	La	0	0	0	0.0001
10	U	0	0	0	0.0034
11	Cd	0	0	0	0.0149
12	Sn	0.0007	0.0276	0.0283	0.2203
16	CsI	0.1138	0.4666	0.5804	0.8864

Note: No releases of class 4 (I) are predicted since the released class 4 (I) combines with class 2 (Cs) to form class 15 (CsI).

vessel" release phase was started at 120 min (7,183 s), when the "gap" release phase ended, and was ended at 500 min when the calculation was terminated. However the release of fission products was terminated at about 250 min when the core was completely cooled. Vessel failure never occurred. Consequently, the "early in-vessel" releases are smaller in this recovered case than in the base case (shown in Table 6.2). No "ex-vessel" or "late in-vessel" releases occurred in the recovered case. The "total" releases are the summation of only the "gap" and "early in-vessel" releases, and they are smaller than the "total" releases of the base station blackout case of Table 6.2, also shown in the last column of Table 7.3.

5. Large pressure spikes in the vessel due to water injection were not calculated for any of the cases of Table 7.2 (column 6). This subject is covered in more detail in Sect. 7.3.
6. When the BH Package is used for reflooding, the water is injected into the lower plenum. Once the lower plenum is full, the excess water is lost instead of getting into the core region and cooling it. This is a shortcoming of the BH Package-MELCOR interface.

7.3 PRESSURE SPIKES IN THE VESSEL DURING WATER INJECTION

All the runs presented in Table 7.2 did not result in significant pressure increases in the vessel when the water was injected. The maximum calculated pressure of 700 psia (4.8 MPa) for the case when the injection was initiated at 183 min did not pose any threat to the vessel. Only pressures above 3,000 psia (20.6 MPa) could fail the vessel, being the vessel connections to the feedwater lines the weakest points and the most likely locations for vessel failure.

Three MELCOR input parameters affect the pressure resulting from hot debris and water interaction. Two of these parameters are the heat transfer coefficient for in-vessel falling debris to the pool and the velocity of this falling debris. Both parameters are input in card COR00012. The third parameter, used by the BH Package in card BH1300, is the maximum rate at which debris falling from the core region is added to the lower plenum. The recommended value for this parameter used in the best-estimate deck is 2,000 kg/s (4,409 lb/s). This last parameter only applies when the BH Package is active after the lower plenum has dried out. If water is injected into the lower plenum, this parameter controls the amount of debris falling from the core that interacts with the water and produces steam.

The first two parameters were varied for the recovery sequence injecting 7,450 gal/min (467.6 kg/s) at 183 min, which is the second case of Table 7.2. The values recommended by ORNL MELCOR development group for these two parameters are 750 W/m^2K (132 $Btu/h{\bullet}ft^2{\bullet}°F$) and 0.1 m/s (0.33 ft/s), respectively. These values are also used in the best-estimate deck. Shortly after water injection is initiated, the core plate of the first ring fails, and debris from this ring falls into the lower plenum where it interacts with water. The results of this sensitivity study are presented in Table 7.4. Using the recommended values for these parameters (750 $W/m^2{\bullet}K$ and 0.1 m/s), the resulting pressure spike was only 700 psia (4.8 MPa). It was observed that by increasing the heat transfer coefficient and/or increasing the debris velocity (up to a limit around 6 m/s), the magnitude of the pressure spike also increases. The vessel "failure" pressure value of 3,000 psia (20.6 MPa) was reached when a heat transfer coefficient of 2,818 $Btu/h{\bullet}ft^2{\bullet}°F$ (16,000 $W/m^2{\bullet}K$) together with a velocity of 19.7 ft/s (6 m/s) were used. The same pressure spike could be obtained if a velocity lower than 6 m/s is used together with a heat transfer coefficient higher than 16,000 $W/m^2{\bullet}K$.

The value of 6 m/s for the debris velocity is a reasonable value. For debris falling 2 m from the core plate to the lower plenum water surface, the free-falling velocity is

$$v = \sqrt{2gh} = \sqrt{(2)(9.8)m / s^2 (2)m} = 6.26\ m / s$$

The value of the heat transfer coefficient is difficult to calculate because the heat transfer coefficient varies with time. First, when the hot debris contacts the water, a <u>film boiling</u> heat transfer coefficient applies. When the debris is quenched, a <u>nucleate boiling</u> heat transfer coefficient applies. Finally, when the debris is cooled and boiling can not be sustained, a single-phase <u>natural convection</u> heat transfer coefficient applies. Heat transfer coefficients for nucleate boiling are very large, larger than the value of 16,000 $W/m^2{\bullet}K$ used in the last case of Table 7.4. However, during the film boiling and natural convection phases, the value of the heat transfer coefficient is much smaller than 16,000 $W/m^2{\bullet}K$. Consequently, the value of the heat transfer coefficient depends on the heat transfer regime that is also a function of the debris

Table 7.4. Effect of the debris/water heat transfer coefficient and debris velocity on vessel pressure for water injection at 183 min

Heat transfer coefficient		Debris velocity		Vessel pressure	
[Btu/h•ft²•°F	(W/m²•K)]	[ft/s	(m/s)]	[psia	(MPa)]
132	(750)	0.33	(0.1)	700	(4.8)
881	(5,000)	0.33	(0.1)	800	(5.5)
1,761	(10,000)	0.33	(0.1)	900	(6.2)
1,761	(10,000)	9.84	(3.0)	1,100	(7.6)
1,761	(10,000)	13.12	(4.0)	1,300	(8.9)
1,761	(10,000)	16.40	(5.0)	1,560	(10.7)
1,761	(10,000)	19.70	(6.0)	2,200	(15.1)
1,761	(10,000)	20.34	(6.2)	2,300	(15.8)
1,761	(10,000)	21.32	(6.5)	2,050	(14.1)
1,761	(10,000)	22.97	(7.0)	1,200	(8.2)
2,642	(15,000)	16.40	(5.0)	2,800	(19.3)
2,642	(15,000)	19.03	(5.8)	2,830	(19.5)
2,642	(15,000)	19.70	(6.0)	2,850	(19.6)
2,642	(15,000)	22.97	(7.0)	2,850	(19.6)
2,818	(16,000)	19.70	(6.0)	3,000	(20.6)

surface temperature. It is difficult to calculate a constant heat transfer coefficient to model these three different heat transfer regimes. Considering that the nucleate boiling phase is shortest and film boiling and natural convection are the predominant heat transfer regimes, the value of 16,000 W/m^2•K is high. Therefore, it seems more appropriate to use an average heat transfer coefficient below 16,000 W/m^2•K. This will result in pressure spikes below 3,000 psia that do not compromise vessel integrity. It seems, therefore, unlikely that a pressure spike would result during the injection of water into the vessel.

The basic station blackout sequence (without water injection) was rerun using the values of 16,000 W/m^2•K and 6 m/s for the debris/water heat transfer coefficient and debris falling velocity, respectively. This basic case also resulted in a pressure spike inside the vessel of about 3,000 psia (20.6 MPa) when the hot debris of core ring 1 fell into the water present in the lower plenum after the core plate of ring 1 failed at 184 min (11,017 s). This indicates that the pressure spike of 3,000 psia (20.6 MPa) calculated by MELCOR is independent of the water injection scenario and is mainly a function of the value of the heat transfer coefficient used.

The value of this heat transfer coefficient in MELCOR should be treated as a parameter that can be varied to model debris/fuel coolant interactions inside the vessel. Since a best-estimate value of this average heat transfer coefficient is difficult to calculate, the MELCOR code can only be used to estimate the steam produced by debris/water interaction.

Finally, the parameter for the maximum rate at which falling debris from the core is added to the lower plenum was increased from 2,000 kg/s (4.409 lb/h), the value used in the best-estimate deck, up to 100,000 kg/s for the case injecting a mass flow rate of water of 467.6 kg/s at 345 min (Table 7.2). The debris of core ring 4 fell into the lower plenum water shortly after injection was initiated and produced steam. However, no significant pressure increases were calculated even when the high value of this falling debris rate parameter (100,000 kg/s) was used.

Thus, pressure spikes that threaten vessel integrity resulting from water injection do not appear to be likely based on the results of this simplified study with MELCOR.

7.4 RECRITICALITY

The material of the control blades (boron carbide and stainless steel) melts before the material of the fuel rods (Zircaloy and uranium dioxide) during the station blackout accident. Consequently, after the core is uncovered, some or many of the control blades may be already melted and relocated onto the core plate while the fuel rods are still standing. If reflooding of the core with unborated water takes place at this moment, recriticality of the core may occur. This section studies this possibility based on MELCOR results.

The MELCOR model divides the core into four concentric rings (Sect. 4.4). The center ring is ring 1 and comprises 56.57% of the core (more than half). This first ring is the largest ring of the core. Ring 2 comprises 20.43% of the core; ring 3, 11.39% (this is the smallest ring); and ring 4, 11.61%. Ring 4 is the outermost radial ring of the core and consequently the coolest and the last to melt. The active core extends from axial level 8 to level 12 (five axial levels) as shown in Fig. 4.4. The control blade material is also located in these five axial levels.

Ring 1, which in addition to being the largest ring is the hottest one, starts melting before the other three rings. The control blade material of this ring starts relocating at 5,500 s (as shown in Fig. 7.1). All the control blade material is relocated onto axial level 7 (above the core plate) at 6,200 s. However, the fuel rods do not relocate until 6,850 s as shown in Fig. 7.2. Figure 7.2 shows the temperature of the Zircaloy cladding of ring 1. At 6,850 s this temperature peaks to 3,320°F (2,100K) and then drops to zero when the cladding collapses.

The control blade material of ring 2 starts relocating at 6,200 s (Fig. 7.3) and ends relocation into axial level 7 at 7,200 s. The fuel rods of ring 2 relocate at 7,500 s (Fig. 7.4).

In ring 3, the control blade material starts relocating at 7,200 s and is completely relocated at 8,500 s (Fig. 7.5). The fuel rods do not relocate until 9,100 s (Fig. 7.6).

Finally, the control blade material of ring 4 (the coolest ring) starts relocating at 9,700 s and ends relocation at 10,200 s (Fig. 7.7). The fuel rods of this ring do not relocate until 11,100 s (Fig. 7.8).

In each ring, the control blade material is melted and relocated well before the fuel rods relocate. The fuel rods of ring 1 do not relocate until 6,850 s (Fig. 7.2). At this time, all the control blades of ring 1 are melted and relocated (Fig. 7.1) as well as most of the control blades of ring 2 (Fig. 7.3). If the core is reflooded with unborated water at around 113 min

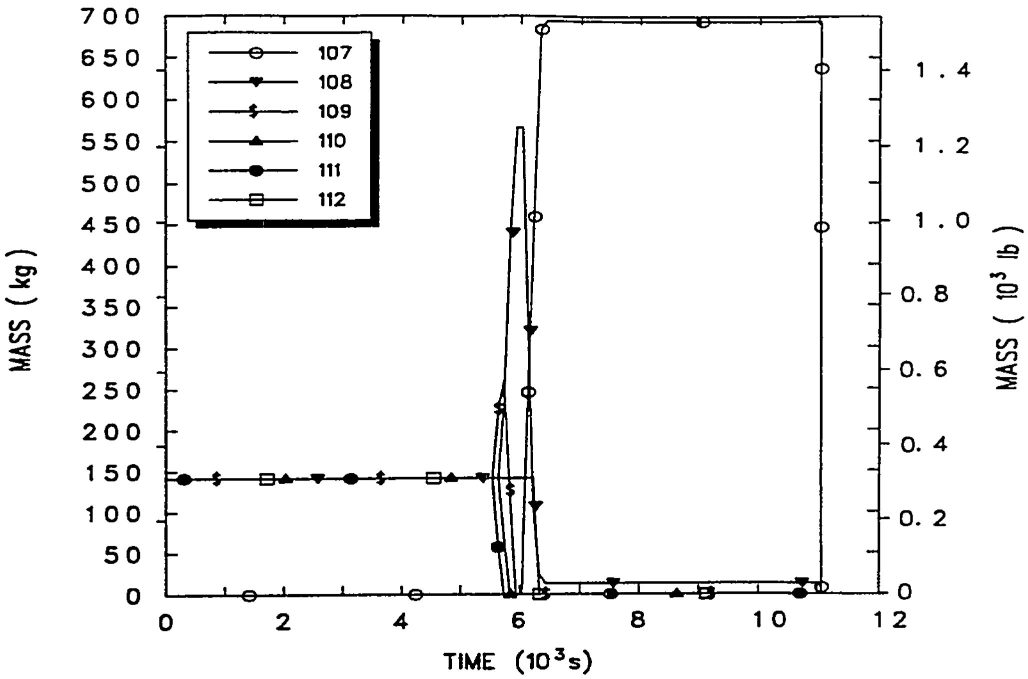

Fig. 7.1 Ring 1 control blade masses

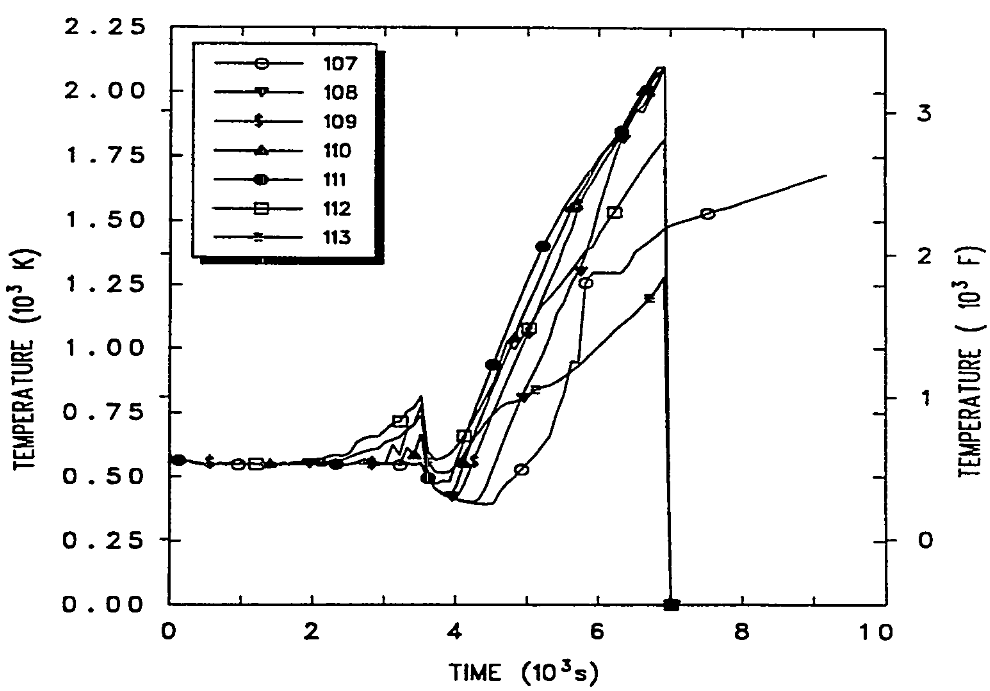

Fig. 7.2 Ring 1 cladding temperatures

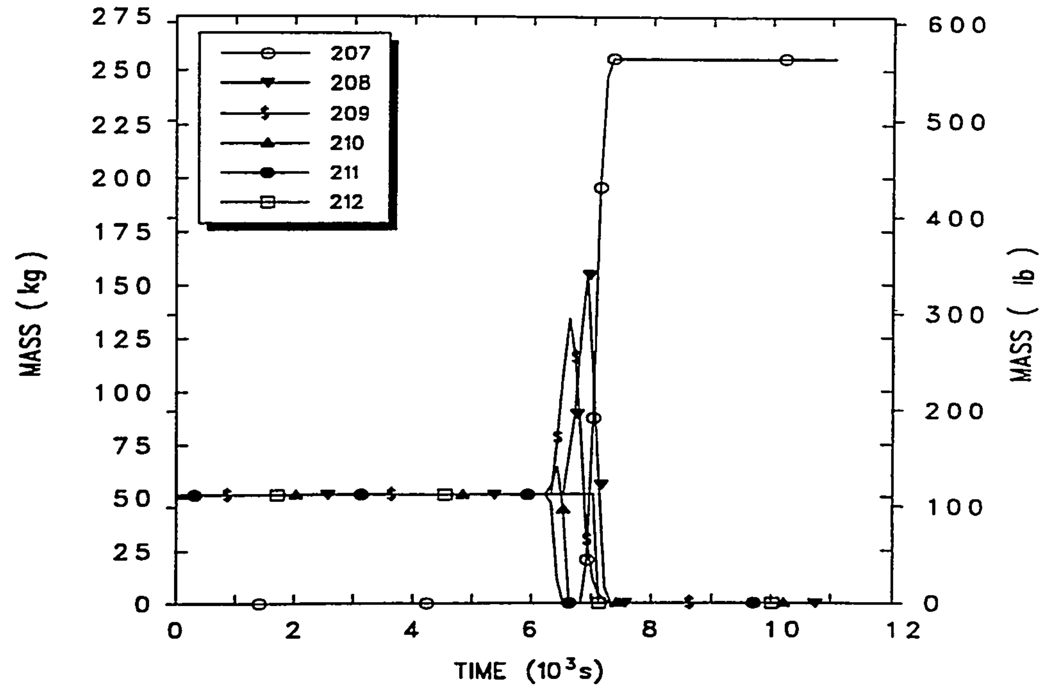

Fig. 7.3 Ring 2 control blade masses

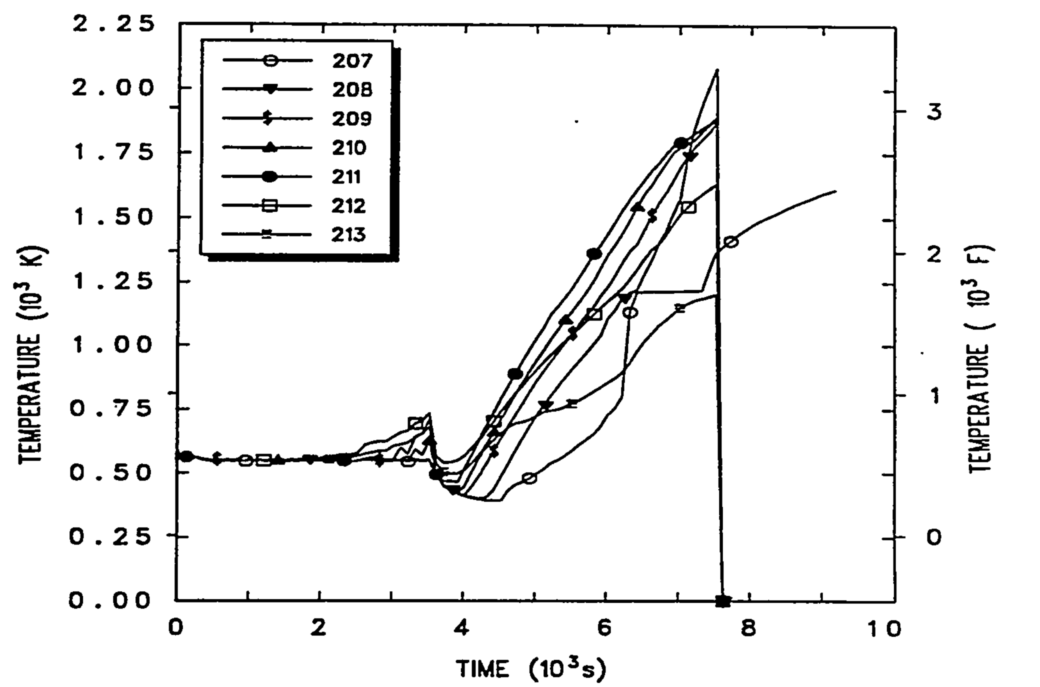

Fig. 7.4 Ring 2 cladding temperatures

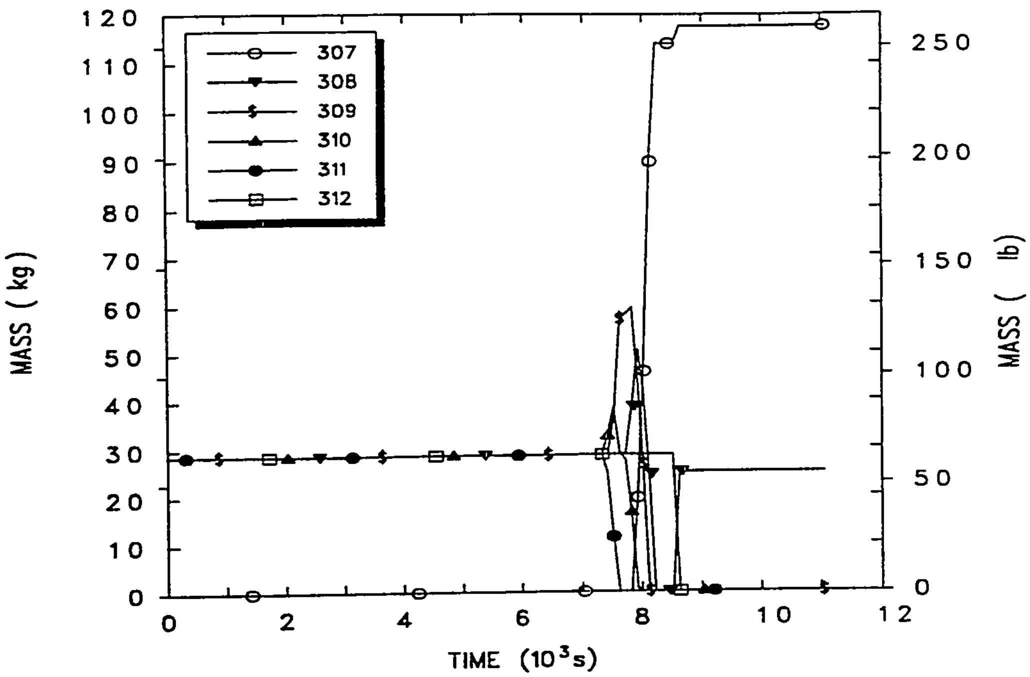

Fig. 7.5 Ring 3 control blade masses

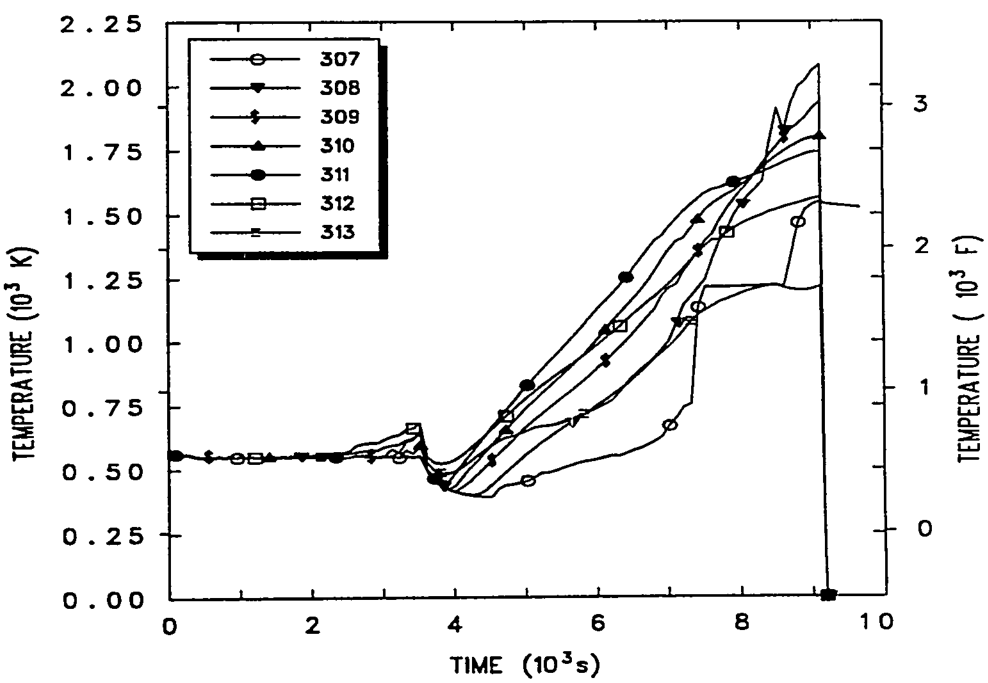

Fig. 7.6 Ring 3 cladding temperatures

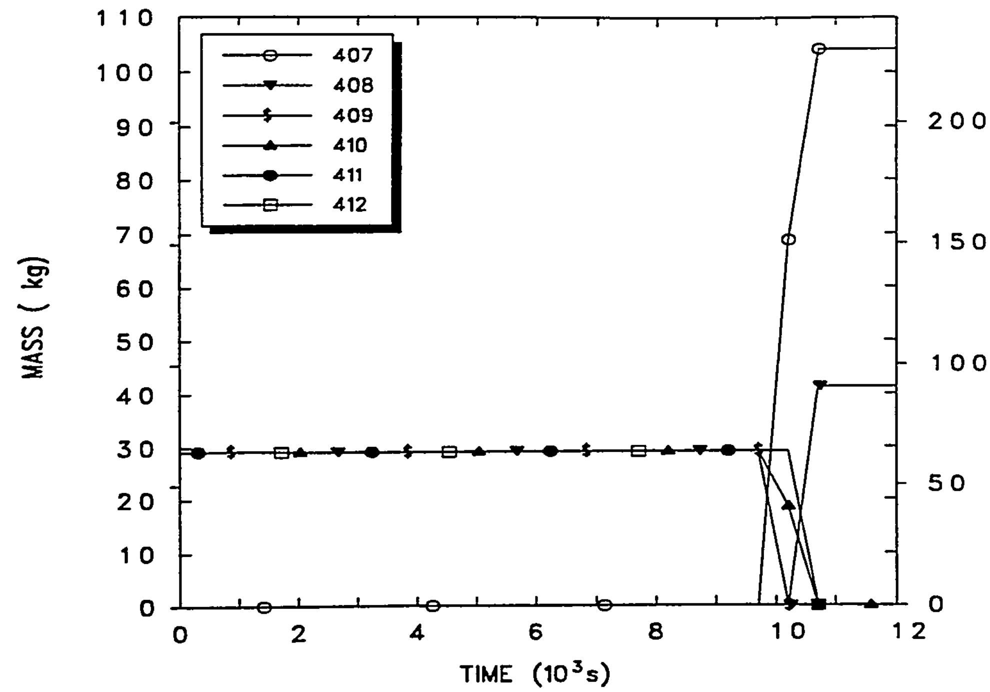

Fig. 7.7 Ring 4 control blade masses

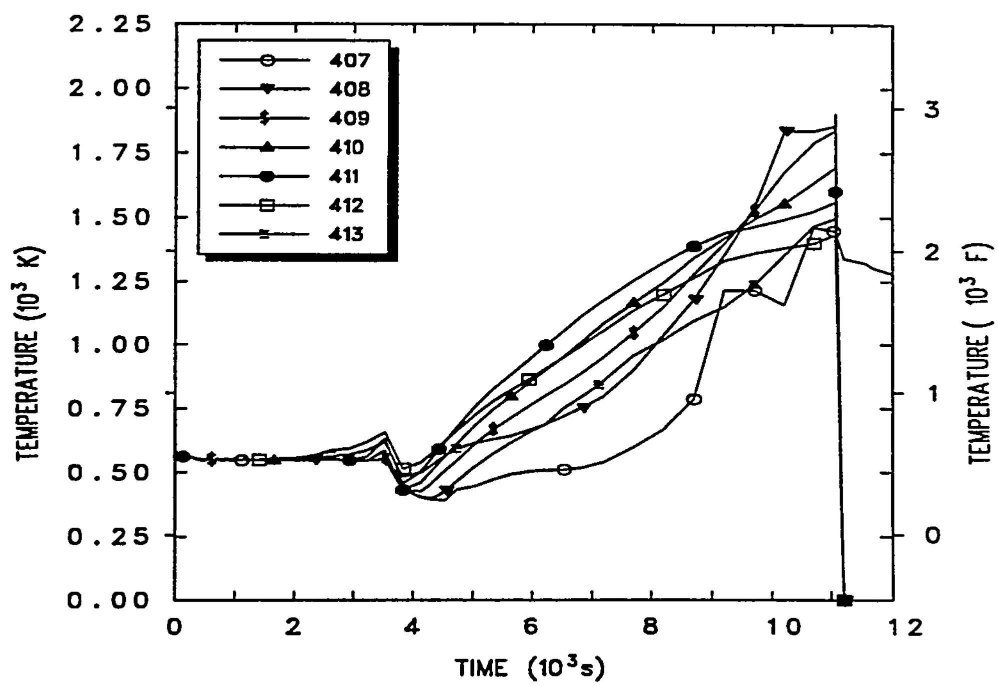

Fig. 7.8 Ring 4 cladding temperatures

(6,800 s), before the fuel rods of ring 1 collapse, there is a chance for recriticality to occur because most of the control blades of rings 1 and 2 are lost. Reflooding after 117 min (7,000 s) is more difficult to characterize because both, control blades and fuel rods, are relocated onto the core plate and probably mixed. Criticality is also possible but not so obvious under these conditions. A criticality code is needed to quantify it.

Reflooding before 103 min or 6,200 s (time when the control blades of ring 2 start relocating) probably will not result in criticality because the control blades of rings 2, 3, and 4 are still intact. A previous study on recriticality during reflood of a BWR[25] also indicated that there is the potential for recriticality in a BWR if core reflood with unborated water occurs after the control blades have started melting but before significant fuel rod melting takes place. Another study[26] concluded that criticality only occurs for void fractions of the coolant below 20% and with more than 95% of the control blades lost. According to this study, recriticality is not possible if the void fraction of the coolant exceeds 20% even if all the control blades are lost. Furthermore, this study indicates that borated water with a concentration of 1,200 ppm of boric acid would prevent recriticality.

In summary, according to these MELCOR results, there are high chances for recriticality when unborated water is injected between 103 and 113 min (6,200 and 6,800 s) after station blackout initiation. If the core is reflooded before 103 min (6,200 s), criticality is unlikely. If reflooded before 92 min (5,500 s), criticality is not possible because the control blades are still intact. For reflood cases after 113 min (6,800 s), criticality is possible, and a criticality code is needed to predict it.

7.5 SUMMARY OF INJECTION RECOVERY SEQUENCES

MELCOR calculations indicate that flooding the core with 7,450 gal/min (467.6 kg/s) of water on or before 268.3 min (16,100 s) after accident initiation will result in core cooling and will prevent vessel failure. The sooner the core is flooded, the less the damage to the core and the smaller the amount of hydrogen produced. Once the core is cooled, the release of fission products stops, and the resulting in-containment source terms are smaller than in the base case without water injection.

Water injection does not appear to result in pressure spikes that can threaten the integrity of the vessel. The injection of unborated water into the core may result in a recriticality event because the control blades melt before the fuel melts. This recriticality event appears to be possible for water injection between 103 and 113 min (6,200 and 6,800 s) after the station blackout initiation. Recriticality is also possible after 113 min (6,800 s) but cannot occur before 92 min (5,500 s). However, a criticality code is needed to precisely quantify this event.

The MELCOR code has proven to be a useful tool to study severe accident management strategies.

8. UNCERTAINTIES

The fully qualified best-estimate MELCOR deck of the Grand Gulf Plant represents accurately the physical variables of the Grand Gulf Nuclear Plant. These physical variables include dimensions, volumes and masses of the different components of the plant. However, some input variables or parameters of MELCOR cannot be obtained directly from actual plant data. These input variables may have uncertainties. Examples of these variables are choice of thermodynamic equilibrium/nonequilibrium model in control volumes, flow form loss coefficients, flow momentum exchange length, heat transfer coefficients, radiative exchange factors, critical thicknesses for debris formation and for other models, eutectic formation parameters, discharge coefficients, fuel and debris porosities, failure temperatures and pressures, failure areas and choice of radionuclide fission product release model. Also a large number of sensitivity coefficients in MELCOR can be changed by user input. In almost all of the input, the default values of these sensitivity coefficients have been used. Considerable effort has been devoted to calculate the best-estimate values for these input variables. However, uncertainties remain.

The values of some of these parameters are different in the best-estimate and in the NUREG-1150 decks. The values chosen for the best-estimate deck are either the best-estimate values of these parameters, or the values required to run the BH Package employed with the best-estimate deck. Table 8.1 lists the input parameters and sensitivity coefficients that are different in the best-estimate and in the NUREG-1150 decks. In addition to the parameters listed in Table 8.1, some flowpaths have different friction factors in both decks. These flowpaths differ also in the areas and lengths. The values chosen for the best-estimate deck are considered more realistic, yielding actual plant pressure drops.

The effect of these different input parameters on the final results of the different MELCOR decks is estimated to be small (second order of magnitude) relative to the effect of the more important differences in some input of physical variables. However, the exact magnitude of this secondary effects is not known. A sensitivity study for these different input parameters would have to be performed to evaluate exactly how much the results are affected.

Table 8.1. Different input parameters employed in the best-estimate and in the NUREG-1150 deck

Parameter	MELCOR Card	Best-estimate	NUREG-1150
Radiative exchange factors	cor00003	0.5, 0.95, 0.5, 0.5, 0.5	0.1, 0.95, 0.01, 1.0, 0.4
Candling heat transfer coefficients, $W/m^2 \cdot K$	cor00005	1,000.0	3,000.0
Lower head heat transfer coefficients, $W/m^2 \cdot K$	cor00009	1,000.0, 1,000.0	500.0, 500.0
Penetration failure temperature, K	cor00009	10,273.15[a]	1,273.15
Quench heat transfer coefficient, $W/m^2 \cdot K$	cor00012	750.0[b]	0
Falling debris velocity, m/s	cor00012	0.1	5.0
Porosity fuel	corzij01	0.53	0.9
Minimum debris porosity for dryout	sc1244-3	0.4	0.15
Solid material radial relocation time, s	sc1020-1	360.0	3.0
Molten material radial relocation time, s	sc1020-2	60.0	1.0
Radiation model for structure	hsxxxxx401	gray-gas-a	equiv-band
Wall emissivity	hsxxxxx401	0.9	0.7
Radiation path length, m	hsxxxxx401	0.1	0.2

[a]This value changed to 1,273.15 for the best-estimate deck without BH.
[b]This value changed to 0 for the best-estimate deck without BH and without debris/water quench.

The largest uncertainties in the input parameters and models employed in the best-estimate deck have been identified in (1) predicting pressure spikes in the vessel during water injection, (2) source term calculations due to the fission product release model used, and (3) containment failure pressure and location.

8.1 UNCERTAINTIES IN PREDICTING PRESSURE SPIKES

Three input variables control the amount of steam produced in the lower plenum when hot debris and water interact as previously discussed in Sect. 7.3. These parameters are: the heat transfer coefficient for in-vessel falling debris to the pool, the velocity of the falling debris and the maximum rate at which falling debris is added to the lower plenum in the BH package. The velocity of the falling debris can be estimated with little uncertainty. The other two parameters are more difficult to estimate. MELCOR calculations using the best-estimate values of these parameters resulted in no pressure spikes threatening vessel integrity when water was injected into the vessel. There are, however, significant uncertainties in this prediction. These uncertainties might be reduced if the MELCOR code would calculate mechanistically the heat transfer coefficient for the falling debris to the pool as a function of the heat transfer regime. Three different heat transfer regimes are possible during this process: film boiling, nucleate boiling and single phase convection. The heat transfer coefficient should vary with time depending on the heat transfer regime. Currently, a constant heat transfer coefficient (input by the user) is employed by the code.

8.2 SOURCE TERM UNCERTAINTIES

There are six different fission product release models in MELCOR. None of them has proven to provide better estimates of the fission products released than the others when their results were compared to experimental data.[27] Each model provided good agreement for some classes of fission products but not for others. Therefore, each single model of fission product release has uncertainties. The model chosen in these calculations, the modified CORSOR with surface to volume ratio, appears to give conservative results for most of the fission product classes (but not for all). Therefore, uncertainties in the source terms calculated by MELCOR in this study are present, and they may not always be on the conservative side.

8.3 CONTAINMENT FAILURE PRESSURE AND LOCATION

The best-estimate deck employs a model for containment failure to occur at the junction of the cylindrical wall and the hemispherical dome of the outer containment building at a pressure differential of 56 psig (0.385 MPa). This model was based on previous studies[7,12,13,20] (Section 3.3). Furthermore, the failure area was assumed to be 1 ft^2 (0.1 m^2) based on NUREG-1150 results.[6]

Comments received from the Grand Gulf plant staff on the draft of this report indicated that there are nine possible failure modes of the outer containment at pressures ranging from 56 to 76 psig (0.385 to 0.522 MPa) and at different locations (dome, cylindrical walls, base mat, joint of containment cylinder and base mat, air lock seals, and upper personnel air lock). Some of these locations will leak into the auxiliary building. These alternate containment failure modes have not been considered in this study. If they were considered, different environmental source terms would be calculated by MELCOR for this severe accident sequence. Neither, the containment failure mode that is more probable nor the containment failure mode that has the largest source term release has been determined. Consequently, uncertainties in this area remain.

9. SUMMARY OF TECHNICAL FINDINGS

A low-pressure, short-term station blackout has been run with MELCOR 1.8.3 (1.8 PN) for the Grand Gulf Nuclear Station using three different models or decks: a fully qualified, best-estimate deck prepared using actual plant data, the same best-estimate deck but without the BH Package, and a deck prepared during the NUREG-1150 project. There are differences in the input decks and in the output from running the three decks. Additionally, injection recovery sequences have been run with the best-estimate deck, and their results are also summarized in this chapter.

9.1 DECK DIFFERENCES

The three MELCOR models used in these calculations, the two best-estimate decks (described in Sect. 4) and the NUREG-1150 deck (described in Sect. 5), exhibit differences in modeling the Grand Gulf plant. The best-estimate deck accurately models the plant and, in particular, has a detailed model of the lower plenum and lower head used with the BH Package of MELCOR. The best-estimate deck without BH and the NUREG-1150 deck do not have this detailed lower plenum and bottom head model with the BH Package. The best-estimate deck also considers quenching of the core debris with the water in the lower plenum, while the other two decks do not. The containment model is different, being more detailed in the best-estimate decks that also include the enclosure building (not present in the NUREG-1150 deck). There are different core material inventories, different SRV operation modes, and different initial conditions for each deck.

The most important deficiencies of the NUREG-1150 model have been identified in the following areas: absence of the BH model, reduced inventory of steel in the core and lower plenum, and lack of detail in the containment (in particular, exclusion of the enclosure building).

9.2 TIMING OF IMPORTANT EVENTS

There are substantial differences between the timing of important events calculated by each deck. These times are presented in Table 6.13. The best-estimate decks predict a later timing than the NUREG-1150 deck for every event except the "gap release" phase duration, which is slightly longer (by 4 min) for the NUREG-1150 deck. The most substantial difference is for the vessel failure time that is predicted to occur at 288 min in the best-estimate deck, more than twice as long as the time predicted in the NUREG-1150 deck (122 min.). This time difference is a direct consequence of the BH Package and of the larger core, core plate, and lower plenum masses of steel employed in the best-estimate deck. The "early in-vessel" phase duration is 168 min for the best-estimate deck and only 14 min for the NUREG-1150 deck.

The timing of events calculated by the NUREG-1150 deck are shorter and therefore more conservative with respect to the timings calculated by the best-estimate deck.

9.3 SOURCE TERMS DIFFERENCES

The in-containment source terms are presented in Table 6.2 for the best-estimate deck, in Table 6.6 for the best-estimate deck without BH, and in Table 6.10 for the NUREG-1150 deck. Comparisons of the source terms by release phase are given in Tables 6.15–6.19.

There are substantial differences between the results of the three runs. The "total" in-containment source term fractions calculated with the NUREG-1150 deck are larger than the corresponding values calculated with the best-estimate deck for all classes except for Class 1 (noble gases), class 2 (Cs), class 6 (Ru), class 10 (U), and class 16 (CsI). The differences for classes 1 and 6 are minimal, the difference for class 2 is 24%, for class 10 is 850%, and for class 16 is 27%; all are larger in the best-estimate deck than in the NUREG-1150 deck. Very large release "total" fractions (almost 100%) are predicted in the NUREG-1150 deck for classes 7 (Mo), 11 (Cd), and 12 (Sn). These releases occur in the "ex-vessel" release phase. Significant "total" releases are predicted for class 3 (61%) and class 8 (14%) in the NUREG-1150 deck. The best-estimate deck does not predict these large releases for classes 3, 7, 8, 11, and 12. However, the best-estimate deck without BH also predicts these large releases, which could be a consequence of the absence of the BH model. Large discrepancies between both results appeared for classes 3, 7–12. Most of the "gap" releases of the NUREG-1150 deck are larger than the releases of the best-estimate deck (class 5 "gap" releases are larger for the best-estimate deck). The duration of the "gap" release phase is also larger in the NUREG-1150 deck.

As expected, because the "early in-vessel" release phase of the NUREG-1150 model is very short (14 min) compared to the same release phase in the best-estimate deck (168 min), smaller "early in-vessel" releases are predicted for the NUREG-1150 deck than for the best-estimate deck. However, for two classes (3 and 12), the NUREG-1150 deck predicts larger releases for the "early in-vessel" phase than the best-estimate deck. The "ex-vessel" releases are larger for the NUREG-1150 deck, except for classes 6 and 10. Some of the "late-in-vessel" releases are larger for the NUREG-1150 deck (classes 1, 3, 5, and 12), and some are larger for the best-estimate deck (classes 2 and 16).

The NUREG-1150 deck predicts larger releases (by a factor of 3) of non-radioactive aerosols into containment than the best-estimate deck.

The source terms released into the environment are presented in Table 6.3 for the best-estimate deck, in Table 6.7 for the best-estimate deck without BH, and in Table 6.11 for the NUREG-1150 deck. Comparison of releases at about the same time for the three decks is given in Table 6.21. It can be seen that the NUREG-1150 deck predicts larger releases than the best-estimate deck except for classes 2 and 16. At least two reasons can be found to account for these differences. First, the NUREG-1150 deck predicts larger in-containment source terms except for classes 2 and 16. Second, the NUREG-1150 deck does not model the enclosure building that appears to retain 7% of the noble gases.

In general, the majority of the source terms calculated by the NUREG-1150 deck are larger and therefore more conservative than the source terms calculated by the best-estimate deck. However, there are many cases where the source terms calculated by the NUREG-1150 deck are not conservative with respect to the best-estimate results.

9.4 INJECTION RECOVERY SEQUENCES

The results of the injection recovery sequences are presented in Table 7.2. Water injection was initiated after core relocation started at 114 min (6,850 s). The following points summarize the results:

1. Vessel failure can be prevented if water at a rate of 7,450 gal/min (467.6 kg/s) is injected into the vessel on or before 268.8 min (16,100 s). This is about 2 1/2 h after fuel relocation started.

2. Water injection into the vessel after penetration failure (which occurred at 288 min or 17,272 s) but before 452 min prevented lower head gross failure,
3. The earlier the water injection, the less in-vessel hydrogen generated. For reflood sequences initiated before 283 min, the larger the mass flow rate of water injected, the smaller the amount of hydrogen generated. For later recovery sequences initiated after 342 min, the opposite is true: the larger the mass flow rate of water injected, the larger the amount of hydrogen generated.
4. No large pressure spikes were predicted by MELCOR during the reflood of either the core or the lower plenum debris bed.
5. Source terms released into containment during the injection recovery sequences are smaller than in the base station blackout without injection recovery. When vessel failure is prevented by water injection, only two phases of fission product releases apply: "gap" and "early in-vessel". The "gap" release phase is the same for the base case (without injection) and the recovered case because water is injected after the "gap" release phase is ended. However, the "in-vessel" releases are smaller for the recovered case because the fuel is cooled by the injected water, and fission product releases are terminated. The "total" source terms are also smaller for the recovered case (that does not have "ex-vessel" and "late-in-vessel" releases),
6. Due to control blade melting, recriticality is possible if nonborated water is injected into the degraded core. Water injection between 103 and 113 min after accident initiation appears to have high probability for recriticality.
7. The MELCOR code has proven to be a useful tool for severe accident management strategies.

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Appendix A

BEST-ESTIMATE DECK, MELGEN INPUT

The model for this input is described in Sect. 4. This file does not include the Lower Plenum Debris Bed (BH) Package input that is listed in Appendix B. Both files, listed in Appendix A and B, are required for the "best-estimate" deck of the Grand Gulf Nuclear Station. For the "best-estimate without BH" deck, only the file of Appendix A is required. The MELCOR input to run this file is listed in Appendix C.

```
**********************************************************************
*
*
*      reactor:   grand gulf BWR-6 with Mark-III containment
*      sequence:  short-term, station blackout with ADS (low pressure)
*                 initial conditions at time 0
*                 dome divided into 6 volumes cv313,314,315,316,317,318
*
*                 deck completed at ornl in May 1994
**********************************************************************
*
title     gg-stsb-w-ads
jobid     'gg2'
*
*
*
restartf gg2.rst
outputf  gg2.out
diagf    gg2.dia
plotf    plot2
dttime    0.002
*
*crtout
*allowreplace
**********************************************************************
***********************************************************************
*     ncg input
**********************************************************************
**********************************************************************
*
ncg004    h2  4  * hydrogen
ncg005    n2  5  * nitrogen
ncg006    co  6  * carbon monoxide
ncg007    co2 7  * carbon dioxide
ncg008    ch4 8  * methane
ncg009    o2  9  * oxygen
*
*
*
**********************************************************************
*     cvh input
**********************************************************************
*
*   reactor vessel
*
**********************************************************************
*   cv 100 - lower plenum
*
cv10000    low-plenum  2  2  1
cv10002    1.80  1.80
cv100a0    3
cv100a1    pvol  7.404972e6        *  1074  psia
cv100a2    zpol  42.707    tpol   551.0
cv100b1    37.414    0.0
cv100b2    42.7071  108.677  * consistent with bh input bh0326
*
*   cv 101 - core
*
```

```
cv10100    core    2  2  1
cv10102    1.334   1.334
cv101a0    3
cv101a1    pvol  7.21880e6          *  1047 psia
cv101a2    zpol  47.1091    tpol   561.0
cv101b1    42.7071    0.0
cv101b2    47.1091   30.976
*
*   cv 102 - bypass
*
cv10200    bypass   2  2  1
cv10202    1.334   1.334
cv102a0    3
cv102a1    pvol  7.21880e6         *   1047  psia
cv102a2    zpol  47.1091    tpol   561.0
cv102b1    42.7071    0.0
cv102b2    47.1091   27.498
*
*   cv 103 - steam separators
*
cv10300    separators   2  2  1
cv10302    5.396   5.396
cv103a0    3
cv103a1    pvol   7.17055e6        *  1040  psia
cv103a2    zpol   51.91     tpol   560.6
cv103b1    47.1091    0.0
cv103b2    52.88     65.129
*
*   cv 104 - steam dome-dryers
*
cv10400    dome-dryers    2   2  1
cv10402    1.92  1.92
cv104a0    3
cv104a1    pvol   7.17055e6       *    1040  psia
cv104a2    vpol  0.0    vfog   0.0  rhum   1.0
cv104b1    52.88    0.0
cv104b2    59.538  207.846
* steam leaving through the MSIVs
cv104c0    mass.3    9  2
cv104c1    te       10  8
tf00900    stm-mass   4   1.0  0.0
tf00910    0.0  -2079.0  1.0  -2079.0  3.0   0.0    1.0e6   0.0
tf01000    stm-tem    2   1.0  0.0
tf01010    0.0  560.0    1.0e6   560.0
*
*   cv 105 - downcomer
*
cv10500    downcomer    2  2  1
cv10502    1.920   1.920
cv105a0    3
cv105a1    pvol   7.17055e6       *  1040  psia
cv105a2    zpol   51.91     tpol  520.0
cv105b1    41.01    0.0
cv105b2    52.88 216.936
* Feedwater  flow  into  downcomer
cv105c0    mass.1    7  2
cv105c1    te        8  8
tf00700    fdw-mass   3   1.0  0.0
```

```
tf00710    0.0   2079.0    5.0   0.0   1.0e6  0.0
tf00800    fdw-temp   2   1.0  0.0
tf00810    0.0   489.0   1.0e6   489.0
*
*
*************************************************************************
*
*   containment
*
*************************************************************************
*   cv 201 - region between top of shield wall and drywell
*           head seals
*           begins elevations at 173' 3" = 52.8066 m
*           ends elevation at 183' 10" = 56.0324 m
*           inner radius = 134 5/16" = 3.412 m  (rpv od =268 7/8")
*           outer radius = 16'4" = 4.9784 m
*           vol = pi *(ro**2-ri**2)*h
*               = 133.075 m**3
*******************************************************************
*
cv20100   dry-head-seal  2  2  2
cv20101   0  0
cv20102   0.0  0.0
cv201a0   3
cv201a1   pvol  1.01353e5  tatm  330.72
cv201a2   mlfr.5  0.79  mlfr.9  0.21
cv201a3   rhum  0.5
cv201b0   52.8066  0.0
cv201b1   56.0324  133.075
*
*********************************************************************
*   cv 202 - pedestal cavity region
*           sump begins at elevation 91' 6" = 27.8892
*           begins at elevation = 94' 6" = 28.8036 m
*           ends at elevation = 121' 4 1/2" =36.9951 m
*           volume = 259.420 m**3  (includes sumps)
*           initial water from bwrltas in sumps = 327.4 lbs=148.5kg
*            r1= 10' 7"
*            r2= 9' 5"
**********************************************************************
*
cv20200  pedestal-cavity  2  2  2
cv20201  0  0
cv20202  0.0  0.0
cv202a0  3
cv202a1  pvol 1.01353e5  tatm 330.72
cv202a2  rhum 0.5  mlfr.5  0.79
cv202a3  mlfr.9  0.21 mass.1 148.51 tpol 330.72
cv202b0  27.8892  0.0
cv202b1  28.8036  4.7714
cv202b2  34.9123  204.47
cv202b3  35.2679  214.88
cv202b4  36.9951  259.42
*
*******************************************************************
*    cv 203- weir wall annulus
*          begins at elevation = 93' 0 1/4"= 28.3528 m
*          ends at elevation = 117' 4" = 35.7632 m
```

```
*          inside radius = 34' 0" = 10.3632 m
*          outside radius = 36' 6" = 11.1252 m
*          volume = 381.198 m**3
*          vent volume = 81.722 m**3  (table a-10 ufsar)
*          total volume = 462.92 m**3
*****************************************************************
*
cv20300  weir-wall-ann.    2  2  2
cv20301  0  0
cv20302  0.0  0.0
cv203a0  3
cv203a1  pvol  1.01353e5  tatm  330.72
cv203a2  zpol  34.017  tpol  308.15  mlfr.5  0.79
cv203a3  mlfr.9  0.21
cv203b0  28.3528  0.0
cv203b1  35.7632  462.92
*
******************************************************************
*   cv 204 - drywell annular region from 161' 6" to 180' 3"
*           begins at elevation = 161' 6" = 49.2252 m
*           ends at elevation = 180' 3" = 54.9402 m
*           inside radius = 16' 4" = 4.9784 m
*           outside radius = 36' 6" = 11.1252 m
*           vol = 1777.208 m**3
*******************************************************************
*
cv20400  drywell-ann-4     2  2  2
cv20401  0  0
cv20402  0.0  0.0
cv204a0  3
cv204a1  pvol  1.01353e5  tatm  330.72
cv204a2  rhum  0.5  mlfr.5  0.79
cv204a3  mlfr.9  0.21
cv204b0  49.2252  0.0
cv204b1  54.9402  1777.208
*
**************************************************************
*   cv 205 - rpv-shield wall annular region
*           rpv midplane outside radius = 133 1/8" = 3.3814 m
*           shield wall inside radius = 14'4" = 4.3688 m
*           begins at elevation = 121' 4 1/2" = 36.995 m
*           ends at elevation = 173' 3" = 52.8066m
*           vol = 380.139 m**3
*
***************************************************************
*
cv20500  shield-wall-ann.  2  2  2
cv20501  0  0
cv20502  0.0  0.0
cv205a0  3
cv205a1  pvol 1.01353e5 tatm 330.72
cv205a2  mlfr.5  0.79  mlfr.9  0.21
cv205a3  rhum  0.5
cv205b0  36.9951  0.0
cv205b1  52.8066 380.139
*
***********************************************************
*  cv 206  drywell annular region from top of grating at 147'7"
```

```
*          level to top of grating at 161'6"
*
*          begins at elevation = 147'7"= 44.9834 m
*          ends at elevation = 161'6" = 49.2252 m
*          ri = 16'4" = 4.9784 m
*          ro = 36'6" = 11.1252 m
*          vol = pi*(ro**2-ri**2)*(height) = 1319.083 m**3
*
*****************************************************************
cv20600   drywell-ann.-3  2  2  2
cv20601   0  0
cv20602   0.0  0.0
cv206a0   3
cv206a1   pvol 1.01353e5  tatm  330.72
cv206a2   rhum  0.5  mlfr.5  0.79
cv206a3   mlfr.9  0.21
cv206b0   44.9834  0.0
cv206b1   49.2252  1319.083
*
**********************************************************************
*  cv207  drywell annular region form top of weir wall to grating at
*         147'7"
*
*         begins at elevation = 117'4" = 35.7632 m
*         ends at elevation = 147' 7" = 44.9834 m
*         inside radius = 16'4" = 4.9784 m
*         outside radius = 36'6" = 11.1252 m
*         vol=pi*(ro**2-ri**2)*(height) = 2867.228 m**3
***********************************************************************
cv20700   drywell-ann.-2  2  2  2
cv20701   0  0
cv20702   0.0  0.0
cv207a0   3
cv207a1   pvol 1.0135e5  tatm  330.72
cv207a2   rhum  0.5  mlfr.5  0.79
cv207a3   mlfr.9  0.21
cv207b0   35.7632  0.0
cv207b1   44.9834  2867.228
*
*************************************************************************
**
*   cv208  drywell annulus region next to weir wall
*
*          begins at elevation  =  100'9" =30.7086
*          ends at elevation =  117'4" = 35.7632 m
*          ro = 32'6" = 9.906 m
*          ri = 16'4" = 4.9784 m
*          vol = pi*(ro**2-ri**2)*(height)
*************************************************************************
**
cv20800   drywell-ann.-1  2  2  2
cv20801   0  0
cv20802   0.0  0.0
cv208a0   3
cv208a1   pvol  1.01353e5   tatm  330.72
cv208a2   rhum  0.5  mlfr.5  0.79
cv208a3   mlfr.9  0.21
cv208b0   30.7086  0.0
```

```
cv208b1   35.7632  1164.672
*
********************************************************************
*   cv 209 - rpv head -drywell head region
*             begins at elevation = 183'10" = 56.0324m
*             ends at elevation = 200' 6" = 61.1112 m
*             vol= 161.460
********************************************************************
*
cv20900  drywell-head    2  2  2
cv20901  0  0
cv20902  0.0  0.0
cv20903  35.873
cv209a0  3
cv209a1  pvol  1.01353e5  tatm 330.72
cv209a2  rhum 0.5  mlfr.5  0.79
cv209a3  mlfr.9  0.21
cv209b0  56.0324 0.0
cv209b1  58.674  100.730
cv209b2  61.112  161.460
*
***********************************************************************
*
*   cv 310  suppression pool
*           begins at elevation = 93'0 1/4" = 28.3528 m
*           ends at elevation = 135' 4" = 41.2496 m
*           outside radius = 62' 0" = 18.8976 m
*           inside  radius = 41' 6" = 12.649 m
*           pool elevation = 34.1078 at t= 300.0 due to steam from srv's
*           top of pool at 111'7 1/6" = 34.015m
*           vol= 7986.6954 m**3
***********************************************************************
*
*
cv31000  suppression-pool  2  2  3
cv31001  0  0
cv31002  0.0  0.0
cv310a0  3
cv310a1  pvol 1.01353e5  tatm 308.15
cv310a2  rhum 0.60  mlfr.5  0.79  mlfr.9  0.21
cv310a3  zpol  34.017  tpol  308.15
cv310b0  28.3528  0.0
cv310b1  34.0150  3507.80
cv310b2  41.2496  7986.7
*
***********************************************************************
*
*   cv 311 - wetwell- drywell annulus
*             begins at elevation = 135' 4" = 41.2496 m
*             ends at elevation = 161' 6" = 49.225 m
*             inside radius = 41' 6" = 12.649 m
*             outside radius = 62' 0" = 18.8976 m
*             vol = 4274.897 m**3
*            vol(cv 311)-vol (equip hatch)= 4274.897-563.277 =3711.62m**3
***********************************************************************
*
cv31100  wetwell-ann-1  2  2  3
cv31101  0  0
```

```
cv31102  0.0  0.0
cv31103  548.637
cv311a0  3
cv311a1  pvol  1.01353e5  tatm  308.15
cv311a2  mlfr.5  0.79  mlfr.9  0.21
cv311a3  rhum  0.6
cv311b0  41.2496  0.0
cv311b1  49.2252  3711.62
*
**********************************************************************
*   cv312 - upper-pool-annulus-1
*         - begins at elevation = 161'6" = 49.2252 m
*         - ends at elevation = 184'6" = 56.2356 m
*         - area = 3254.72 ft**2 = 302.3734 m**2
*      - area=area(cv312)-area(equip hatch)=302.3724-70.625=231.7484m**2
*         - vol = area *h =(302.3734m**2)*(56.2356-49.2252)m
*               = 2119.7584 m**3
*      -vol=vol(cv 312)-vol(equip hatch)=2119.7584-495.1096=1624.649m**3
*
**********************************************************************
*
cv31200  upper-pool-ann-1  2  2  3
cv31201  0  0
cv31202  0.0  0.0
cv31203  231.7484
cv312a0  3
cv312a1  pvol 1.01353e5 tatm  308.15
cv312a2  rhum 0.6  mlfr.5  0.79  mlfr.9  0.21
cv312b0   49.2252  0.0
cv312b1   56.2356  1624.649
*
**********************************************************************
*   cv 313 - refueling pool/ upper containment pool
*          - begins at elevation = 167' 6 1/4" = 51.0604 m
*          - ends at elevation = 208'10" = 63.6524
*          - midpoint elevation = 184'6 1/4" = 56.242 m
*          - total water volume = 73000 ft**3 = 2067.13 m**3
*          - normal water level = 207' 10" = 63.3476 m
*          - total volume = vol pool + vol air
*                         = 2067.13 + 86.70
*                         = 2154.09 m**3
*          - 36,380 ft**3 can be dumped (1030.167 m**3)
*
**********************************************************************
*
*
cv31300    refuelpool  2  2  3
cv31301    0  0
cv31302    0.0  0.0
cv313a0    3
cv313a1    pvol 1.01353e5  tatm  308.15 tpol 308.15
cv313a2    rhum 0.6  mlfr.5  0.79  mlfr.9  0.21
cv313a3    zpol  63.3476
cv313b0    51.0604   0.0
cv313b1    56.2420   102.0
cv313b2    63.3476   2067.13
cv313b3    63.6524   2154.10
*
```

```
**********************************************************************
*
*  cv314 - upper containment region 1 above water pool
*        - begins at elevation = 208' 10" =63.6524 m
*        - ends at elevation = 226'2" = 68.9356 m
*        - vol = 669.134 m**2 * 5.2832 m = 3535.1695 m**3
*
**********************************************************************
*
cv31400    upper-ctmt-reg1   2  2  3
cv31401    0  0
cv31402    0.0  0.0
cv31403    669.134
cv314a0    3
cv314a1    pvol 1.01353e5  tatm  308.15
cv314a2    rhum  0.6  mlfr.5 0.79  mlfr.9  0.21
cv314b0    63.6524   0.0
cv314b1    68.9356   3535.1695
*
**********************************************************************
*
*  cv315 - upper containment region 2 above water pool
*        - begins at elevation 226'2" = 68.6524 m
*        - ends at elevation 243'6" = 74.2188 m
*        - volume = 3535.1695 m**3
*
**********************************************************************
*
*
cv31500    upper-ctmt-reg2  2  2  3
cv31501    0  0
cv31502    0.0  0.0
cv31503    669.134
cv315a0    3
cv315a1    pvol 1.01352e5   tatm  308.15
cv315a2    rhum  0.6   mlfr.5 0.79  mlfr.9  0.21
cv315b0    68.9356   0.0
cv315b1    74.2188   3535.1695
*
**********************************************************************
*  cv316 - hemispherical portion of the dome
*        - begins at elevation 243'6" = 74.2188 m
*        - ends at elevation 299'9" = 91.3638 m
*
**********************************************************************
*
cv31600    dome-hemisphere   2  2  3
cv31601    0  0
cv31602    0.0  0.0
cv316a0    3
cv316a1    pvol 1.01352e5   tatm  308.15
cv316a2    rhum  0.6  mlfr.5  0.79  mlfr.9  0.21
cv316b0    74.2188    0.0
cv316b1    91.3638   10555.3132
*
**********************************************************************
*  cv317 - wetwell containment annular region (lower)
*        - begins at elevation 208'10" = 63.6524 m
```

```
*         - ends at elevation 226'2" = 68.6524 m
*
**********************************************************************
*
cv31700    ww-annulus-lower  2 2 3
cv31701    0  0
cv31702    0.0  0.0
cv31703    452.798
cv317a0    3
cv317a1    pvol  1.01352e5   tatm  308.15
cv317a2    rhum  0.6  mlfr.5  0.79   mlfr.9  0.21
cv317b0    63.6524   0.0
cv317b1    68.9356   2392.2224
*
********************************************************************
*  cv318 - wetwell containment annular region (upper)
*         - begins at elevation 226'2" = 68.6524 m
*         - ends at elevation 243'6" = 74.2188 m
*
********************************************************************
*
cv31800    ww-annulus-upper  2  2  3
cv31801    0  0
cv31802    0.0  0.0
cv31803    452.798
cv318a0    3
cv318a1    pvol  1.01352e5  tatm  308.15
cv318a2    rhum  0.6  mlfr.5  0.79  mlfr.9  0.21
cv318b0    68.6524    0.0
cv318b1    74.2188   2392.2224
*
*****************************************************************
*  cv319 - upper pool annulus 2
*         - begins at elevation = 184'6" = 56.2356 m
*         - ends at elevation = 208' 10" = 63.6524 m
*         - area = 270.8588 m**2
*         - area=area(cv319)-area(equip hatch)=200.2338 m**2
*         - vol = 2230.717 m**3
*      - vol=vol(cv 319)-vol(equip hatch) =2230.717-523.812=1706.905m**3
*
*****************************************************************
*
cv31900  upper-pool-ann-2  2  2  3
cv31901  0  0
cv31902  0.0  0.0
cv31903  200.2338
cv319a0  3
cv319a1  pvol 1.01353e5  tatm 308.15  rhum 0.6
cv319a2  mlfr.5  0.79  mlfr.9  0.21
cv319b0  56.2356  0.0
cv319b1  62.4332   1240.969
cv319b2  63.6524   1706.9050
*
*******************************************************************
*   cv 320 - rwcu holding pump & sampling room
*          - figure 6.2.56-57 fsar
*          - begins at elevation = 184'6" = 56.2356 m
*          - ends at elevation =204'10" = 62.4332 m
```

```
*          - vol = 12525 ft**3 = 354.67  m**3
*
**********************************************************************
*
cv32000  pump-sampling  1  1  3
cv32001  0  0
cv32002  0.0  0.0
cv320a0  3
cv320a1  pvol  1.01353e5  tatm 330.72
cv320a2  mlfr.5  0.79  mlfr.9  0.21  rhum 1.0
cv320b0  56.2356  0.0
cv320b1  62.4332  354.67
*
**********************************************************************
*  cv 321 - main steam tunnel
*          - vol = 16,800 ft**3 = 475.723 m**3
*          - begins at elevation =140'0" = 42.672m
*          - ends at elevation = 166'0" = 50.5968 m
*
***********************************************************************
*
cv32100  main-steam-room  1  2  3
cv32101  0  0
cv32102  0.0   0.0
cv321a0  3
cv321a1  pvol 1.01353e5  tatm 308.15
cv321a2  mlfr.5  0.79  mlfr.9  0.21  rhum  0.5
cv321b0  42.672   0.0
cv321b1  50.5968  475.723
*
*******************************************************************
*  cv 322 - rwcu hx room
*          - vol = 10,500 ft**3 = 297.327 m**3
*          - begins at elevation = 170' = 51.816 m
*          - ends at elevation = 205'10" = 62.738 m
*          - initial temp = 80 f
*
*******************************************************************
*
cv32200  rwcu-hx-room  1   2   3
cv32201  0  0
cv32202  0.0  0.0
cv322a0  3
cv322a1  pvol  1.01353e5  tatm  308.15
cv322a2  mlfr.5  0.79  mlfr.9  0.21  rhum  0.5
cv322b0  51.8160  0.0
cv322b1  62.7380  297.327
*
************************************************************************
*  cv 323 - valve nest room (combine compt's 1,2,3 - fig 6.2-62)
*          - vol = 2686 ft**3 + 367 ft**3 + 154 ft**3 = 3207 ft**3
*                = 90.812 m**3
*          - begins at elevation = 173'2" = 52.7812 m
*          - ends at elevation = 180'6" = 55.0164 m
*
************************************************************************
*
*
```

```
cv32300  valve-nest-room  1  1  3
cv32301  0  0
cv32302  0.0  0.0
cv323a0  3
cv323a1  pvol 1.01353e5 tatm 308.15
cv323a2  mlfr.5  0.79  mlfr.9  0.21  rhum 1.0
cv323b0  52.7812  0.0
cv323b1  55.0164  90.812
*
*******************************************************************
*  cv 324  - rwcu filter/demineralizer rooms 1 & 2
*          - vol = 4574 ft**3 = 129.52 m**3
*          - begins at elevation = 184'6" = 56.2356 m
*          - ends at elevation = 204'10" = 62.4332 m
*
********************************************************************
*
cv32400  rcwu-filter-dem   1  1  3
cv32401  0  0
cv32402  0.0  0.0
cv324a0  3
cv324a1  pvol 1.01353e5  tatm  308.15
cv324a2  mlfr.5  0.79  mlfr.9  0.21  rhum 0.50
cv324b0  56.2356  0.0
cv324b1  62.4332  129.52
*
**********************************************************************
*   cv 325 - rwcu pump room
*          - begins at elevation = 161'10" = 49.3268 m
*          - ends at elevation = 166'10" = 50.8508 m
*          - vol = 771.7 ft**3 = 21.852 m**3
*
**********************************************************************
*
*
cv32500  rwcu-pump-room  1  2  3
cv32501  0  0
cv32502  0.0  0.0
cv325a0  3
cv325a1  pvol 1.01353e5  tatm 308.15
cv325a2  mlfr.5  0.79   mlfr.9  0.21  rhum  1.0
cv325b0  49.3268  0.0
cv325b1  50.8508  21.852
*
**********************************************************************
**
*  cv 326  - rwcu backwash recieving tank room
*          - begins at elevation = 161'10"= 49.3268 m
*          - ends at elevation = 170'10" = 52.0700 m
*          - vol = 3446.8 ft**3 = 97.603 m**3
*
**********************************************************************
**
*
cv32600  rcwu-tank-room  1  2  3
cv32601  0  0
cv32602  0.0  0.0
cv326a0  3
```

```
cv326a1  pvol  1.01353e5  tatm  308.15
cv326a2  mlfr.5  0.79  mlfr.9  0.21   rhum 1.0
cv326b0  49.3268  0.0
cv326b1  52.0700  97.603
*
**********************************************************************
**
*
*  cv 327 - control volume representing equipment hatch space in
*           the drywell-wetwell annular region
*          - area = 760.2 ft**2 = 70.625 m**2
*          - begins at 135'4" (41.2496 m)
*          - ends at 208'10" (63.6524 m)
*          - vol = (70.625m**2)*(22.4028m) = 1582.198 m**3
*
**********************************************************************
***
cv32700  equip-hatch  2  2  3
cv32701  0  0
cv32702  0.0  0.0
cv32703  70.625
cv327a0  3
cv327a1  pvol 1.01353e5  tatm 308.15  rhum 0.6
cv327a2  mlfr.5  0.79   mlfr.9  0.21
cv327b0  41.2496  0.0      * 135'4"
cv327b1  63.6524  1582.198 * 208'10"
*
**********************************************************************
**
*
*  cv 399 - enclosure bldg
*
cv39900  enclosure   1  1  7
cv399a0  3
cv399a1  pvol  1.01353e5  tatm  300.0  rhum  0.6
cv399a2  mlfr.5  0.79   mlfr.9  0.21
cv399b0  56.2356     0.0
cv399b1  93.574  16990.0
*
**********************************************************************
***
*
* environment
*
**********************************************************************
**
*
cv40000     environment  1  2  6
cv400a0     3
cv400a1     pvol  1.01353e5   rhum  0.5   tatm   300.0
cv400a2     mlfr.5  0.79    mlfr.9  0.21
cv400b0       28.3528       0.0
cv400b1       95.1738       1.0e7
*
*********************************************************************
*
*    flow path input
*
```

```
*****************************************************************
*
*    flows in and from the reactor vessel
*
*
fl01000  lp-core  100  101   42.7071  42.7071
fl01001  7.62677  4.85  0.61443
fl01002  0  0  0  0
fl01003  10.0 10.0
fl01004  0.0  2.6
fl010s1  7.62677  4.85  0.01139
fl010v1  -1  90  90
*
cf09000  frac-area  divide  2  1.0  0.0
cf09001  0.61443
cf09002  3   0.03  0.61443
cf09010  0.0   7.62677   cfvalu.91
cf09011  1.0  0.0   cfvalu.91
*
cf09100  flow-area   add   4  1.0  0.0
cf09111  1.0  0.0   cfvalu.92
cf09112  1.0  0.0   cfvalu.93
cf09113  1.0  0.0   cfvalu.94
cf09114  1.0  0.0   cfvalu.95
*
cf09200  flarea1  min   2  1.0 0.0
cf09210  0.0  2.651  cor-aflmin.106.113
cf09211  1.0  0.0    cor-aflmin.106.113
*
cf09300  flarea2  min  2   1.0  0.0
cf09310  0.0   0.957   cor-aflmin.206.213
cf09311  1.0  0.0      cor-aflmin.206.213
*
cf09400  flarea3  min  2   1.0  0.0
cf09410  0.0  0.534   cor-aflmin.306.313
cf09411  1.0  0.0     cor-aflmin.306.313
*
cf09500  flarea4  min  2  1.0  0.0
cf09510  0.0  0.544   cor-aflmin.406.413
cf09511  1.0   0.0    cor-aflmin.406.413
*
fl01100  lp-bypass   100 102   42.7071   42.7071
fl01101  6.7606   4.85  0.01
fl01102  0  0  0  0
fl01103  5.0  5.0
fl01104  0.0  0.5
fl011s1  6.7606   4.85  0.04261
*
fl01200  core-uplenum   101  103   47.1091  47.1091
fl01201  7.62677  5.0  1.0
fl01202  0  0  0  0
fl01203  40.0 40.0
fl01204  0.0 2.6
fl012s1  7.62677  5.0  0.01139
*
fl01300  byp-uplenum   102  103   47.1091  47.1091
fl01301  6.7606   5.0  1.0
fl01302  0  0  0  0
```

```
f101303  30.  30.
f101304  0.0  0.5
f1013s1  6.7606   5.0  0.04261
*
f101400  sep-dryers    103  104  52.88    52.88
f101401  13.229  6.21  1.0
f101402  0  0  0  0
f101403  8.0  8.0
f1014s1  13.229  6.21  0.2366
*
f101500  dome-downc    104  105  52.88   52.88
f101501  16.0536  9.26  1.0
f101502  0  0  0  0
f101503  8.0  8.0
f1015s1  16.0536  9.26  1.638
*
f101800  sep-downc   103  105  51.0   51.0
f101801  90.86  1.594  1.0
f101802  2  0 0 0   * vertical liquid drains first
f101803  4.0  4.0
f1018s1  90.86  1.594  9.58
*
f101600  jet-pumps   105  100   45.49   41.01
f101601  1.65   4.48   0.0           *open after the RCPs stop or 40 sec
f101602  0  0   0  0
f101603  0.1   17.0
f1016s1  0.4981  0.5486   0.1626
f1016s2  0.7263  0.9906   0.1963
f1016s3  1.0032  0.2692   0.2307
f1016s4  1.8399  1.5723   0.3124
f1016s5  2.6279  1.0973   0.3734
f1016v0  -1   80  80
*
cf08000   jet-rcp   l-a-ifte   3  1.0  0.0
cf08001  0.0
cf08010  1.0  0.0  cfvalu.81
cf08011  0.0  1.0  time
cf08012  0.0  0.0  time
*
cf08100  time-crite  l-gt   2   1.0  0.0
cf08101  .false.
cf08110  1.0  0.0  time
cf08111  0.0 40.0  time
*
f101700  rcpumps   105  100    45.49  41.01
f101701  1.65  4.48  1.0
f101702  0  0  0  0
f101703  1.0  20.0
f1017s1  1.65   4.48   0.163
f1017t0  1  11
*
tf01100  rcp-vel     9   1.0  0.0
tf01110  0.0  11.4284   1.5  9.1427   3.0  6.857  5.0  5.9428
tf01111  10.0  4.114   15.0   3.3714  20.0 2.857 40.0  0.0  1.0e6  0.0
*
f101900  bh-ves-breach  100   202   37.414  36.99
f101901  0.1   0.2413  0.0
f101902  0  0  0  0
```

```
fl01903  1.0  20.0
fl019s1  0.1  0.2413  0.10  *large Dh
fl019v0  -1  2  2
*
cf00200  bh-ves-bre   equals  1  1.0  0.0
cf00201  0.0
cf00210  1.0  0.0  bh-fflag
*
fl02000  vessel-breach   100   202   37.414  36.99
fl02001  0.01   0.2413   0.0
fl02002  0  0  0  0
fl02003  1.0 20.0
fl020s1  0.01  0.2413  0.0381  *  Dh of instrument tube
fl020v0  -1  82  82
*
cf08200  vessel-breach   divide  2  1.0 0.0
cf08210  0.0  0.1   cor-abrch
cf08211  1.0  0.0  cor-abrch
*
fl02100  leak-crds  100   202   38.0   36.0
fl02101  3.4e-6  2.0   1.0
fl02102  0  0  0  0
fl02103  1.0 20.0
fl021s1  3.4e-6  2.0  0.0018
*
fl02200  leak-rcps   105  208  41.816  32.721
fl02201  2.8e-6  16.0  1.0
fl02202  3  0 0  0    *horizontal flow
fl02203  1.0 20.0
fl022s1  2.8e-6  16.0  0.0016
*
*   SRVs  flows
*
fl10000  srvs  104  310   53.899  29.877
fl10001  0.2374   30.0  0.0
fl10002  0  0  0  1
fl10003  3.0  4.0
fl100v0  -1  100  100
fl100s1  0.2374   30.0  0.305
*
cf10000  srv-criteria  l-a-ifte   3  1.0 0.0
cf10001  0.0
cf10010  1.0  0.0  cfvalu.101
cf10011  1.0  0.0  cfvalu.102
cf10012  1.0  0.0  cfvalu.103
*
cf10100  time-criteria  l-gt  2  1.0  0.0
cf10101  .false.
cf10110  1.0  0.0  time
cf10111  0.0 29.0  time ***** chech times between 25 and 200 sec
*
cf10200  open-srv  hyst  1   1.0  0.0
cf10201  0.0
cf10203  -12  -13
cf10210  1.0  0.0  cfvalu.99
*
cf09900  pdif   add  2  1.0  0.0
cf09910  1.0  0.0  cvh-p.104
```

```
cf09911  0.0  -1.01353e5  time
*
tf01200  srv-open  5  1.0  0.0
tf01210  7.12e6      0.0
tf01211  7.122284e6  0.05   * 1/20=0.05 1 SRV at 1033 psig
tf01212  7.3980e6    0.05
tf01213  7.3981e6    0.1    * 2/20=0.1  2 SRVs at 1073 psig
tf01214  8.6738e6    0.1
*
tf01300  srv-close  6  1.0  0.0
tf01311  6.3845e6    0.0   * 1 SRV (last) closes at 926 psig
tf01312  6.3846e6    0.05
tf01313  6.4535e6    0.05  * 1 SRV closes at  936 psig
tf01314  6.454e6     0.1
tf01315  6.52244e6   0.1   * 2 SRVs close at 946 psig
tf01316  8.523e6     0.1
*
tf00100  srv-open  11  1.0  0.0
tf00110  7.12e6      0.0
tf00111  7.122284e6  0.05   * 1/20=0.05 1 SRV at 1033 psig
tf00112  7.3980e6    0.05
tf00113  7.3981e6    0.1    * 2/20=0.1  2 SRVs at 1073 psig
tf00114  7.6738e6    0.1
tf00115  7.67387e6   0.3    * 6/20=0.3  6 SRVs at 1113 psig
tf00116  7.7083e6    0.3
tf00117  7.70834e6   0.55   * 11/20=0.55 11 SRVs at 1118 psig
tf00118  7.742e6     0.55
tf00119  7.7428e6    1.0   *  all (20) SRVs at  1123 psig
tf00120  8.0e6       1.0
*
tf00200  srv-close  11  1.0  0.0
tf00211  6.3845e6    0.0   * 1 SRV (last) closes at 926 psig
tf00212  6.3846e6    0.05
tf00213  6.4535e6    0.05  * 1 SRV closes at  936 psig
tf00214  6.454e6     0.1
tf00215  6.52244e6   0.1   * 4 SRVs close at 946 psig
tf00216  6.523e6     0.3
tf00217  6.98439e6   0.3   * 5 SRVs close at 1013 psig
tf00218  6.9844e6    0.55
tf00219  7.05334e6   0.55  * 9 SRVs close at 1023 psig
tf00220  7.0534e6    1.0
tf00221  8.0e6       1.0   * all 20 SRVs open
*
cf10300  first-srvs  hyst  1  1.0  0.0
cf10301  0.0
cf10303  -3  -4
cf10310  1.0  0.0  cfvalu.99
*
tf00300  srv-first-open   9  1.0  0.0
tf00310  7.6e6      0.0
tf00311  7.6049e6   0.05  *Fist SRV 1/20=0.05 opens at 1103 psig
tf00312  7.673e6    0.05
tf00313  7.67387e6 0.1    *Second SRV opens at 1113 psig
tf00314  7.677e6    0.1
tf00315  7.6777e6   0.55  *11 SRVs open at 1115 psig
tf00316  7.7427e6   0.55
tf00317  7.7428e6   1.0   * all 20 SRVs open
tf00318  9.99e6     1.0
```

```
*
tf00400  srv-f-close   6  1.0  0.0
tf00410  6.91544e6 0.0   * SRV-1 closes at 1003 psig
tf00411  6.916e6   0.05
tf00412  6.98439e6 0.05  *11 SRVs close at 1013 psig
tf00413  6.9844e6  0.55
tf00414  7.05334e6 0.55  *9 SRVs close
tf00415  9.99e6    1.0   *all 20 SRVs open
*
fl10100  ads  104  310  53.899  29.877
fl10101  0.09496  30.0  0.0
fl10102  0  0  0  1
fl10103  3.0  4.0
fl101v0  -1  104  104
fl101s1  0.09496  30.0  0.305
*
cf10400  open-ads  l-a-ifte  3  1.0  0.0
cf10401  0.0
cf10405  normal
cf10410  1.0  0.0  cfvalu.105
cf10411  0.0  0.0  time
cf10412  0.0  1.0  time
*
cf10500  vessel-level  l-gt   2  1.0 0.0
cf10501  .true.
cf10505  latch
cf10506  2  'water level at 1/3 active core height'
cf10510  1.0  0.0  cvh-cliqlev.101
cf10511  0.0  44.204  time
*
fl10200  manual-srv  104  310  53.899  29.877
fl10201  0.0119   30.0  0.0
fl10202  0 0 0 1
fl10203  3.0  4.0
fl102v0  -1  106  106
fl102s1  0.0119  30.0  0.305
*
cf10600  srv-manual  l-a-ifte  3  1.0 0.0
cf10601  0.0
cf10610  1.0  0.0  cfvalu.107
cf10611  1.0  0.0  cfvalu.108
cf10612  0.0  0.0  time
*
cf10700  time-crit-2  l-gt  2  1.0  0.0
cf10701  .false.
cf10710  1.0  0.0  time
cf10711  0.0 300.0 time  ******* manual ope. after 300 sec (5 min)
*
cf10800  srv-man-hys   hyst 1  1.0  0.0
cf10801  0.0
cf10803  -5  -6
cf10810  1.0  0.0  cfvalu.99
*
tf00500  srv-man-open  3   1.0  0.0
tf00510  6.20e6    0.0
tf00511  6.205e6   1.0  *  SRV opens at 900 psig
tf00512  7.50e6    1.0
*
```

```
tf00600  srv-man-close  3  1.0
tf00610  5.516e6   0.0   * SRV closes at 800 psig
tf00611  5.52e6    1.0
tf00612  7.50e6    1.0
*
************************************************************************
***
*
*   containment  flow  paths
*
************************************************************************
***
*  fl201 - flowpath between cv 207 and cv 208
*         - area = 1681.75 ft**2 = 156.2397 m**2 (per table 6.2-31)
*         - begins at elevation = 117'4" = 35.7632 m
*         - delta r =4.9276 m
*         - length = midpoint cv207 to midpoint 208 =132'5.5"-108'10.75"
*                  = 23.5625 ' = 7.1819 m
*      - seg 1: p=2*pi*(ri+ro)=93.5214 m; a'=230.418m**2  ;4a'/p=9.8552m
*      - seg 2: p=2*pi*ri=31.280; a'=230.418 m**2; 4a'/p=29.465m
*
************************************************************************
*
*
fl20100   fl201  208  207  35.7632  35.7632
fl20101   156.2397  7.1819  1.0  4.9276  4.9276
fl20102   0  0  0  1
fl20103   1.0  1.0  1.0  1.0
fl20104   0.0  0.0
fl201s1   156.2387  2.5718  9.8522  * seg 1 100'9" -117'4"
fl201s2   156.2387  4.6101  29.465  * seg 2 117'4" -132'5.5"
*
************************************************************************
**
*   fl202 - flowpath between cv207 and cv206
*          - area =2356.80 ft**2 = 218.9539 m**2 (per fsar table 6.2-31)
*          - begins at elevation = 147'7" =44.9834 m
*          - delta r = 6.1468 m
*          - 4*a'/p = 4(310.972)/(2*pi*(11.1252+4.9784)=12.2936m
*
************************************************************************
**
*
fl20200  fl202  207  206  44.9834  44.9834
fl20201  218.9539  6.7818  1.0  6.1469  6.1469
fl20202  0  0  0  0
fl20203  1.0  1.0  1.0  1.0
fl20204  0.0  0.0
fl202s1  218.9539  6.7818  12.2936
*
************************************************************************
*
*   fl203 - flowpath between cv 206 and cv 204 (per table 6.2-31 fsar)
*          - area = 2354.84 ft**2 = 218.7718 m**2
*          - begins at elevation = 161'6" = 49.2252 m
*          - length = midpoint cv204 - midpoint cv206 = 171'1/2"-154'7.5"
*                   = 16'4" = 4.9784 m
*
```

```
************************************************************************
*
*
fl20300  fl203  206  204  49.2252  49.2252
fl20301  218.7718  4.9784  1.0  6.1468  6.1468
fl20302  1  0  0  0
fl20303  1.0  1.0  1.0  1.0
fl20304  0.0  0.0
fl203s1  218.7718  4.9784  12.2936
*
************************************************************************
*
*   fl204 - flowpath between cv204 and cv201
*           - begins at elevation =  173'3"
*           - ends at elevation = 180'3"
*           - area = 67.07+174.15+447.01 ft**2 = 63.9387m**2
*       - note:melcor cv201 = vol 1 + vol 2 + vol 3 of fsar(table 6.2-31)
*           - opening diameter = 7'= 2.1336 m
*           - length = 1.72 m
*           - k eff = 1/.93 = 1.08
*           - 4a/p = 2*1 =4.2672 m
*
************************************************************************
***
*
fl20400  fl204  204  201  53.8734  53.8734
fl20401  63.9387  1.720  1.0  2.1336  2.1336
fl20402  3  0  0  0
fl20403  1.08  1.08  999.0  999.0
fl20404  0.0  0.0
fl204s1  63.9387  1.720  4.2672  0.5e-5  0.0
*
************************************************************************
***
*   fl205 - flowpath between cv205 and cv201
*           - begins at elevation = 173'3" = 52.8066 m
*           - ends at elevation = same
*           - area = 25.03+62.57+162.69 ft**2 = 23.2527 m**2
*           - length = 9.22 m
*           - k eff = 1/.92 = 1.087
*           - delta r = 0.5548 m
*           - 4a/p= 1.975 m
*
************************************************************************
***
*
fl20500  fl205  205  201  52.8066  52.8066
fl20501  23.2527  9.220   1.0  0.5548  0.5548
fl20502  0  0  0  0
fl20503  1.087  1.087  999.0  999.0
fl20504  0.0  0.0
fl205s1  23.2527  9.220   1.975  0.5e-5  0.0
*
*******************************************************************
*   fl 206 - flowpath between cv 209 and cv201
*            - elevation = 183'10"=56.0324m
*            - area = 1/2 * 8.72 ft**2 = 0.405m**2
*            - length = 2.488 m
```

```
*          - orifice , therefore k= 1.0
*
*****************************************************************
*
fl20600   fl206  209  201  56.0324  56.0324
fl20601   0.405 2.488  1.0
fl20602   1  0  0  0
fl20603   1.0  1.0  1.0   1.0
fl20604   0.0  0.0
fl206s1   0.405 2.488  1.016  0.5e-5  0.0
*
*************************************************************
*   fl 207 - horizontal flowpath between cv 202 and cv 205
*          - centerline elevation = 122' 10" = 37.4396 m
*          - area = 1.824 m**2 (30 " o.d.)
*          - length = midpoint cv 202 - micpoint cv 205 at 122'10"
*                   = 3.875 m (midpoint of shield wall ann.)
*          - ls = thickness = 4.25 " = 0.108 m
*          - 30" manholes (2/4 in skirt; currently using 4)
*          - 4a/p = o.d. = 30" = 0.762 m
*
*****************************************************************
*
fl20700  fl207  202  205  36.9951  37.4396
fl20701  1.824  3.875  1.0  0.762  0.762
fl20702  3  0  0  0
fl20703  1.0  1.0  1.0  1.0
fl20704  0.0  0.0
fl207s1  1.824  0.108  0.762
*
****************************************************************
*
*  fl 208  - horizontal flowpath between cv 208 and cv 202
*          -  centerline elevation = 107' 7" = 32.7914 m
*          - wall thickness = ls = 5.75' = 1.7526 m
*          - l = midpoint cv 208 to midpoint cv 202
*              = 24' 5" = 7.4422 m
*          - area = 7' x 3' = 21 ft**2 = 1.951 m**2
*          - 4*a/p = 4.2' = 1.2802 m
*
****************************************************************
*
fl20800  fl208  208  202  32.7914  32.7914
fl20801  1.951  7.4422  1.0  2.1336  2.1336
fl20802  3  0  0  0
fl20803  1.0  1.0  1.0  1.0
fl20804  0.0  0.0
fl208s1  1.951  1.7526  1.2802  0.5e-5
*
************************************************************
*   fl209  - drain flowpath between cv208 and cv202
*          - begins at elevation = 100'9"=30.7086m
*          - ends at elevation = 96'10.5"=29.5275m
*          - flowpath area = 2-8" pipes =2*pi*16 in**2 = 0.06486m**2
*          - elevation opening height = o.d. of circle with area
*            = 2-6" o.d. pipes and 2-8" o.d. pipes = 157.08 in**2
*            = 0.10134 m**2 , therefore o.d. = 0.3592m
*
```

```
***********************************************************************
*
f120900  f1209  208  202  30.7086  29.5275
f120901  0.06486  17.222  1.0  0.3592  0.28206
f120902  3  0  0  1
f120903  1.0  1.0  1.0  1.0
f120904  0.0  0.0
f1209s1  0.05067  12.802  0.1814  *8" & 6" lines parallel for 42'
f1209s2  0.06486  2.8956  0.2032  * 2 -8" lines parallel for 9.5'
f1209s3  0.03243  1.5240  0.2032  *8" single line for 5'
*
*******************************************************************
*   fl 210 - drywell vacuum breaker flowpath
*          - begins at elevation = 179'2" = 54.610 m
*          - ends at elevation = 194' 0" = 59.1312 m
*          - id =10.02"
*          - od = 10.75"   (10" sch 40 pipe)
*          - a/sqrt(k) = 0.225 ft**2  , therefore k =5.93
*
*******************************************************************
*
*
*  valve = closed for station blackout
*
f121000  f1210  204  319  54.610  59.1312
f121001  5.0903e-2  6.985  0.0  0.1273  0.2545 *flow area zero
f121002  0  0  0  0
f121003  5.93  5.93  1.0  1.0
f121004  0.0  0.0
f1210s1  0.050903  4.4704  0.2545  *vertical section
f1210s2  0.10186   1.3462  0.2545  *53" parallel segment
f1210s3  0.050903  1.1684  0.2545  *rest of 93" segment
*f1210v1  -250  250  250        *  control function deactivated
*
cf25000  vac-bkr-open  l-a-ifte  3  1.0  0.0
cf25010  1.0  0.0  cfvalu.251
cf25011  0.0  1.0  time
cf25012  0.0  0.0  time
*
cf25100  dual-test-logic  l-and  2  1.0  0.0
cf25110  1.0  0.0     cfvalu.252
cf25111  1.0  0.0     cfvalu.253
*
cf25200  vac-open-start  l-gt  2  1.0  0.0
cf25210  1.0  0.0     time
cf25211  0.0  0.0     time
*
cf25300  ww-dw-dp  l-ge  2  1.0  0.0
cf25310   1.0  0.0       cfvalu.311
cf25311   0.0  3.4474e3  time  * differential pressure
*
*************************************************************
*   f1211 - top row of vents
*         - centerline at elevation = 104'4" = 31.8008 m
*
*************************************************************
*
f121100  top-row-vents  203  310  31.8008  31.8008
```

```
fl21101  0.37987  1.524  1.0  0.69546  0.69546
fl21102  3  0  1  1
fl21103  1.48  1.48  1.48  1.48
fl21104  0.0  0.0
fl211s1  17.09  1.524  2.2311  0.5e-5  0.0
*
***************************************************************
*    fl212 - middle row of vents
*          - centerline at 100'2" = 30.5308 m
*
***************************************************************
*
fl21200  mid-row-vents  203  310  30.538  30.5308
fl21201  0.37987  1.524  1.0  0.69546  0.69546
fl21202  3  0  1  1
fl21203  1.48  1.48  1.0  1.0
fl21204  0.0  0.0
fl212s1  17.09  1.524  2.2311  0.5e-5  0.0
*
***************************************************************
*  fl213 - bottom row of vents
*        - centerline at elevation = 96'0" = 29.2608 m
*
***************************************************************
*
fl21300  bottom-row-vents  203  310  29.2608  29.2608
fl21301  0.37987  1.524  1.0  0.69546  0.69546
fl21302  3  0  1  1
fl21303  1.48  1.48  1.0  1.0
fl21304  0.0  0.0
fl213s1  17.09  1.524  2.2311  0.5e-5  0.0
*
*******************************************************************
*  fl 214 - flowpath between cv207 and cv203
*         - elevation = 117'4" = 35.7632 m
*         - area = 51.4409 m**2
*         - ri = 10.3632 m
*         - ro = 11.1252 m
*         - delta r = 0.762 m
*         - length = midpoint of air portion of cv 203 to midpoint
*                    of cv 207 =131'1/2"-11' 10 5/12" = 18'1/2" =5.4885 m
*         - neglect friction losses f= 0.0
*         - 4*a/p = 1.524 m
*         - ls = 117'4" - 111'7 1/6" = 1.7484 m
**********************************************************************
***
*
fl21400  fl214  207  203  35.7632  35.7632
fl21401  51.4409  5.4885  1.0  0.762  0.762
fl21402  0  0  0  1
fl21403  1.0  1.0  1.0  1.0
fl21404  0.0  0.0
fl214s1  51.4409  1.7484  1.524  0.5e-5  0.0
*
*******************************************************************
*  fl215  - drywell-wetwell leakage
*         - a/sqrt(k)=0.048ft**2=4.46e-03 ; (fig 6.2-16 fsar)
*         - therefore set k=1.0, and area =0.048ft**2
```

```
*          - assume elevation = 135' = 41.148m (horizontal flowpath)
*          - ls = 5' =1.524 m
*          - ds = 4*a/p =2*(ro-ri) for concentic circles
*          - assume ro-ri=1/4" ; ds=0.013 m
*          - note: a/sqrt(k) = 0.048 no spray
*                            = 0.9  for spray
*
**********************************************************************
*
fl21500  fl215  207  310  41.148  41.148
fl21501  4.46e-3  1.524  1.0
fl21502  3  0  0  0
fl21503  1.0  1.0  1.0  1.0
fl21504  0.0  0.0
fl215s1  4.46e-3  1.524  0.013  0.5e-5  0.0 * f=0.0 since a/sqrt(k)
*                                                            known
*
*********************************************************************
*   fl 216 - flowpath between cv 209 and cv201
*          - elevation = 183'10"=56.0324m
*          - area = 1/2 * 8.72 ft**2 = 0.405 m**2
*          - length = 2.488 m
*          - orifice , therefore k= 1.0
*
*********************************************************************
*
fl21600   fl216  209  201  56.0324  56.0324
fl21601   0.405  2.488  1.0
fl21602   1  0  0  0
fl21603   1.0  1.0  1.0   1.0
fl21604   0.0  0.0
fl216s1   0.405  2.488  1.016  0.5e-5  0.0
*
****************************************************************
*   fl301 - flowpath between cv 310 and cv311
*         - elevation = 135'4"=41.2496m
*         - grating area = 2883 ft**2 = 267.8395 m**2
*         - ctmt annulus area = 6665.7 ft**2 =619.2638 m**2
*         - no communication area =  3783 ft**2 = 351.5422 m**2
*         - assume orifice , therefore k=1.0
*         - 73% of grating area open, therefore area =2104.6 ft**2
*           = 195.523 m**2
*         - length = midpoint cv311 - midpoint cv310
*                  =148'5"-114'1.875"=34'3.125"=10.4426m
*         -segment 1:ls=131'4"-114'1.875"=5.2356m;area=619.277m**2
*                    ds=4a/p=12.497
*         -segment 2:ls=4'=1.2192m; area=197.2145m**2; ds=4a/p=6.23
*         -segment 3:ls=148'5"-135'4"=3.9878m; area=619.277m**2
*                    ds=4a/p=12.497m
*         - p (seg 2)= 126.63m  (measured)
* - reduce area of flow 302 by area of hatch (267.8395-70.625=197.2145)
*
**********************************************************************
*
fl30100  fl301  310  311  41.2496  41.2496
fl30101  197.2145  10.4426  0.73  6.2486  6.2486
fl30102  0  0  0  1
fl30103  1.0  1.0  1.0  1.0
```

```
fl30104  0.0  0.0
fl301s1  619.277  5.2356  12.497
fl301s2  197.2145  1.2192  6.23
fl301s3  619.277  3.9878  12.497
*
*****************************************************************
*   fl302 - flowpath  between cv311 and cv312
*         - grating area = 3254.2 ft**2 = 302.3251 m**2
*         - ctmt annulus area =6665.7 ft**2
*         -  no communication area = 3411.5 ft**2
*         - 73% open
*         - elevation = 161'6"=49.2252m
*         - segment 1: ls=161'6"-148'5"=3.9878m; area=619.277 m**2
*                      ds=12.497 m
*         - segment 2: ls=173'-161'6"=11'6"=3.5052m
*                      area=231.700m**2
*                      ds=4a/p=6.73      (p measured = 137.7m)
*    - reduce area of fl302 by area of hatch=302.3251-70.625=231.7m**2
*
*******************************************************************
*
fl30200  fl302  311 312  49.2252  49.2252
fl30201  231.700  7.493  0.73  6.2486  6.2486
fl30202  0  0  0  0
fl30203  1.0  1.0  1.0  1.0
fl30204  0.0  0.0
fl302s1  619.277  3.9878  12.497
fl302s2  231.700  3.5052  6.73
*
*****************************************************************
*   fl303 -flow path between cv319 and cv317
*         - elevation =208'10" = 63.6524 m
*         - containment area = 12.076.3 ft**2 = 1121.925 m**2
*         - no communication area = 7202.5 ft**2 = 669.1342 m**2
*         - grating area = 4091.6 ft**2 = 380.1221 m**2
*         - open area = 760.2 ft**2 = 70.6249 m**2
*         - total open area = 760.2 ft**2 + 0.73 *(4091.6 ft**2)
*                           = 3747.068 ft**2 = 348.114 m**2
*         - length = midpoint cv317 to midpoint cv319 = 217'6"-196'8'
*                  = 20' 10"
*         - 4*a/p=  = 6.86
*         - delta r = 62' - ri = 4.3034 m
*         - length (segment) = 208'10"-184'6"=7.4168 m
*         - reduce fl303 area by area of hatch (70.625 m**2)
*
********************************************************************
***
*
fl30300  fl303  319  317  63.6524  63.6524
fl30301  277.489  6.350  1.0  4.3034  4.3034
fl30302  0  0  0  0
fl30303  1.0   1.0  1.0  1.0
fl30304  0.0   0.0
fl303s1  277.489  7.4168  6.86
*
********************************************************************
*
*   fl304 - flow path between cv317 and cv318
```

```
*          - elevation = 226'2" = 68.9356 m
*          - area = 4873.8 ft**2 = 452.7908 m**2
*
**************************************************************************
*
fl30400   fl304  317  318   68.9356  68.9356
fl30401   452.7908  5.2832  1.0  4.3034   4.3034
fl30402   0  0  0  0
fl30403   1.0  1.0  1.0  1.0
fl30404   0.0  0.0
fl304s1   452.7908  5.2832  15.2336
*
**************************************************************************
*   fl305 - flow path between cv317 and cv314
*          - elevation = 216'8" = 66.04 m
*          - area = 484.4609 m**2
*
**************************************************************************
*
fl30500   fl305  317  314   66.04   66.04
fl30501   484.4609  16.7459  1.0  5.2832   5.2832
fl30502   3  0  0  0
fl30503   1.0  1.0  1.0  1.0
fl30504   0.0  0.0
fl305s1   484.4609  16.7459  10.5664   0.5e-5  0.0
*
**************************************************************************
*   fl306 - flow path between cv318 and cv315
*          - elevation = 234'8"= 71.5264 m
*          - area = 484.4609 m**2
*
**************************************************************************
*
fl30600   fl306  318  315  71.5264  71.5264
fl30601   484.4609  16.7459  1.0  5.2832  5.2832
fl30602   3 0  0  0
fl30603   1.0  1.0  1.0  1.0
fl30604   0.0  0.0
fl306s1   484.4609  16.7459  10.5664  0.5e-5  0.0
*
**************************************************************************
*   fl307 - flow path between cv318 and cv316
*          - elevation = 243'6" = 74.2188 m
*          - area = 452.7908 m**2
*
**************************************************************************
*
fl30700   fl307  318  316  74.2188  74.2188
fl30701   452.7908  19.1576  1.0  4.3034  4.3034
fl30702   0  0  0  0
fl30703   1.0  1.0  1.0  1.0
fl30704   0.0  0.0
fl307s1   452.4609  19.1576  15.2336
*
**************************************************************************
*   fl308 - flow path between cv315 and cv316
*          - elevation = 243'6" = 74.2188 m
*          - area = 669.1346 m**2
```

```
*
*****************************************************************
*
fl30800   fl308  315  316  74.2188  74.2188
fl30801   669.1346  11.5951  1.0  29.1885  29.1885
fl30802   0  0  0  0
fl30803   1.0  1.0  1.0  1.0
fl30804   0.0  0.0
fl308s1   669.1346  11.5951  29.1885  0.5e-5  0.0
*
*****************************************************************
*   fl309 - flow path between cv314  and cv315
*         - elevation = 226'2" = 68.9356 m
*         - area = 669.1346 m**2
*
*****************************************************************
*
fl30900   fl309  314  315   68.9356  68.9356
fl30901   669.1346  5.2832  1.0  29.1885  29.1885
fl30902   0  0  0  0
fl30903   1.0  1.0  1.0  1.0
fl30904   0.0  0.0
fl309s1   669.1346  5.2832  29.1885  0.5e-5  0.0
*
*****************************************************************
*   fl310 - flow path between cv313 and cv314
*         - elevation = 208'10" = 63.6524 m**2
*         - area = 669.1346 m**2
*
*******************************************************************
*
fl31000   fl310  313  314  63.6524  63.6524
fl31001   669.1346  2.921  1.0  29.1885  29.1885
fl31002   0  0  0  0
fl31003   1.0  1.0  1.0  1.0
fl31004   0.0  0.0
fl310s1   669.1346  2.921 29.1885  0.5e-5  0.0
*
*********************************************************************
*
*   fl399- containment failure between cv318and cv399
*         - failure pressure  56 psig (70.7 psia or 4.8746e5 Pa)
*         - failure elevation  74.21 m
*         - assumed failure area 1 ft**2 or 0.1 m**2
*
*********************************************************************
*
fl39900  cont-fail   318   399   74.21  74.21
fl39901  0.1  0.762  0.0
fl39902  3  0  0  0
fl39903  1.0  1.0
fl399s0  0.1  0.762   0.356825
fl399v0  98  97  97
*
cf09800  fail-cont   t-o-f  1  1.0 0.0
cf09803  -1.0e9  4.8746e5
cf09810  1.0  0.0  cvh-p.317
*
```

```
cf09700  cont-area   equals   1  0.0  1.0
cf09710  1.0  0.0   time
*
cf09600  cont-fail-mes  l-gt   2   1.0  0.0
cf09601  .false.
cf09605  latch
cf09606  2 'containment  failed'
cf09611  1.0   0.0  cvh-p.317
cf09612  0.0   4.8746e5   time
*
*******************************************************************
*   fl311 - flow path between cv312 and c319
*         - elevation = 184'6" = 56.2356 m
*         - ctmt annulus area = 6665.7 ft**2= 619.2638 m**2
*         - no communication area = 3750.2 ft**2 = 348.405 m**2
*         - grating area = 1909.32 ft**2 = 177.3816 m**2
*         - open area = 1006.18 ft**2 = 93.4772 m**2
*         - total area =open + 0.73 *grating area = 222.9658 m**2
*         - length = midpoint 318 - midpoint 312 = 196'8"- 173'0"
*                  = 23'8" = 7.2136 m
*         - ro = 18.8976 m
*         - 4*a/p = 2.708
*         - delta r = 1.9817
*         - length (segment) = 184'6"-161'6" = 23' =7.0104 m
*     - reduce area of fl311 by area of hatch(222.9658-70.625=152.3408)
*
*****************************************************************
*
fl31100  fl311  312  319  56.2356  56.2356
fl31101  152.3408  7.2136  1.0  1.9817  1.9817
fl31102  0  0  0  0
fl31103  1.0  1.0  1.0  1.0
fl31104  0.0  0.0
fl311s1  152.3408  7.0104  2.708
*
*****************************************************************
*   fl 312 - horizontal flowpath between cv 399 and cv 400
*          - enclosure leakage into environment
*
******************************************************************
*
*
fl31200  encl-fail  399  400  75.  75.
fl31201  1.00  0.5  1.0
fl31202  3  0  0  0
fl31203  1.0  1.0
fl312s1  0.02 0.5   0.16
*
********************************************************************
*  fl 313 - horizontal flowpath between cv 321 and cv 322
*         - midpoint of elevation = 188'= 57.3024 m
*         - area = 28 ft**2 = 2.6013 m**2
*         - k eff = 1.205
*         -  wall thickness = ls =4 1/2' = 1.3716 m
*         - p = 2 * 4' + 2 * 7' = 11.5824 m
*         - 4*a/p = ds = 0.8984
*         - f = 0.0
*         - door = 4' x 7' x 4 1/2' thick
```

```
*         - l/a = 0.0511 ft-1 , therfore l = 0.4361 m
*
*****************************************************************
*
fl31300  fl313  319  320  57.3024  57.3024
fl31301  2.6013  0.4361  1.0  2.1336  2.1336
fl31302  3  0  0  0
fl31303  1.205  1.205  999.0  999.0
fl31304  0.0  0.0
fl313s1  2.6013  0.4361  0.8984  0.5e-5  0.0
*
**********************************************************************
*  fl314 - vertical flowpath between cv 321 and cv322
*        - k tot = 1.42, keff = 1/c = 1.192
*        - area = 33.75 ft**2 = 3.1355 m**2
*        - l/a=0.1898 ; therefore l = 6.4058 ft = 1.9525 m
*        - elevation opening = 170' = 51.816 m
*        - exit elevation = 166' = 50.5968 m
*        - friction loss =0.0
*        - p = 4'6" x 6'3" = 6.5532 m
*        - 4a/p = 1.914 m
*
***********************************************************************
***
*
fl31400  fl314  322  321  51.816  50.5968
fl31401  3.1355  1.9525  1.0  1.905  1.905
fl31402  1  0  0  0
fl31403  1.192  1.192  999.0  999.0
fl31404  0.0  0.0
fl314s1   3.1355  1.9525  1.914  0.5e-5  0.0
*
***********************************************************************
*
*  fl 315 - flowpath between cv322 and cv319
*         - area = 20.93 ft**2 = 1.9445 m**2
*         - k tot = 1.4 ; keff = 1/c = 1/0.82 = 1.22
*         - l/a = 0.1953 ; therefore l = 4.088 ft = 1.246 m
*         - f =0.0
*         - assume elevation = 187' 8.5" = 57.2135 m
*         - 4a/p = 1.246
*
***********************************************************************
**
*
fl31500  fl315  319  322  57.2135  57.2135
fl31501  1.9445  1.246  1.0  0.7867  0.7867
fl31502  3  0  0  0
fl31503  1.22  1.22  999.0  999.0
fl315s1  1.9445 1.246  1.5734  0.5e-5  0.0
*
*****************************************************************
*   fl 316 - suppression pool dump (30" dump lines)
*          -  vertical flowpath between cv 313 and cv310
*          - begins at elevation = 187' 10"=57.2516 m
*          - opening = 30" o.d. pipe
*          - ends at elevation = 120'10" = 36.830 m
*          - 2 - 30" lines in parallel
```

```
*           - segment area 9.8175 ft**2 = 0.9121 m**2
*           - length = 20.422m = 20.5 m
*
********************************************************************
*
*   for  this case this flow is closed
*
fl31600  fl316  313  310  57.2516  36.830
fl31601  0.4561  20.500  0.0  0.381  0.381
fl31602  2  0  0  0
fl31603  1.0  1.0  1.0  1.0
fl31604  0.0  0.0
fl316s1  0.9121  20.500  0.762  * 2- 30" parallel lines
*fl316v1  -316  316  316  * cf  deactivated
*
cf31600 supp-pool-dump   l-a-ifte 3  1.0  0.0
cf31610  1.0  0.0   cfvalu.317
cf31611  0.0  1.0   time
cf31612  0.0  0.0   time
*
cf31700  dump-start  l-gt  2  1.0  0.0
cf31710  1.0  0.0    time
cf31711  0.0  1.0e9  time
*
*************************************************************************
*   fl 317 - horizontal flowpath from cv 312 to cv 323
*           - area = 3.6ft**2 + 16.8ft**2 = 20.4ft**2 = 1.895m**2
*           -l/a=0.177 (area weighted) , therefore l =3.61 ft = 1.101m
*           - k eff=1/c = 1.63
*           - f = 0.0
*           - elevation = 173'2"+(7'/2)=176'8"=53.848m
*           - opening height = 3' = 0.9144m
*           - 3' x 7' opening each side, therefore p = 40'=0.6218m
*
*************************************************************************
**
*
fl31700  fl317  312  323  53.848  53.848
fl31701  1.895  1.101  1.0  0.9144  0.9144
fl31702  3  0  0  0
fl31703  1.63  1.63  999.0  999.0
fl31704  0.0  0.0
fl317s1  1.895  1.101  0.6218  0.5e-5  0.0
*
*************************************************************************
**
*  fl 318 - flowpath between cv 324 (rwcu demin room) and cv 319
*          - vent area = 2 x 15ft**2 = 30ft**2 = 0.8495m**2
*          - k = 1.44, f=0.0; keff = 1/.833 = 1.200
*          - centerline elevation = 204'4" = 62.2808m
*          - vent = 12" x 15'
*          - p = 32' = 9.7536 m
*          - 4a/p = 0.3484 m
*          - l/a = 0.1812 ft-1 , therefore l =5.436' = 1.657 m
*
*************************************************************************
***
*
```

```
fl31800  fl318  319  324  62.2808  62.2808
fl31801  0.8495  1.657  1.0  0.3048  0.3048
fl31802  3  0  0  0
fl31803  1.200  1.2000  999.0  999.0
fl31804  0.0  0.0
fl318s1  0.8495  1.657  0.3484  0.5e-5  0.0
*
***********************************************************************
***
*  fl 319 - vertical flowpath between cv 325 and cv 312
*         - area = 21 ft**2 = 1.95096 m**2
*         - k tot = 1.504 ; k eff = 1/c = 1/.82 =1.22
*         - f = 0.0
*         - l/a = 0.54; therefore l = 1.05352 m
*         - assume centerline elevation = 170'10" = 52.070 m
*         - assume exit elevation = 166'10" = 50.8508 m
*
***********************************************************************
***
*
fl31900  fl319  312  325  52.070  50.8508
fl31901  1.951  1.0535  1.0  0.788  0.788
fl31902  1  0  0  0
fl31903  1.22  1.22  999.0  999.0
fl31904  0.0  0.0
fl319s1  1.951  1.0535  1.576  0.5e-5  0.0
*
***********************************************************************
***
*
*  fl 320 - horizontal flowpath between cv 325 and cv 326
*         - assume elevation = 164'4" = 50.0898 m
*         - area = 21 ft**2 = 1.950964 m**2 = 1.9510 m**2
*         - k eff = 1/c =1/0.84 = 1.19
*         - l/a = 0.499 ft-1 ; l = 0.9735 m
*         - f = 0.0
*
***********************************************************************
**
*
fl32000  fl320  325  326  50.0888  50.0888
fl32001  1.9510  0.9735  1.0  0.788  0.788
fl32002  3  0  0  0
fl32003  1.19  1.19  999.0  999.0
fl32004  0.0  0.0
fl320s1  1.9510  0.9735  1.576  0.5e-5  0.0
*
****************************************************************
*     the  following flowpaths represent the equipment hatch
*     to dw-ww annular regions
*
****************************************************************
*
fl32500  hatch-dome  327  317  63.6524  63.6524
fl32501  70.625  13.843  1.0  6.1  6.1
fl32502  0  0  0  0
fl32503  1.0  1.0
fl325s1  70.625  13.843  10.0  0.5e-5  0.0
```

```
*
fl32400  hatch-uppann  327  319  59.944  59.944
fl32401  127.73  49.55  1.0  17.22  17.22
fl32402  3  0  0  0
fl32403  1.5  1.5
fl324s1  127.73  49.55  10.0  0.5e-5  0.0
*
fl32300  hatch-uppann  327  312  52.7304  52.7304
fl32301  120.73  49.55  1.0  17.22  17.22
fl32302  3  0  0  0
fl32303  1.5  1.5
fl323s1  120.73  49.55  10.0  0.5e-5  0.0
*
fl32200  hatch-lowann  327  311  45.2374  45.2374
fl32201  137.35  49.55  1.0  17.22  17.22
fl32202  3  0  0  0
fl32203  1.0  1.0
fl322s1  137.35  49.55  10.0  0.5e-5  0.0
*
fl32100  hatch-ww  310  327  41.2496  41.2496
fl32101  70.625  17.656  1.0  6.1  6.1
fl32102  0  0  0  0
fl32103  1.0  1.0
fl321s1  70.625  17.656  10.0  0.5e-5  0.0
*
***********************************************************************
*
*     core  input
*
***********************************************************************
*
*       nrad   naxl  ntlp   ncvol   nlh    npntot
cor00000  4     13     6      3      5       4
*          rfuel     rclad     drgap     pitch     dxcan       dxss    dzlh
cor00001 0.00466  0.005572  7.62e-5   0.0143   0.003048  0.00114  0.2413
*
cor00002   bwr   b4c
*    radiative  exchange  factors
cor00003  0.50   0.95   0.50    0.50    0.50
*          ntpcor
cor00004    101
*          candling  heat  transfer  coefficients
cor00005   1000.0   1000.0   1000.0   1000.0  1000.0   1000.0
*          materials interaction switch
cor00006    1
*          candling secondary  materials   transport   parameters
cor00007   1    2    2    2    0.2    1.0    1.0    0.0
*          debris formation parameters
cor00008   0.0001    0.0001
* lower head failure model (* values to be changed for the  BH  package)
*          hdbpn*   hdblh    tpfail*   cdispn
cor00009  1000.0   1000.0   10273.15   1.0  * high tpfail
*
sc00010  1244    0.4  3
sc00011  1020  360.0  1
sc00012  1020   60.0  2
*
*          hdbh2o  ppfail  iaxsup  vfall
```

```
cor00012    750.0   2.0e7     6      0.1
*       axial  segment  input
*
*           z          dz       porin  pordp
corz1301  46.7439  0.3652     0.53  0.3
corz1201  45.9819  0.762      0.53  0.3  * active fuel ends
corz1101  45.2199  0.762      0.53  0.3
corz1001  44.4579  0.762      0.53  0.3
corz0901  43.6959  0.762      0.53  0.3
corz0801  42.9339  0.762      0.53  0.3  * active fuel starts
corz0701  42.7071  0.2268     0.53  0.3
corz0601  42.6563  0.0508     0.00  0.3  * core plate
corz0501  41.6744  0.9819     0.00  0.3
corz0401  40.6925  0.9819     0.00  0.3
corz0301  39.7106  0.9819     0.00  0.3
corz0201  38.7287  0.9819     0.00  0.3
corz0101  37.4396  1.2891     0.00  0.3
*
*     radial boundary heat structures  and  support flag
*              ihsa    isup
corz1302    10113
corz1202    10112            *end of active fuel
corz1102    10111
corz1002    10110
corz0902    10109
corz0802    10108            *beginning of active fuel
corz0702    10107
corz0602    10006    11       *core plate
corz0502    10005
corz0402    10004
corz0302    10003
corz0202    10002
corz0102    10001
*
*           radial  rings  cross-sectional  areas
corr0101   10.5071
corr0201    3.7942
corr0301    2.1160
corr0401    2.1561
* total    18.5734
*
*      upper boundary  heat  structures
corr0102   10302
corr0202   10302
corr0302   10302
corr0402   10302
*
*      cell  reference  and  boundary  volumes
*        irefn    icvhc  icvhb
* ring 1
cor11301   108
cor11201   108
cor11101   108
cor11001   108
cor10901   108
cor10801    -1      101   102
cor10701   108
cor10601   101
```

```
cor10501   101
cor10401   101
cor10301   101
cor10201   101
cor10101    -1      100   100
*  ring 2
cor21301   208
cor21201   208
cor21101   208
cor21001   208
cor20901   208
cor20801    -1      101   102
cor20701   208
cor20601   201
cor20501   201
cor20401   201
cor20301   201
cor20201   201
cor20101    -1      100   100
*  ring 3
cor31301   308
cor31201   308
cor31101   308
cor31001   308
cor30901   308
cor30801    -1      101   102
cor30701   308
cor30601   301
cor30501   301
cor30401   301
cor30301   301
cor30201   301
cor30101    -1      100   100
*  ring 4
cor41301   408
cor41201   408
cor41101   408
cor41001   408
cor40901   408
cor40801    -1      101   102
cor40701   408
cor40601   401
cor40501   401
cor40401   401
cor40301   401
cor40201   401
cor40101    -1      100   100
*
*    cell  components  masses in kg
*
*  totals for all four rings (kg)
*
*  level  uo2    zr-clad  ss(can+ Crods)   b4c     zr-can      inconel
*   13             2655         1360        0     3142
*   12   32030     8125         3645 r   250.3    6556           229.6
*   11   32030     8125         3645 r   250.3    6556           229.6
*   10   32030     8125         3645 r   250.3    6556           229.6
*    9   32030     8125         3645 r   250.3    6556           229.6
```

```
*    8   32030      8125        3645 r  250.3    6556           229.6
*    7               120       10606.8           100
*    6                         16636
*    5                         23806
*    4                         11023
*    3                         21625
*    2                         21133
*    1                         15424
* total 160150     43400      139838.8  1251.5   36022          1148.0   kg
*
*  ring  1  (0.5657  volume  fraction)
*         uo2       zr-clad      ss         b4c     zr-can
cor11302      0.0   1502.0      769.4      0.0    1777.4   0.0    0.0
cor11202  18119.4   4596.3     2061.9    141.6    3708.7   0.0  129.9
cor11102  18119.4   4596.3     2061.9    141.6    3708.7   0.0  129.9
cor11002  18119.4   4596.3     2061.9    141.6    3708.7   0.0  129.9
cor10902  18119.4   4596.3     2061.9    141.6    3708.7   0.0  129.9
cor10802  18119.4   4596.3     2061.9    141.6    3708.7   0.0  129.9
cor10702      0.0     68.0     6000.3      0.0      56.6   0.0    0.0
cor10602      0.0      0.0     9411.0      0.0       0.0
cor10502      0.0      0.0    13467.1      0.0       0.0
cor10402      0.0      0.0     6235.7      0.0       0.0
cor10302      0.0      0.0    12233.3      0.0       0.0
cor10202      0.0      0.0    11954.9      0.0       0.0
cor10102      0.0      0.0     8725.4      0.0       0.0
*  ring  2  (0.2043  volume   fraction)
cor21302      0.0    542.4      277.8      0.0     641.9   0.0    0.0
cor21202   6543.7   1660.0      744.7     51.1    1339.4   0.0   46.9
cor21102   6543.7   1660.0      744.7     51.1    1339.4   0.0   46.9
cor21002   6543.7   1660.0      744.7     51.1    1339.4   0.0   46.9
cor20902   6543.7   1660.0      744.7     51.1    1339.4   0.0   46.9
cor20802   6543.7   1660.0      744.7     51.1    1339.4   0.0   46.9
cor20702      0.0     24.5     2166.9      0.0      20.4   0.0    0.0
cor20602      0.0      0.0     3398.7      0.0       0.0
cor20502      0.0      0.0     4863.6      0.0       0.0
cor20402      0.0      0.0     2252.0      0.0       0.0
cor20302      0.0      0.0     4418.0      0.0       0.0
cor20202      0.0      0.0     4317.5      0.0       0.0
cor20102      0.0      0.0     3151.1      0.0       0.0
*  ring  3  (0.1139  volume  fraction)
cor31302      0.0    302.4      154.9      0.0     357.9   0.0    0.0
cor31202   3648.2    925.4      415.2     28.5     746.7   0.0   26.2
cor31102   3648.2    925.4      415.2     28.5     746.7   0.0   26.2
cor31002   3648.2    925.4      415.2     28.5     746.7   0.0   26.2
cor30902   3648.2    925.4      415.2     28.5     746.7   0.0   26.2
cor30802   3648.2    925.4      415.2     28.5     746.7   0.0   26.2
cor30702      0.0     13.6     1208.1      0.0      11.4   0.0    0.0
cor30602      0.0      0.0     1894.8      0.0       0.0
cor30502      0.0      0.0     2711.5      0.0       0.0
cor30402      0.0      0.0     1255.5      0.0       0.0
cor30302      0.0      0.0     2463.1      0.0       0.0
cor30202      0.0      0.0     2407.4      0.0       0.0
cor30102      0.0      0.0     1756.8      0.0       0.0
*  ring 4  (0.1161  volume  fraction)
cor41302      0.0    308.3      157.9      0.0     364.8   0.0    0.0
cor41202   3718.7    943.3      423.2     29.1     761.2   0.0   26.7
cor41102   3718.7    943.3      423.2     29.1     761.2   0.0   26.7
cor41002   3718.7    943.3      423.2     29.1     761.2   0.0   26.7
```

```
cor40902   3718.7    943.3      423.2     29.1     761.2  0.0   26.7
cor40802   3718.7    943.3      423.2     29.1     761.2  0.0   26.7
cor40702      0.0     13.9     1231.4      0.0      11.6  0.0    0.0
cor40602      0.0      0.0     1931.4      0.0       0.0
cor40502      0.0      0.0     2763.9      0.0       0.0
cor40402      0.0      0.0     1279.8      0.0       0.0
cor40302      0.0      0.0     2510.7      0.0       0.0
cor40202      0.0      0.0     2453.5      0.0       0.0
cor40102      0.0      0.0     1790.7      0.0       0.0
*
*   cell  initial  temperatures
* ring 1   uo2      zr-cla    other   canister
cor10803 1237.0     595.0    556.0   556.0
cor10103  551.0     551.0    551.0   551.0
* ring 2
cor20803 1237.0     595.0    556.0   556.0
cor20103  551.0     551.0    551.0   551.0
* ring 3
cor30803 1237.0     595.0    556.0   556.0
cor30103  551.0     551.0    551.0   551.0
* ring 4
cor40803 1237.0     595.0    556.0   556.0
cor40103  551.0     551.0    551.0   551.0
*
*  equivalent  diameters
* ring 1   clad    other   debris  can-in  can-out
cor11304  0.0122  0.010   0.010   0.132   0.022
cor10804  0.0122  0.015   0.010   0.132   0.022
cor10704  0.0122  0.01    0.010   0.132   0.022
cor10604  0.0122  0.086   0.01    0.132   0.022
cor10204  0.0122  0.154   0.01    0.132   0.022
cor10104  0.0122  1.195   0.01    0.132   0.022
* ring 2
cor21304  0.0122  0.01    0.01    0.132   0.022
cor20804  0.0122  0.015   0.01    0.132   0.022
cor20704  0.0122  0.01    0.01    0.132   0.022
cor20604  0.0122  0.086   0.01    0.132   0.022
cor20204  0.0122  0.154   0.01    0.132   0.022
cor20104  0.0122  1.195   0.01    0.132   0.022
* ring 3
cor31304  0.0122  0.01    0.01    0.132   0.022
cor30804  0.0122  0.015   0.01    0.132   0.022
cor30704  0.0122  0.01    0.01    0.132   0.022
cor30604  0.0122  0.086   0.01    0.132   0.022
cor30204  0.0122  0.154   0.01    0.132   0.022
cor30104  0.0122  1.195   0.01    0.132   0.022
* ring 4
cor41304  0.0122  0.01    0.01    0.132   0.022
cor40804  0.0122  0.015   0.01    0.132   0.022
cor40704  0.0122  0.01    0.01    0.132   0.022
cor40604  0.0122  0.086   0.01    0.132   0.022
cor40204  0.0122  0.154   0.01    0.132   0.022
cor40104  0.0122  1.195   0.01    0.132   0.022
*
*    cell  boundary  and  flow  areas
*
*                   total flows
* node    dz        aflowc  aflowb
```

```
*  13      0.3652    7.691   2.42
*  12-8    0.762     7.691   2.42
*   7      0.2268   10.968   3.205
*   6      0.9819    4.69
*   5      0.9819    3.632
*   4      0.9819    5.126
*   3      0.9819    8.906
*   2      0.9819   11.077
*   1      1.2891   11.028
*
* ring 1  r=6ft      2(pi)r=11.49m  volume fraction=0.5657
* ring 2  r=7ft      2(pi)r=13.406m volume fraction=0.2043
* ring 3  r=7.5ft    2(pi)r=14.363m volume fraction=0.1139
* ring 4 r=7.9773ft 2(pi)r=15.277m volume fraction=0.1161
*
* ring 1   ascelr   aflowc  aflowb
cor11305   4.197    4.351   1.369
cor10805   8.756    4.351   1.369
cor10705   2.606    6.205   1.813
cor10605   0.584    2.653   0.0
cor10505  11.283    2.055   0.0
cor10405  11.283    2.900   0.0
cor10305  11.283    5.038   0.0
cor10205  11.283    6.266   0.0
cor10105  14.813    6.239   0.0
* ring 2
cor21305   4.896    1.571   0.494
cor20805  10.215    1.571   0.494
cor20705   3.04     2.241   0.655
cor20605   0.681    0.958   0.0
cor20505  13.163    0.742   0.0
cor20405  13.163    1.047   0.0
cor20305  13.163    1.820   0.0
cor20205  13.163    2.263   0.0
cor20105  17.282    2.253   0.0
* ring 3
cor31305   5.245    0.876   0.276
cor30805  10.945    0.876   0.276
cor30705   3.258    1.249   0.365
cor30605   0.73     0.534   0.0
cor30505  14.103    0.414   0.0
cor30405  14.103    0.584   0.0
cor30305  14.103    1.014   0.0
cor30205  14.103    1.262   0.0
cor30105  18.515    1.256   0.0
* ring 4
cor41305   5.579    0.893   0.281
cor40805  11.641    0.893   0.281
cor40705   3.465    1.274   0.372
cor40605   0.776    0.545   0.0
cor40505  15.0      0.422   0.0
cor40405  15.0      0.595   0.0
cor40305  15.0      1.034   0.0
cor40205  15.0      1.286   0.0
cor40105  19.694    1.280   0.0
*
*    surface  areas
*
```

```
* totals for all four rings
*
*  node     fuel     cladding     other   can-in
*   13         0        564.8      60.1    154.8
*   12      1356       1728       153.5    323
*   11      1356       1728       153.5    323
*   10      1356       1728       153.5    323
*    9      1356       1728       153.5    323
*    8      1356       1728       153.5    323
*    7         0         20.0     170.4     37.25
*    6                             10.25
*    5                            171.6
*    4                            171.6
*    3                            171.6
*    2                            171.6
*    1                             83.71
*
* ring fractions
* ring 1  0.5657
* ring 2  0.2043
* ring 3  0.1139
* ring 3  0.1161
*
* ring 1    fuel     cladding     other   can-in
cor11306     0.0        319.5      34.0    87.6
cor10806   767.1        977.6      86.8   182.7
cor10706     0.0         11.3      96.4    21.1
cor10606     0.0          0.0       5.8     0.0
cor10206     0.0          0.0      97.1     0.0
cor10106     0.0          0.0      47.4     0.0
* ring 2
cor21306     0.0        115.4      12.3    31.6
cor20806   277.0        353.0      31.4    66.0
cor20706     0.0          4.1      34.8     7.6
cor20606     0.0          0.0       2.1     0.0
cor20206     0.0          0.0      35.1     0.0
cor20106     0.0          0.0      17.1     0.0
* ring 3
cor31306     0.0         64.4       6.8    17.6
cor30806   154.5        196.8      17.5    36.8
cor30706     0.0          2.3      19.5     4.23
cor30606     0.0          0.0       1.2     0.0
cor30206     0.0          0.0      19.6     0.0
cor30106     0.0          0.0       9.5     0.0
* ring 4
cor41306     0.0         65.6       7.0    18.0
cor40806   157.4        200.6      19.8    37.5
cor40706     0.0          2.3      20.4     4.32
cor40606     0.0          0.0       1.2     0.0
cor40206     0.0          0.0      19.9     0.0
cor40106     0.0          0.0       9.7     0.0
*
*      lower  head  input
*         irs  ire     xmlh         tlh        aslh icvlh icvcav
corlhd01   1    1    22020.0      520.0       10.5   0    202
corlhd02   2    2     7953.0      520.0        3.8   0    202
corlhd03   3    3     4434.0      520.0        2.1   0    202
corlhd04   4    4     4519.0      520.0        2.2   0    202
```

```
* totals               38926.0             18.6
*
*       ipnref irp      xmpn      tpn      aspn  axpn    dflpn
corpen01  -1    1     1555.0    520.0     46.0  14.0    0.038
corpen02  -1    2      561.0    520.0     17.0   5.0    0.038
corpen03  -1    3      313.0    520.0      9.0   3.0    0.038
corpen04  -1    4      319.0    520.0      9.0   3.0    0.038
*   totals             2748.0             81.0  25.0
*
*    control  volume temperature input
*           ivol  itin
cortin01    100   100
cortin02    102   100
cortin03    101   100
*
************************************************************************
*******
*
*       BH  input
*
r*i*f 'bh'
*
************************************************************************
*******
************************************************************************
*******
*
*     radionuclide input
*      and
*     decay  heat  input
*
***********************************************************************
*
rn1000 0
rn1001 5 1 16 14 13 0 0   * 16 classes, includes CsI
rn1100 1.0e-6 50.e-6 1000.
*
*
* core fission product inventories
* based on 3578 mw(t) bwr inventories
*
*  add new class of CsI
rncls0100   16
rncls0101   2   1.0  *  Cs
rncls0102   4   0.5  *   I
*
*   decay  heat  input
*
dchreactor  bwr
dchshut    0  0.0
dchdecpow  origen
sc00001 3210 1.07123  1 * increase power to  3833 Mw, 3833/3578=1.07127
dchdefcls0  all
dchclsnorm no
*
*    decay heat for CsI
*
dchnem0100   Ci   1.0e-6
```

```
dchnem0101 0.0 5.00574e5 6.12 4.03447e5 18.0 3.496544e5  61.2  2.8166e5
dchnem0102  118.8  2.390796e5   612.0  2.039649e5  1188.0  1.865569e5
dchnem0103 3600. 1.45241e5 7200. 1.1339e5 14400. 7.513e4 36000. 4.6456e4
dchnem0104  72000.0  2.84631e4  86400.0  2.39715e4   129600.0  1.57395e4
dchnem0105  172800.0   1.19938e4   259200.0   8.2425e3
dchcls0160  CsI
dchcls0161  Ci
*
* aerosol coefficients
*
rnacoef 1
*
rnfp000   -2   * CORSOR-M with S/V ratio
*sc00020   7103  1.0  16
*
*  fission product distribution
*  ring  1       axial    radial
rnfpn11301   0  0.0       0.0
rnfpn11201   0  0.13683   0.7199
rnfpn11101   0  0.23393   0.7199
rnfpn11001   0  0.21804   0.7199
rnfpn10901   0  0.21466   0.7199
rnfpn10801   0  0.19654   0.7199
rnfpn10701   0  0.0       0.0
rnfpn10601   0  0.0       0.0
*  ring 2
rnfpn21301   0  0.0       0.0
rnfpn21201   0  0.14222   0.1755
rnfpn21101   0  0.23919   0.1755
rnfpn21001   0  0.21581   0.1755
rnfpn20901   0  0.20778   0.1755
rnfpn20801   0  0.195     0.1755
rnfpn20701   0  0.0       0.0
rnfpn20601   0  0.0       0.0
*  ring 3
rnfpn31301   0  0.0       0.0
rnfpn31201   0  0.17792   0.0575
rnfpn31101   0  0.25872   0.0575
rnfpn31001   0  0.21617   0.0575
rnfpn30901   0  0.19163   0.0575
rnfpn30801   0  0.15557   0.0575
rnfpn30701   0  0.0       0.0
rnfpn30601   0  0.0       0.0
* ring 4
rnfpn41301   0  0.0       0.0
rnfpn41201   0  0.1836    0.0471
rnfpn41101   0  0.2624    0.0471
rnfpn41001   0  0.2201    0.0471
rnfpn40901   0  0.1851    0.0471
rnfpn40801   0  0.1488    0.0471
rnfpn40701   0  0.0       0.0
rnfpn40601   0  0.0       0.0
*
* gap fractions
*
rngap10700  1173.0
rngap10701  1  0.03     1.0  * Noble gases
rngap10702  2  0.05     1.0  * Cs
```

```
rngap10703  3  0.000001 1.0   * Ba, Sr
rngap10704  4  0.017    1.0   * I
rngap10705  5  0.0001   1.0   * Te
*
rngap10800  1173.0
rngap10801  -107  1.0  1.0
rngap10900  1173.0
rngap10901  -107  1.0  1.0
rngap11000  1173.0
rngap11001  -107  1.0  1.0
rngap11100  1173.0
rngap11101  -107  1.0  1.0
rngap11200  1173.0
rngap11201  -107  1.0  1.0
rngap11300  1173.0
rngap11301  -107  1.0  1.0
*
rngap20700  1173.0
rngap20701  -107  1.0  1.0
rngap20800  1173.0
rngap20801  -107  1.0  1.0
rngap20900  1173.0
rngap20901  -107  1.0  1.0
rngap21000  1173.0
rngap21001  -107  1.0  1.0
rngap21100  1173.0
rngap21101  -107  1.0  1.0
rngap21200  1173.0
rngap21201  -107  1.0  1.0
rngap21300  1173.0
rngap21301  -107  1.0  1.0
*
rngap30700  1173.0
rngap30701  -107  1.0  1.0
rngap30800  1173.0
rngap30801  -107  1.0  1.0
rngap30900  1173.0
rngap30901  -107  1.0  1.0
rngap31000  1173.0
rngap31001  -107  1.0  1.0
rngap31100  1173.0
rngap31101  -107  1.0  1.0
rngap31200  1173.0
rngap31201  -107  1.0  1.0
rngap31300  1173.0
rngap31301  -107  1.0  1.0
*
rngap40700  1173.0
rngap40701  -107  1.0  1.0
rngap40800  1173.0
rngap40801  -107  1.0  1.0
rngap40900  1173.0
rngap40901  -107  1.0  1.0
rngap41000  1173.0
rngap41001  -107  1.0  1.0
rngap41100  1173.0
rngap41101  -107  1.0  1.0
rngap41200  1173.0
```

```
rngap41201  -107  1.0  1.0
rngap41300  1173.0
rngap41301  -107  1.0  1.0
*
*  vanesa to class map
rnvncl01   25  16
*
*  deposition surfaces
*
*  settling areas
*  areas are from flows connecting both volumes
*          fr    to     elev         area
*
rnset001  204   206    49.2252     218.7718  *flow 203
rnset002  206   207    44.9834     218.9539  *flow 202
rnset003  207   208    35.7632     156.2397  *flow 201
rnset004  207   203    35.7632      51.4409  *flow 214
rnset005  100   101    42.7071        7.6     *flow  10
rnset006  102   100    42.7071        6.7     *flow  11
rnset007  101   103    47.1091        7.6     *flow  12
rnset008  103   102    47.1091        6.7     *flow  13
rnset009  104   103    52.88        28.64    *flow  14
rnset010  317   319    63.6524     277.489   *flow 303
rnset011  319   312    56.2356     152.3408  *flow 311
rnset012  312   311    49.2252     231.7     *flow 302
rnset013  311   310    41.2496     197.2145  *flow 301
rnset014  201   205    52.8066      23.2527  *flow 205
rnset015  104   105    52.88        16.05    *flow  15
rnset016  312   325    50.0          1.951   *flow 319
rnset017  205   202    36.9951       1.824   *flow 207
rnset018  209   201    56.0324       0.8100  *flow 206
rnset019  105   100    41.01         2.6279  *flow  16
rnset020  317   327    63.6524      70.625   *flow 325
rnset021  327   310    41.2496      70.625   *flow 321
rnset022  400   400    75.0         10.0     *assumed value
rnset023  313   314    63.6524     669.1346  *flow 310
rnset024  314   315    68.9356     669.1346  *flow 309
rnset025  315   316    74.2188     669.1346  *flow 308
rnset026  317   318    68.9356     452.7908  *flow 304
rnset027  318   316    74.2188     452.7908  *flow 307
*
*
*
*  pool scrubbing - rn package
*    01-suppression pool
*    04-pedestal cavity
*
rn2pls01  100  0.005  1.5  0.20  1.16
rn2pls02  101  0.005  1.5  0.20  1.16
rn2pls03  102  0.005  1.5  0.20  1.16
rn2pls04 1001  0.005  1.5  0.20  1.16
*
*
*
************************************************************************
*
* heat structure input
*
```

```
************************************************************************
*
*       core   heat    slabs
*
*
hs10001000   6   2  0  0
hs10001001   low-head-1
hs10001002   38.014   1.0
hs10001003   1.0
hs10001004   401  0
hs10001100   -1    1     2.5
hs10001101   2.54206  2
hs10001102   2.58412  3
hs10001103   2.62619  4
hs10001104   2.66825  5
hs10001105   2.71031  6
hs10001200   -1
hs10001201   carbon-steel     5
hs10001300   0
hs10001400   1   100    int  0.5   0.5
hs10001500   1.0    2.5    0.7147
hs10001600  5120  205    ext  1.0   1.0
hs10001700   1.0    2.71   0.7147
*
hs10002000   6   2   0  0
hs10002001   low-head-2
hs10002002   38.7287  1.0
hs10002003   1.0
hs10002004   402  0
hs10002100   -1       1   3.1877
hs10002101   3.2298  2
hs10002102   3.2718  3
hs10002103   3.3139  4
hs10002104   3.356   5
hs10002105   3.398   6
hs10002200   -1
hs10002201   carbon-steel   5
hs10002300   0
hs10002400   1   100   int  0.5   0.5
hs10002500   1.0   3.23  0.9819
hs10002600  5120   205    ext  1.0  1.0
hs10002700   1.0   3.4    0.9819
*
hs10003000   6   2   0  0
hs10003001   low-head-3
hs10003002   39.7106  1.0
hs10003003   1.0
hs10003004   403  0
hs10003100   10002   1   3.1877
hs10003200   10002
hs10003300   0
hs10003400   1   100   int   0.5  0.5
hs10003500   1.0   3.2  0.9819
hs10003600  5120 205   ext   1.0  1.0
hs10003700   1.0   3.4   0.9819
*
hs10004000   5   2   0  0
hs10004001   lp-shroud-4
```

```
hs10004002   41.01   1.0
hs10004003   1.0
hs10004004   404  0
hs10004100   -1       1   2.638
hs10004101   2.654    2
hs10004102   2.670    3
hs10004103   2.686    4
hs10004104   2.702    5
hs10004200   -1
hs10004201   stainless-steel    4
hs10004300   0
hs10004400   1  100   int   0.5  0.5
hs10004500   1.0   2.638   0.6644
hs10004600   1  105   ext  0.5   0.5
hs10004601   0.9  gray-gas-a   0.1
hs10004700   1.0   2.702    0.6644
*
hs10005000   5  2  0  0
hs10005001   lp-shroud-5
hs10005002   41.6744  1.0
hs10005003   1.0
hs10005004   405   0
hs10005100   10004   1   2.638
hs10005200   10004
hs10005300   0
hs10005400   1  100  int  0.5  0.5
hs10005500   1.0  2.638   0.9819
hs10005600   1  105   ext  0.5  0.5
hs10005601   0.9  gray-gas-a  0.1
hs10005700   1.0  2.702  0.9819
*
hs10006000   5  2  -1  0
hs10006001   cp-shroud-6
hs10006002   42.6563 1.0
hs10006003   1.0
hs10006004   406  0
hs10006100   -1   1   2.70256
hs10006101   2.71526   2
hs10006102   2.72796   3
hs10006103   2.74066   4
hs10006104   2.75336   5
hs10006200   -1
hs10006201   stainless-steel  4
hs10006300   0
hs10006400   1   100   int   0.5  0.5
hs10006500   1.0   2.7026 0.0508
hs10006600   1   105   ext   0.5  0.5
hs10006601   0.9  gray-gas-a   0.1
hs10006700   1.0  2.7534  0.0508
hs10006800   -1
hs10006801   541.6  1
hs10006802   537.5  2
hs10006803   533.5  3
hs10006804   529.5  4
hs10006805   525.5  5
*
hs10010000   5  2  0  0
hs10010001   lp-shroud-24
```

```
hs10010002   38.7287  1.0
hs10010003   1.0
hs10010100   10004  1  2.638
hs10010200   10004
hs10010300   0
hs10010400   1   100  int  0.5 0.5
hs10010401   0.9  gray-gas-a   0.1
hs10010500   1.0  2.638  1.22673
hs10010600   1   100  ext  0.5  0.5
hs10010601   0.9  gray-gas-a  0.1
hs10010700   1.0  2.702  1.22673
*
hs10011000   5  2  0  0
hs10011001   baffle-bh  *part of hs10010, added for bh
hs10011002   41.01  1.0
hs10011003   1.0
hs10011100   10004  1  2.638
hs10011200   10004
hs10011300   0
hs10011400   1  100  int  0.5  0.5
hs10011401   0.9  gray-gas-a  0.1
hs10011500   1.0  2.638  0.33280
hs10011600   1  105  ext  0.5  0.5
hs10011601   0.9  gray-gas-a  0.1
hs10011700   1.0  2.702  0.33280
*
hs10107000   5  2  0  0
hs10107001   core-shroud-7
hs10107002   42.7071   1.0
hs10107003   1.0
hs10107004   407  0
hs10107100   10006   1   2.70256
hs10107200   10006
hs10107300   0
hs10107400   1  101   int  0.5  0.5
hs10107500   1.0  2.70256  0.2268
hs10107600   1   105  ext  0.5  0.5
hs10107601   0.9   gray-gas-a  0.1
hs10107700   1.0 2.7534  0.2268
*
hs10108000   5  2  0  0
hs10108001   core-shroud-8
hs10108002   42.9339   1.0
hs10108003   1.0
hs10108004   408  0
hs10108100   10006  1  2.70256
hs10108200   10006
hs10108300   0
hs10108400   1  101  int  0.5  0.5
hs10108500   1.0  2.703  0.762
hs10108600   1  105  ext  0.5  0.5
hs10108601   0.9  gray-gas-a  0.1
hs10108700   1.0  2.7534 0.762
*
hs10109000   5   2   0  0
hs10109001   core-shroud-9
hs10109002   43.6959   1.0
hs10109003   1.0
```

```
hs10109004   409   0
hs10109100   10006  1  2.70256
hs10109200   10006
hs10109300   0
hs10109400   1  101  int  0.5  0.5
hs10109500   1.0  2.703  0.762
hs10109600   1  105   ext  0.5  0.5
hs10109601   0.9  gray-gas-a  0.1
hs10109700   1.0   2.7534 0.762
*
hs10110000   5  2  0  0
hs10110001   core-shroud-10
hs10110002   44.4579   1.0
hs10110003   1.0
hs10110004   410   0
hs10110100   10006  1  2.70256
hs10110200   10006
hs10110300   0
hs10110400   1  101  int   0.5  0.5
hs10110500   1.0  2.703  0.762
hs10110600   1  105  ext  0.5  0.5
hs10110601   0.9  gray-gas-a  0.1
hs10110700   1.0  2.7534  0.762
*
hs10111000   5  2  0  0
hs10111001   core-shroud-11
hs10111002   45.2199  1.0
hs10111003   1.0
hs10111004   411   0
hs10111100   10006  1  2.70256
hs10111200   10006
hs10111300   0
hs10111400   1  101  int  0.5  0.5
hs10111500   1.0  2.703   0.762
hs10111600   1  105  ext  0.5 0.5
hs10111601   0.9  gray-gas-a  0.1
hs10111700   1.0  2.7534  0.762
*
hs10112000   5  2   0   0
hs10112001   core-shroud-12
hs10112002   45.9819  1.0
hs10112003   1.0
hs10112004   412   0
hs10112100   10006  1  2.70256
hs10112200   10006
hs10112300   0
hs10112400   1   101  int  0.5  0.5
hs10112500   1.0  2.703  0.762
hs10112600   1   105  int  0.5  0.5
hs10112601   0.9  gray-gas-a  0.1
hs10112700   1.0  2.7534   0.762
*
hs10113000   5  2  0  0
hs10113001   core-shroud-13
hs10113002   46.7439 1.0
hs10113003   1.0
hs10113004   413  0
hs10113100   -1  1   2.67132
```

```
hs10113101   2.69723   2
hs10113102   2.72314   3
hs10113103   2.74904   4
hs10113104   2.77495   5
hs10113200   -1
hs10113201   stainless-steel  4
hs10113300   0
hs10113400   1  101  int  0.5  0.5
hs10113500   1.0  2.6713  0.3651
hs10113600   1  105  ext  0.5  0.5
hs10113601   0.9  gray-gas-a  0.1
hs10113700   1.0  2.775  0.3651
*
hs10301000   5  2  0  0
hs10301001   up-shroud
hs10301002   47.1091  1.0
hs10301003   1.0
hs10301100   -1     1   2.784
hs10301101   2.797  2
hs10301102   2.809  3
hs10301103   2.822  4
hs10301104   2.835  5
hs10301200   -1
hs10301201   stainless-steel  4
hs10301300   0
hs10301400   1  103  int  0.5  0.5
hs10301500   1.0  2.784  1.168
hs10301600   1  105   ext  0.5 0.5
hs10301601   0.9  gray-gas-a  0.1
hs10301700   1.0  2.835  1.168
*
hs10302000   5  1  0  0
hs10302001   up-shroud-dome
hs10302002   48.278   0.0
hs10302003   1.0
hs10302100   -1     1  0.0
hs10302101   0.0127 2
hs10302102   0.0254 3
hs10302103   0.0381 4
hs10302104   0.0508 5
hs10302200   -1
hs10302201   stainless-steel  4
hs10302300   0
hs10302400   1  103   int  1.0  1.0
hs10302500   49.4   5.67   0.815
hs10302600   1  103  ext  1.0  1.0
hs10302601   0.9  gray-gas-a  0.1
hs10302700   49.4   5.67   0.815
*
hs10303000   5  1 -1  0
hs10303001   separators
hs10303002   49.093   1.0
hs10303003   1.0
hs10303100   -1       1   0.0
hs10303101   0.001356 2
hs10303102   0.002711 3
hs10303103   0.004067 4
hs10303104   0.005423 5
```

```
hs10303200   -1
hs10303201   stainless-steel    4
hs10303300   0
hs10303400   1   103   int   0.5  0.5
hs10303500   855.8   0.26  3.787
hs10303600   1   105   ext  0.5   0.5
hs10303700   855.8   0.26 3.787
hs10303800   -1
hs10303801   550.0  5
*
hs10401000   5  1  0  0
hs10401001   dryers
hs10401002   52.88   1.0
hs10401003   1.0
hs10401100   -1        1   0.0
hs10401101   0.000611 2
hs10401102   0.001221 3
hs10401103   0.001832 4
hs10401104   0.002443 5
hs10401200   -1
hs10401201   stainless-steel   4
hs10401300   0
hs10401400   1   104   int  1.0  1.0
hs10401500   2000.0   0.8645  3.0
hs10401600   1  104   ext   1.0  1.0
hs10401700   2000.0   0.8645  3.0
*
*
*********************************************************************
*   hs20145xnn - misc steel horizontal heat slab for cv 201
*              - elevation = 176'9" = 53.8734 m
*              - area = 1490.2 ft**2 = 138.43 m**2
*              - length = delta r = 1.5664 m
*              -  assume thickness = 1/8" = 0.003175 m
*
************************************************************************
*
hs20145000  5  1  -1  0
hs20145001  misc-steel-cv201
hs20145002  53.8734  0.0
hs20145003  1.0
hs20145100  -1  1  0.0
hs20145102  0.000794  2 * 1/32" steel
hs20145103  0.001589 3  * 2/32" steel
hs20145104  0.002381 4  * 3/32 " steel
hs20145105  0.003175 5  * 4/32 " steel
hs20145200  -1
hs20145201  carbon-steel  4
hs20145300  0
hs20145400  1  201  int  1.0  1.0
hs20145500  138.43  1.5664  1.5664
hs20145600  1  201  ext  1.0  1.0
hs20145700  138.43  1.5664  1.5664
hs20145800  -1
hs20145801  330.72  5
*
***************************************************************
*    hs20215xnn -pedestal cavity wall
```

```
*                 begins at elevation = 94' 6" =28.8036 m
*                 ends at elevation = 100' 9" = 30.7086 m
*                 length = 1.905 m
*                 ri = 10' 7" =3.2258 m
*                 ro = 16' 4" = 4.9784 m
***************************************************************
*
hs20215000   15   2   -1   0
hs20215001  ped-cavity-wall
hs20215002  28.8036  1.0
hs20215003  1.0
hs20215100  -1  1  3.2258
hs20215102  3.2283  2 * 1/10" concrete
hs20215103  3.2309  3 * 2/10" concrete
hs20215104  3.2360  4 * 4/10" concrete
hs20215105  3.2512  5 * 1"    concrete
hs20215106  3.3528  6 * 5"    concrete
hs20215107  3.6068  7 * 15"   concrete
hs20215108  4.1021  8 * 34.5" concrete
hs20215109  4.5974  9 * 54"   concrete
hs20215110  4.8514 10 * 64"   concrete
hs20215111  4.9530 11 * 68"   concrete
hs20215112  4.9682 12 * 68.6" concrete
hs20215113  4.9733 13 * 68.8" concrete
hs20215114  4.9759 14 * 68.9" concrete
hs20215115  4.9784 15 * 69.0" concrete
hs20215200  -1
hs20215201  concrete              14
hs20215300  0
hs20215400  1  202  int  1.0  1.0
hs20215500  1.0  6.4516  1.905
hs20215600  0
hs20215800  -1
hs20215801  330.72  15
*
**********************************************************************
*   hs20216xnn - pedestal cavity  wall
*                 begins at elevation = 114' 9" = 34.9758 m
*                 ends at elevation = 117' 4" = 35.7632 m
*                 ri=  9'5" = 2.8702 m
*                 ro = 16'4" = 4.9784 m
*                 wall thickness = 83" concrete
**********************************************************************
*
hs20216000  17  2  -1  0
hs20216001  ped-cavity-wall
hs20216002  34.9758  1.0
hs20216003  1.0
hs20216100  -1  1  2.8702
hs20216102  2.8727  2 * 1/10"   concrete
hs20216103  2.8753  3 * 2/10"   concrete
hs20216104  2.8804  4 * 4/10"   concrete
hs20216105  2.8956  5 * 1 "     concrete
hs20216106  2.9972  6 * 5 "     concrete
hs20216107  3.2512  7 *15 "     concrete
hs20216108  3.6322  8 *30 "     concrete
hs20216109  3.9243  9 *41.5"    concrete
hs20216110  4.2164 10 *53  "    concrete
```

```
hs20216111  4.5974 11 *68 "     concrete
hs20216112  4.8514 12 *78 "     concrete
hs20216113  4.9530 13 *82 "     concrete
hs20216114  4.9682 14 *82.6"    concrete
hs20216115  4.9733 15 *82.8"    concrete
hs20216116  4.9759 16 *82.9"    concrete
hs20216117  4.9784 17 *83.0"    concrete
hs20216200  -1
hs20216201  concrete              16
hs20216300  0
hs20216400  1  202  int  1.0  1.0
hs20216500  1.0 5.7404  0.7874
hs20216600  1  208  ext 1.0  1.0
hs20216700  1.0  9.9568  0.7874
hs20216800  -1
hs20216801  330.72  17
*
******************************************************************
*   hs20226xnn - pedestal cavity floor
*                begins at elevation = 83'6" = 25.4508 m
*                ends at elevation = 94' 6" = 28.8036 m
*                 r = 10' 7" = 3.2258 m
*                delta z =length = 3.3528 m
*                area = pi*r**2 = 32.691m**2
*******************************************************************
*
hs20226000  12  1  -1  0
hs20226001  ped-cavity-floor
hs20226002  25.4508  0.0
hs20226003  1.0
hs20226100  -1  1  25.4508
hs20226102  27.1272  2  *5.5'  concrete
hs20226103  28.1534  3  *6' 8.8" concrete
hs20226104  28.4785  4  *8' 10.4" concrete
hs20226105  28.6410  5  *9' 11.2" concrete
hs20226106  28.7232  6  *10'5.6" concrete
hs20226107  28.7629  7  *10' 8.8" ocncrete
hs20226108  28.7833  8  *10' 10.4" concrete
hs20226109  28.7934  9  *10' 11.6" concrete
hs20226110  28.7985 10  *10' 11.8" concrete
hs20226111  28.8010 11  *10' 11.9" concrete
hs20226112  28.8036 12  *11' 0"    concrete
hs20226200  -1
hs20226201  concrete              11
hs20226300  0
hs20226400  0
hs20226600  1  202  ext  0.5  0.5
hs20226700  32.691  3.2258  3.3528
hs20226800  -1
hs20226801  330.72 12
*
*******************************************************************
*   hs202228xnn = cavity  pedestal wall
*                 similar to hs20215xnn
*                 begins at elevation = 100'9" = 30.7086 m
*                 ends at elevation = 114'9" =34.9758 m (midpoint of
*                 tapered region
*******************************************************************
```

```
*
hs20228000  15  2  -1  0
hs20228001  ped-cavity-wall
hs20228002  30.7086  1.0
hs20228003  1.0
hs20228100  20215  1  3.2258
hs20228200  20215
hs20228300  0
hs20228400  1  202  int  1.0  1.0
hs20228500  1.0  6.4516  4.2672
hs20228600  1  208  ext  1.0  1.0
hs20228700  1.0  9.9568  4.2672
hs20228800  20215
*
*******************************************************************
*  hs20229xnn - same as hx20216
*               begins at elevation = 117'4" = 35.7632 m
*               ends at  elevation = 121'4" = 36.9824 m
*******************************************************************
*
hs20229000  17  2  -1  0
hs20229001  ped-cavity-wall
hs20229002  35.7632  1.0
hs20229003  1.0
hs20229100  20216  1  2.8702
hs20229200  20216
hs20229300  0
hs20229400  1  202  int  1.0  1.0
hs20229500  1.0  5.7404  1.2192
hs20229600  1  207  ext  1.0  1.0
hs20229700  1.0  9.9568  1.2192
hs20229800  20216
*
************************************************************************
*   hs20330 - weir wall annulus floor
*           - begins at elevation = 83'6" = 25.4508 m
*           - ends at elevation = 93' 0 1/4" = 28.3528 m
*           - ri = 10.3632 m
*           - ro = 11.1252 m
*           - similar to hs 31027
*           - area = 51.4409 m**2
************************************************************************
*
hs20330000  11  1  -1  0
hs20330001  weir-wall-ann-fl
hs20330002  25.4508  0.0
hs20330003  1.0
hs20330100  31027  1  25.4508
hs20330200  31027
hs20330300  0
hs20330400  0
hs20330600  1   203  ext  0.0  0.0
hs20330700  51.4409  0.762  2.902
hs20330800  31027
*
*************************************************************
*   hs20421 - drywell wall
*            begins at elevation = 161'6" = 49.2252 m
```

```
*              ends at elevation = 180' 3" = 54.9402 m
*              length = 5.7150 m
*              same as heat slab 20717
*************************************************************
*
hs20421000  18  2  0  0
hs20421001  drywell-wall-21
hs20421002  49.2252  1.0
hs20421003  1.0
hs20421100  20717  1  11.1252
hs20421200  20717
hs20421300  0
hs20421400  1  204  int  1.0  1.0
hs20421500  1.0  22.2504  5.7150
hs20421600  1  312 ext  1.0   1.0
hs20421700  1.0  25.2984  5.7150
*hs20421800  20717
*
******************************************************************
*   hs20446xnn - misc steel horizontal heat slab for cv 204
*               - area = 19926.97 ft**2 = 1851.2  m**2
*               - elevation = 170' 4.5" = 51.9303 m
*               - same as hs20145xnn
*               - length = delta r = 6.1468 m
*
******************************************************************
*
hs20446000  5  1  -1  0
hs20446001  misc-steel-cv204
hs20446002  51.9303  0.0
hs20446003  1.0
hs20446100  20145  1  0.0
hs20446200  20145
hs20446300  0
hs20446400  1  204  int  1.0  1.0
hs20446500  1851.2  6.1468  6.1468
hs20446600  1  204  ext  1.0  1.0
hs20446700  1851.2  6.1468  6.1468
hs20446800  20145
*
******************************************************************
*
*           heat slabs to model the reactor vessel
*
*           20500, 20501, 20503, 20505, 20100, 20900 and 20901
*                  20502 added for the BH package
*******************************************************************
*
hs20500000   6  2  0  0
hs20500001  vessel-0
hs20500002  40.6925  1.0
hs20500003  1.0
hs20500100  10002   1   3.1877
hs20500200  10002
hs20500300  0
hs20500400  1   100  int  0.5  0.5
hs20500401  0.9  gray-gas-a  0.1
hs20500500  1.0  3.188  0.3175
```

```
hs20500600  1  205  ext  1.0  1.0
hs20500700  1.0  3.398  0.3175
*
hs20501000  6  2  0  0
hs20501001  vessel-1
hs20501002  41.01   1.0
hs20501003  1.0
hs20501100  10002  1  3.1877
hs20501200  10002
hs20501300  0
hs20501400  1  105  int  0.5  0.5
hs20501401  0.9  gray-gas-a  0.1
hs20501500  1.0  3.1877  0.076
hs20501600  1  205  ext  1.0  1.0
hs20501700  1.0  3.398  0.076
*
hs20502000  6  2  0  0
hs20502001  vessel-2
hs20502002  41.086  1.0
hs20502003  1.0
hs20502100  10002  1  3.1877
hs20502200  10002
hs20502300  9001  -111  1.0  *input for bh 9001
hs20502301  0.19508  1       * bh
hs20502302  0.19716  2       * bh
hs20502303  0.20019  3       * bh
hs20502304  0.20275  4       * bh
hs20502305  0.20482  5       * bh
hs20502400  1  105  int  0.5  0.5
hs20502401  0.9  gray-gas-a  0.1
hs20502500  1.0  3.1877  1.67465
hs20502600  1  205  ext  1.0  1.0
hs20502700  1.0  3.398   1.67465
*
cf00100     'conduction-power'  equals  1  1.0  0.0    * bh
cf00101     0.0                                        * bh
cf00110     1.0   0.0   bh-cond-pow                    * bh
*cf00110     0.0   0.0  time
*
*
hs20503000  6  2  0  0
hs20503001  vessel-3
hs20503002  42.76065  1.0
hs20503003  1.0
hs20503100  -1     1  3.1877
hs20503101  3.219  2
hs20503102  3.251  3
hs20503103  3.282  4
hs20503104  3.313  5
hs20503105  3.345  6
hs20503200  -1
hs20503201  carbon-steel  5  *steel
hs20503300  0
hs20503400  1   105 int 0.5  0.5
hs20503401  0.9   gray-gas-a  0.1
hs20503500  1.0  3.188  8.80545
hs20503600  1  205  ext  1.0  1.0
hs20503700  1.0  3.345  8.80545
```

```
*
*
hs20505000  6  2  0  0
hs20505001  vessel-4
hs20505002  51.5661 1.0
hs20505003  1.0
hs20505100  10002  1  3.1877
hs20505200  10002
hs20505300  0
hs20505400  1   105  int  0.5  0.5
hs20505401  0.9  gray-gas-a  0.1
hs20505500  1.0  3.188  1.2404
hs20505600  1  205  ext  1.0  1.0
hs20505700  1.0  3.395  1.2404
*
hs20100000  6   2   0   0
hs20100001  vessel-5
hs20100002  52.88   1.0
hs20100003  1.0
hs20100100  10002   1   3.1877
hs20100200  10002
hs20100300  0
hs20100400  1  104  int  1.0  1.0
hs20100401  0.9  gray-gas-a  0.1
hs20100500  1.0  3.188   3.1523
hs20100600  1  201  ext  1.0  1.0
hs20100700  1.0   3.398  3.1523
*
hs20900000  6   2   2   2
hs20900001  vessel-5
hs20900002  56.0324  1.0
hs20900003  1.0
hs20900100  10002  1  3.1877
hs20900200  10002
hs20900300  0
hs20900400  1  104  int  1.0  1.0
hs20900401  0.9  gray-gas-a  0.1
hs20900500  1.0  3.188  0.3302
hs20900600  1  209  ext  1.0 1.0
hs20900700  1.0  3.398  0.3302
*
hs20901000  5  5  0  0
hs20901001  upper-head
hs20901002  56.3626 0.0
hs20901003  1.0
hs20901100  -1     1  3.175
hs20901101  3.2179  2
hs20901102  3.26075 3
hs20901103  3.30363 4
hs20901104  3.3465  5
hs20901200  -1
hs20901201  carbon-steel    4
hs20901300  0
hs20901400  1  104  int  1.0  1.0
hs20901401  0.9  gray-gas-a  0.1
hs20901500  1.0  3.175  3.175
hs20901600  1  209  ext  1.0  1.0
hs20901700  1.0  3.3465  3.3465
```

```
*
*****************************************************************
*   hs20547xnn - misc steel horizontal heat slab for cv 205
*              - area = 3465.6 ft**2 = 321.965  m**2
*              - elevation = 147' 3.75" = 44.90080 m
*              - same as hs20145xnn
*              - length = delta r = 0.9874 m
*
*****************************************************************
*
hs20547000  5  1  -1  0
hs20547001  misc-steel-cv205
hs20547002  44.90080  0.0
hs20547003  1.0
hs20547100  20145  1  0.0
hs20547200  20145
hs20547300  0
hs20547400  1  205  int  1.0  1.0
hs20547500  321.965  0.9874  0.9874
hs20547600  1  205  ext  1.0  1.0
hs20547700  321.965  0.9874  0.9874
hs20547800  20145
*
*****************************************************************
*   hs20850xnn - misc steel horizontal heat slab for cv 208
*              - area = 13056.51 ft**2 = 1213.0  m**2
*              - elevation = 109' 0.5" = 33.2359 m
*              - same as hs20145xnn
*              - length = delta r = 4.9276 m
*
*****************************************************************
*
hs20850000  5  1  -1  0
hs20850001  misc-steel-cv208
hs20850002  33.2359  0.0
hs20850003  1.0
hs20850100  20145  1  0.0
hs20850200  20145
hs20850300  0
hs20850400  1  208  int  1.0  1.0
hs20850500  1213.0  4.9276  4.9276
hs20850600  1  208  ext  1.0  1.0
hs20850700  1213.0  4.9276  4.9276
hs20850800  20145
*
*****************************************************************
*   hs20951xnn - misc steel horizontal heat slab for cv 209
*              - area = 1810.767 ft**2 = 168.23  m**2
*              - elevation = 192' 2" = 58.5724 m
*              - same as hs20145xnn
*              - length = delta r = 9.7536 m
*
*****************************************************************
*
hs20951000  5  1  -1  0
hs20951001  misc-steel-cv209
hs20951002  58.5724  0.0
hs20951003  1.0
```

```
hs20951100  20145  1  0.0
hs20951200  20145
hs20951300  0
hs20951400  1  209  int  1.0  1.0
hs20951500  168.23  9.7536  9.7536
hs20951600  1  209  ext  1.0  1.0
hs20951700  168.23  9.7536  9.7536
hs20951800  20145
*
*****************************************************************
*   hs20648xnn - misc steel horizontal heat slab for cv 206
*              - area = 14780.62 ft**2 = 1373.17  m**2
*              - elevation = 153' 11.5" = 46.9265 m
*              - same as hs20145xnn
*              - length = delta r = 6.1468 m
*
*****************************************************************
*
hs20648000  5  1  -1  0
hs20648001  misc-steel-cv206
hs20648002  46.9265  0.0
hs20648003  1.0
hs20648100  20145  1  0.0
hs20648200  20145
hs20648300  0
hs20648400  1  206  int  1.0  1.0
hs20648500  1373.17  6.1468  6.1468
hs20648600  1  206  ext  1.0  1.0
hs20648700  1373.17  6.1468  6.1468
hs20648800  20145
*
*****************************************************************
*   hs20749xnn - misc steel horizontal heat slab for cv 207
*              - area = 32134.41 ft**2 = 2985.38  m**2
*              - elevation = 132' 5.5" = 40.3733 m
*              - same as hs20145xnn
*              - length = delta r = 6.1468 m
*
*****************************************************************
*
hs20749000  5  1  -1  0
hs20749001  misc-steel-cv207
hs20749002  40.3733  0.0
hs20749003  1.0
hs20749100  20145  1  0.0
hs20749200  20145
hs20749300  0
hs20749400  1  207  int  1.0  1.0
hs20749500  2985.38  6.1468  6.1468
hs20749600  1  207  ext  1.0  1.0
hs20749700  2985.38  6.1468  6.1468
hs20749800  20145
*
*****************************************************************
*   hs31052xnn - misc steel horizontal heat slab for cv 310
*              - area = 117885.8 ft**2 = 10951.95  m**2
*              - elevation = 123' 10" = 37.7444 m
*              - same as hs20145xnn
```

```
*               - length = delta r = 6.2484 m
*
*****************************************************************
*
hs31052000  5  1  -1  0
hs31052001  misc-steel-cv310
hs31052002  37.7444  0.0
hs31052003  1.0
hs31052100  20145  1  0.0
hs31052200  20145
hs31052300  0
hs31052400  1  310  int  1.0  1.0
hs31052500  10951.95  6.2484  6.2484
hs31052600  1  310  ext  1.0  1.0
hs31052700  10951.95  6.2484  6.2484
hs31052800  -1
hs31052801  308.15  5
*
*****************************************************************
*   hs31153xnn - misc steel horizontal heat slab for cv 311
*              - area = 78296.3 ft**2 = 7273.96  m**2
*              - elevation = 148' 5" = 45.2374 m
*              - same as hs20145xnn
*              - length = delta r = 6.2484 m
*
*****************************************************************
*
hs31153000  5  1  -1  0
hs31153001  misc-steel-cv311
hs31153002  45.2374  0.0
hs31153003  1.0
hs31153100  20145  1  0.0
hs31153200  20145
hs31153300  0
hs31153400  1  311  int  1.0  1.0
hs31153500  7273.96  6.2484  6.2484
hs31153600  1  311  ext  1.0  1.0
hs31153700  7273.96  6.2484  6.2484
hs31153800  31052
*
*****************************************************************
*   hs31254xnn - misc steel horizontal heat slab for cv 312
*              - area = 31546.3 ft**2 = 2930.75  m**2
*              - elevation = 173' 0" = 52.7304 m
*              - same as hs20145xnn
*              - length = delta r = 1.9817 m
*
*****************************************************************
*
hs31254000  5  1  -1  0
hs31254001  misc-steel-cv312
hs31254002  52.7304  0.0
hs31254003  1.0
hs31254100  20145  1  0.0
hs31254200  20145
hs31254300  0
hs31254400  1  312  int  1.0  1.0
hs31254500  2930.75  1.9817  1.9817
```

```
hs31254600  1  312  ext  1.0  1.0
hs31254700  2930.75  1.9817  1.9817
hs31254800  31052
*
*********************************************************************
*  hs31300 and hs31301- upper pool vertical walls (slab)
*            - begins at elevation = 167'6.25" = 51.0604 m
*            - ends at elevation = 208' 10" = 63.6524 m
*            - lined with 1/4" steel plate
*            - model wall as 2' thick concrete with insulated boundary
*            - area = 9303 ft**2 = 964.3 m**2 split into tow hs:
*            -for hs31300, height  5.1752m, area 396.32 m2
*            -for hs31301, height  7.4168m, area 567.98 m2
*                    totals . . .12.592 m       964.3  m2
*
*********************************************************************
*
hs31300000  11  1  -1  0
hs31300001  upper-pool-wall-1
hs31300002  51.0604  1.0
hs31300003  1.0
hs31300100  -1  1  0.0
hs31300102  0.00254  2  * 1/10" steel
hs31300103  0.00508  3  * 2/10" steel
hs31300104  0.00635  4  * 1/4"  steel
hs31300105  0.01270  5  * 1/2"  concrete
hs31300106  0.02540  6  * 1 "   concrete
hs31300107  0.05080  7  * 2"    concrete
hs31300108  0.10160  8  * 4 " concrete
hs31300109  0.20320  9  * 8 " concrete
hs31300110  0.40640 10  * 16' concrete
hs31300111  0.81280 11  * 24" concrete
hs31300200  -1
hs31300201  carbon-steel  3
hs31300202  concrete  10
hs31300300  0
hs31300400  1  313 int  0.5  0.5
hs31300500  396.32 5.175  5.1752
hs31300600  1  312  ext  1.0  1.0
hs31300700  396.32  5.1752  5.1752
hs31300800  -1
hs31300801  308.15 11
*
hs31301000  11  1  0  0
hs31301001  up-pool-wall-2
hs31301002  56.2356  1.0
hs31301003  1.0
hs31301100  31300  1  0.0
hs31301200  31300
hs31301300  0
hs31301400  1  313  int  0.5  0.5
hs31301500  567.98  7.42  7.4168
hs31301600  1  319  ext  1.0  1.0
hs31301700  567.98  7.42  7.4168
*
*********************************************************************
*     hs31309xnn - upper pool floor horizontal slab
*              - begins at elevation = 180'3" = 54.9402 m
```

```
*               - ends at elevation = 184' 6.25" = 56.2420 m
*               - area = 3652 ft**2 (measured) = 339.3 m**2
*               - thickness = 4'3" = 1.2954 m
*               - 1/4 " steel plate next to pool and drywell
*               - 106.25' x 34.375'
*
***********************************************************************
*
hs31309000  19  1  0  0
hs31309001  upper-pool-floor
hs31309002  54.9402  0.0
hs31309003  1.0
hs31309100  -1  1  0.0
hs31309102  0.00254  2  * 1/10" steel
hs31309103  0.00635  3  * 1/4 " steel
hs31309104  0.01270  4  * 1/2 " concrete
hs31309105  0.02540  5  * 1"  concrete
hs31309106  0.05080  6  * 2 " concrete
hs31309107  0.10160  7  * 4 " concrete
hs31309108  0.20320  8  * 8 " concrete
hs31309109  0.40640  9  * 16" concrete
hs31309110  0.64770 10  * 25.5" concrete
hs31309111  0.88900 11  * 35"  concrete
hs31309112  1.09220 12  * 43" concrete
hs31309113  1.19380 13  * 47" concrete
hs31309114  1.24460 14  * 49" concrete
hs31309115  1.27000 15  * 50" concrete
hs31309116  1.28270 16  * 50.5" concrete
hs31309117  1.28905 17  * 50.75" steel
hs31309118  1.29286 18  * 50.90" steel
hs31309119  1.29540 19  * 51.00" steel
hs31309200  -1
hs31309201  carbon-steel  2
hs31309202  concrete  14
hs31309203  carbon-steel  18
hs31309300  0
hs31309400  1  204  int 1.0  1.0
hs31309500  339.3  10.48  10.48
hs31309600  1  313  ext  0.0  0.0
hs31309700  339.3  10.48  10.48
*hs31309800  -1
*hs31309801  294.3  19
*
*****************************************************************
*   hs31900xnn - vertical cylindrical wall of cv319
*              - begins at elevation 56.2356 m
*              - ends at elevation 63.6524 m
*                height 7.4168
*****************************************************************
*
hs31900000  11  2  0  0
hs31900001  cont-wall-319
hs31900002  56.2356  1.0
hs31900003  1.0
hs31900100  31007  1  18.8976
hs31900200  31007
hs31900300  0
hs31900400  1  319  int  1.0  1.0
```

```
hs31900500  1.0   37.7952  7.4167
hs31900600  1  399  ext  1.0  1.0
hs31900700  1.0   39.9288  7.4167
*
*******************************************************************
*   hs31955xnn - misc steel horizontal heat slab for cv 319
*              - area = 38307.67 ft**2 = 3558.9  m**2
*              - elevation = 196' 8" = 59.9440 m
*              - same as hs20145xnn
*              - length = delta r = 4.3034 m
*
*******************************************************************
*
hs31955000  5  1  -1  0
hs31955001  misc-steel-cv319
hs31955002  59.9440  0.0
hs31955003  1.0
hs31955100  20145  1  0.0
hs31955200  20145
hs31955300  0
hs31955400  1  319  int  1.0  1.0
hs31955500  3558.9  4.3034  4.3034
hs31955600  1  319  ext  1.0  1.0
hs31955700  3558.9  4.3034  4.3034
hs31955800  -1
hs31955801  308.15  5
*
*******************************************************************
*   hs32056xnn - misc steel horizontal heat slab for cv 320
*              - area = 4447.08 ft**2 = 413.15  m**2
*              - elevation = 194' 8" = 59.3344 m
*              - same as hs20145xnn
*              - length = delta r = 10.140 m
*
*******************************************************************
*
hs32056000  5  1  -1  0
hs32056001  misc-steel-cv320
hs32056002  59.3344  0.0
hs32056003  1.0
hs32056100  20145  1  0.0
hs32056200  20145
hs32056300  0
hs32056400  1  320  int  1.0  1.0
hs32056500  413.15  10.140  10.140
hs32056600  1  320  ext  1.0  1.0
hs32056700  413.15  10.140  10.140
hs32056800  -1
hs32056801  330.72  5
*
*******************************************************************
*   hs32157xnn - misc steel horizontal heat slab for cv 321
*              - area = 5967.24 ft**2 = 554.4  m**2
*              - elevation = 153' 0" = 46.6344 m
*              - same as hs20145xnn
*              - length = delta r = 6.2484 m
*
*******************************************************************
```

```
*
hs32157000  5  1  -1  0
hs32157001  misc-steel-cv321
hs32157002  46.6344  0.0
hs32157003  1.0
hs32157100  20145  1  0.0
hs32157200  20145
hs32157300  0
hs32157400  1  321  int  1.0  1.0
hs32157500  554.4  6.2484  6.2484
hs32157600  1  321  ext  1.0  1.0
hs32157700  554.4  6.2484  6.2484
hs32157800  31955
*
******************************************************************
*   hs32258xnn - misc steel horizontal heat slab for cv 322
*              - area = 3743.72 ft**2 = 347.80  m**2
*              - elevation = 187' 11" = 52.277 m
*              - same as hs20145xnn
*              - length = delta r = 4.064 m
*
******************************************************************
*
hs32258000  5  1  -1  0
hs32258001  misc-steel-cv322
hs32258002  52.277  0.0
hs32258003  1.0
hs32258100  20145  1  0.0
hs32258200  20145
hs32258300  0
hs32258400  1  322  int  1.0  1.0
hs32258500  347.80  4.064  4.064
hs32258600  1  322  ext  1.0  1.0
hs32258700  347.80  4.064  4.064
hs32258800  31955
*
******************************************************************
*   hs32359xnn - misc steel horizontal heat slab for cv 323
*              - area = 1134.46 ft**2 = 105.395  m**2
*              - elevation = 176' 10" = 53.8988 m
*              - same as hs20145xnn
*              - length = delta r = 3.81 m
*
******************************************************************
*
hs32359000  5  1  -1  0
hs32359001  misc-steel-cv323
hs32359002  53.8988  0.0
hs32359003  1.0
hs32359100  20145  1  0.0
hs32359200  20145
hs32359300  0
hs32359400  1  323  int  1.0  1.0
hs32359500  105.395  3.81  3.81
hs32359600  1  323  ext  1.0  1.0
hs32359700  105.395  3.81  3.81
hs32359800  31955
*
```

```
****************************************************************
*   hs32460xnn - misc steel horizontal heat slab for cv 324
*              - area = 1633.62 ft**2 = 151.77  m**2
*              - elevation = 194' 8" = 59.3344 m
*              - same as hs20145xnn
*              - length = 30' = 9.144 m
*
****************************************************************
*
hs32460000  5  1  -1  0
hs32460001  misc-steel-cv324
hs32460002  59.3344  0.0
hs32460003  1.0
hs32460100  20145  1  0.0
hs32460200  20145
hs32460300  0
hs32460400  1  324  int  1.0  1.0
hs32460500  151.77  9.144  9.144
hs32460600  1  324  ext  1.0  1.0
hs32460700  151.77  9.144  9.144
hs32460800  31955
*
****************************************************************
*   hs32561xnn - misc steel horizontal heat slab for cv 325
*              - area = 274.54 ft**2 = 25.506  m**2
*              - elevation = 164' 4" = 50.0888 m
*              - same as hs20145xnn
*              - length = 7.5' (measured) = 2.286 m
*
****************************************************************
*
hs32561000  5  1  -1  0
hs32561001  misc-steel-cv325
hs32561002  50.0888  0.0
hs32561003  1.0
hs32561100  20145  1  0.0
hs32561200  20145
hs32561300  0
hs32561400  1  325  int  1.0  1.0
hs32561500  25.506  2.286  2.286
hs32561600  1  325  ext  1.0  1.0
hs32561700  25.506  2.286  2.286
hs32561800  31955
*
****************************************************************
*   hs32662xnn - misc steel horizontal heat slab for cv 326
*              - area = 1225.21 ft**2 = 113.825  m**2
*              - elevation = 166' 4" = 50.6984 m
*              - same as hs20145xnn
*              - length = 13.333' (measured) = 4.064 m
*
****************************************************************
*
hs32662000  5  1  -1  0
hs32662001  misc-steel-cv326
hs32662002  50.6984  0.0
hs32662003  1.0
hs32662100  20145  1  0.0
```

```
hs32662200  20145
hs32662300  0
hs32662400  1  326  int  1.0  1.0
hs32662500  113.825  4.064  4.064
hs32662600  1  326  ext  1.0  1.0
hs32662700  113.825  4.064  4.064
hs32662800  31955
*
*******************************************************************
*   hs20518 - shield wall
*             begins at elevation = 121' 4 1/2" = 36.995 m
*             ends at elevation = 147'7" = 44.9834 m
*             ri = 14'4" = 4.3688 m
*             ro = 16'4" = 4.9784 m
*             length = 7.9884 m
*             3/4" steel plate on internal surface , 1 1/4" plate
*             on outer surface, thickness = 24" (22" concrete  )
*
*********************************************************************
*
hs20518000  15  2  -1  0
hs20518001  shield-wall-18
hs20518002  36.9951  1.0
hs20518003  1.0
hs20518100  -1  1  4.3688
hs20518102  4.37388  2  *2/10"  steel
hs20518103  4.37896  3  *4/10"  steel
hs20518104  4.38785  4  *3/4"   steel
hs20518105  4.40690  5  *1.5"   concrete
hs20518106  4.44500  6  *3"     concrete
hs20518107  4.52120  7  *6"     concrete
hs20518108  4.67360  8  *12"    concrete
hs20518109  4.82600  9  *18"    concrete
hs20518110  4.90220 10  *21"    concrete
hs20518111  4.94030 11  *22.5"  concrete
hs20518112  4.94665 12  *22.75" concrete
hs20518113  4.96570 13  *23.50" steel
hs20518114  4.97205 14  *23.75  steel
hs20518115  4.97840 15  *24.0"  steel
hs20518200  -1
hs20518201  carbon-steel         3
hs20518202  concrete             11
hs20518203  carbon-steel         14
hs20518300  0
hs20518400  1  205  int  1.0  1.0
hs20518500  1.0  8.7376  7.9883
hs20518600  1  207  ext  1.0  1.0
hs20518700  1.0  9.9568  7.9883
hs20518800  -1
hs20518801  330.72  15
*
**************************************************************
*   hs20520 - shield wall
*             begins at elevation = 147' 7" =44.9834 m
*             ends at elevation = 161' 6" =49.2252 m
*             length = 4.2418 m
*             same as heat slab 20518xnn
**************************************************************
```

```
*
hs20520000  15  2  -1  0
hs20520001  shield-wall-20
hs20520002  44.9834  1.0
hs20520003  1.0
hs20520100  20518  1  4.3688
hs20520200  20518
hs20520300  0
hs20520400  1  205  int  1.0  1.0
hs20520500  1.0  8.7376  4.2418
hs20520600  1  206  ext  1.0  1.0
hs20520700  1.0  9.9568  4.2418
hs20520800  20518
*
*************************************************************
*   hs20522 - shield wall
*             begins at elevation = 161'10" = 49.3268 m
*             ends at elevation = 173' 3" = 52.8066 m
*             length = 3.4802 m
*             same as heat slab 20518
*************************************************************
*
hs20522000  15  2  -1  0
hs20522001  shield-wall-22
hs20522002  49.3268  1.0
hs20522003  1.0
hs20522100  20518  1  4.3688
hs20522200  20518
hs20522300  0
hs20522400  1  205  int  1.0  1.0
hs20522500  1.0  8.7376  3.4797
hs20522600  1  204  ext  1.0  1.0
hs20522700  1.0  9.9568  3.4797
hs20522800  20518
*
*************************************************************
*   hs20615xnn - drywell wall
*                begins at 147' 7" = 44.9834 m
*                ends at 161'6" = 49.2252 m
*                ri = 36' 6" = 11.1252 m
*                ro = 41' 6" = 12.6492 m
*                length = 4.2418 m
*                same as hs20717xnn
*************************************************************
*
hs20615000  18  2  0  0
hs20615001  drywell-wall-15
hs20615002  44.9834  1.0
hs20615003  1.0
hs20615100  20717  1  11.1252
hs20615200  20717
hs20615300  0
hs20615400  1  206  int  1.0  1.0
hs20615500  1.0  22.2504  4.2418
hs20615600  1  311  ext  1.0  1.0
hs20615700  1.0  25.2984  4.2418
*hs20615800  20717
*
```

```
***************************************************************
*    hs20717 - drywell wall
*              begins at elevation = 117'4" = 35.7632 m
*              ends at elevation = 135'4" = 41.2496 m
*              length = 5.4864 m
*              1/4" thick steel plate on inside surface
*              ri= 36'6" = 11.1252 m
*              ro= 41'6" = 12.6492 m
***************************************************************
*
hs20717000  18  2  0  0
hs20717001  drywell-wall-17
hs20717002  35.7632  1.0
hs20717003  1.0
hs20717100  -1  1  11.1252
hs20717102  11.12774  2  *1/10" steel
hs20717103  11.13028  3  *2/10" steel
hs20717104  11.13155  4  * 1/4" steel
hs20717105  11.15060  5  *1"    concrete
hs20717106  11.17600  6  *2"    concrete
hs20717107  11.22680  7  *4"    concrete
hs20717108  11.32840  8  *8"    concrete
hs20717109  11.53160  9  *16"   concrete
hs20717110  11.88720 10  *30"   concrete
hs20717111  12.24280 11  *44"   concrete
hs20717112  12.44600 12  *52"   concrete
hs20717113  12.54760 13  *56"   concrete
hs20717114  12.59840 14  *58"   concrete
hs20717115  12.62380 15  *59"   concrete
hs20717116  12.63650 16  *59.5" concrete
hs20717117  12.64290 17  *59.75" concrete
hs20717118  12.64920 18  *60"   concrete
hs20717200  -1
hs20717201  carbon-steel          3
hs20717202  concrete              17
hs20717300  0
hs20717400  1  207  int  1.0  1.0
hs20717500  1.0  22.2504  5.4864
hs20717600  1  310  ext  1.0  1.0
hs20717700  1.0  25.2984  5.4864
*hs20717800  -1
*hs20717801  320.0  18
*
*******************************************************************
*   hs 20729 - drywell -wall
*            - begins at elevation = 135'4" = 41.2496 m
*            - ends at elevation = 147'7" = 44.9834 m
*            - length = 3.7338 m
*            - same as hs20717
*
*******************************************************************
*
hs20729000  18  2  0  0
hs20729001  drywell-wall-29
hs20729002  41.2496  1.0
hs20729003  1.0
hs20729100  20717  1  11.1252
hs20729200  20717
```

```
hs20729300  0
hs20729400  1  207  int  1.0  1.0
hs20729500  1.0  22.2504  3.7338
hs20729600  1  311  ext  1.0  1.0
hs20729700  1.0  25.2984  3.7338
*hs20729800  20717
*
***********************************************************************
*   hs20813 - weir wall heat slab
*             ri = 32'6" = 9.906 m
*             ro = 34'0" = 10.3632 m
*             begins at elevation = 100'9"
*             ends at elevation = 117' 4"
*             3/8" plate on suppression pool side
*
***********************************************************************
*
hs20813000  17  2  -1  0
hs20813001  weir-wall
hs20813002  30.7086  1.0 * elevation = 100'9"
hs20813003  1.0
hs20813100  -1  1  9.906
hs20813102  9.90854  2  *1/10"   concrete
hs20813103  9.91108  3  *2/10"   concrete
hs20813104  9.91616  4  *4/10"   concrete
hs20813105  9.92632  5  *8/10"   concrete
hs20813106  9.94664  6  *1.6"    concrete
hs20813107  9.98728  7  *3.2"    concrete
hs20813108  10.06856 8  *6.4"    concrete
hs20813109  10.13460 9  *9.0"    concrete
hs20813110  10.20064 10 *11.6"   concrete
hs20813111  10.28192 11 *14.8"   concrete
hs20813112  10.32256 12 *16.4"   concrete
hs20813113  10.34288 13 *17.2"   concrete
hs20813114  10.35304 14 *17.6"   concrete
hs20813115  10.35685 15 *17.75"  steel
hs20813116  10.35939 16 *17.85"  steel
hs20813117  10.36320 17 *18.00"  steel
hs20813200  -1
hs20813201  concrete               13
hs20813202  carbon-steel           16
hs20813300  0
hs20813400  1  208  int  1.0  1.0
hs20813500  1.0  19.8120  5.0546
hs20813600  1  203  ext  0.5  0.5
hs20813700  1.0  20.7264  5.0546
hs20813800  -1
hs20813801  330.72  17
*
********************************************************************
*   hs 20814 - drywell floor
*              begins at elevation = 83'6" = 25.4508 m
*              ends at elevation = 100'9" = 30.7086 m
*              ri = 16'4" = 4.9784 m
*              ro = 32'6" = 9.9060 m
*              delta r = 4.9276 m
*              area = 230.418 m**2
********************************************************************
```

```
*
hs20814000  9  1  -1  0
hs20814001  drywell-floor
hs20814002  25.4508  0.0
hs20814003  1.0
hs20814100  -1  1  25.4508
hs20814102  28.11780  2  * 92'1 1/2" concrete
hs20814103  29.39415  3  *96' 5 1/4"  concrete
hs20814104  30.05140  4  *98' 7.125" concrete
hs20814105  30.40380  5  *99'9"       concrete
hs20814106  30.55620  6  *100'3"      concrete
hs20814107  30.63240  7  *100'6"      concrete
hs20814108  30.68320  8  *100'8"      concrete
hs20814109  30.70860  9  *100'9"      concrete
hs20814200  -1
hs20814201  concrete  8
hs20814300  0
hs20814400  0
hs20814600  1  208  ext  0.5  0.5
hs20814700  230.418  4.9276  4.9276
hs20814800  -1
hs20814801  330.72  9
*********************************************************************
*   hs20923 - drywell head cylindrical portion
*           - thickness = 1 1/2" = 0.0381 m
*           - inside radius = 16' =4.8768 m
*           - outside radius = 16' 1 1/2" = 4.9149 m
*           - begins at elevation = 183' 10" = 56.032 m
*           - ends at elevation = 192' 6" = 58.674 m
*           - length = 2.6416 m
*
*********************************************************************
*
hs20923000  8  2  0  0
hs20923001  dw-head-cylinder
hs20923002  56.0324  1.0
hs20923003  1.0
hs20923100  -1  1  4.8768
hs20923102  4.87934  2  *1/10" ss
hs20923103  4.88188  3  *2/10" ss
hs20923104  4.88696  4  *4/10" ss
hs20923105  4.89712  5  *8/10" ss
hs20923106  4.90728  6  *1 2/10" ss
hs20923107  4.91236  7  *1 4/10" ss
hs20923108  4.91490  8  *1 1/2" ss
hs20923200  -1
hs20923201  'stainless steel'  7
hs20923300  0
hs20923400  1  209  int  1.0  1.0
hs20923500  1.0  9.7536  2.6416
hs20923600  1  313  ext  0.0  0.0
hs20923700  1.0  9.8298  2.6416
*hs20923800  -1
*hs20923801  294.3  8
*
*********************************************************************
*
*  hs20925  - drywell head elliptical portion
```

```
*           - thickness = 1 2/16" = 0.028575
*           - ellipsoid surface area = 2*pi*b**2 + 2*pi*a*b*sin-1(e)/e
*                                    = 127.706 m**2
*           - b = 8' = 2.4384 m
*           - a = 2*b = 16' = 4.8768 m
*           - eccentricity (e) = sqrt((a**2-b**2)/a**2) = .866
*       - model as semi-spherical shell and require equal surface areas
*           - a (semi-sphere) = 2*pi*r**2 = 127.706 m**2
*           - r = 4.508 m
*           - ends at elevation = 200'6" = 61.1124 m
*           - require beginning elevation = 61.1124m -4.508 m =56.6044m
*
***********************************************************************
*
*
hs20925000  9  5  0  0
hs20925001  dw-head-ellipse
hs20925002  56.604
hs20925003  1.0
hs20925100  -1  1  4.508
hs20925102  4.51054  2  *1/10" ss
hs20925103  4.51308  3  *2/10" ss
hs20925104  4.51816  4  *4/10" ss
hs20925105  4.52229  5  *9/16" ss
hs20925106  4.52642  6  *0.725" ss
hs20925107  4.53150  7  *0.925" ss
hs20925108  4.53404  8  *1.025" ss
hs20925109  4.53658  9  *1.125" ss
hs20925200  -1
hs20925201  'stainless steel'  8
hs20925300  0
hs20925400  1  209  int  1.0  1.0
hs20925500  1.0  4.8768  2.4384
hs20925600  1  313  ext  0.0  0.0
hs20925700  1.0  4.93395  2.466975
*hs20925800  -1
*hs20925801  294.3  9
*
******************************************************************
*    hs31007xnn - wetwell wall - suppression pool water
*                 begins at elevation = 93' 01/4" = 28.3528 m
*                 ends at elevation = 111' 7 1/6" = 34.015 m
*                 ri = 62'0" = 18.8976 m
*                 ro = 65'6" = 19.9644 m
*                 1/4 " steel plate on inside surface
*                 3' 6" thick wall
******************************************************************
*
hs31007000  11  2  -1  0
hs31007001  wetwell-wall-h20
hs31007002  28.3528  1.0
hs31007003  1.0
hs31007100  -1  1  18.8976
hs31007102  18.90014  2  *1/10" steel
hs31007103  18.90268  3  *2/10" steel
hs31007104  18.90776  4  *1/4"  steel
hs31007105  18.92300  5  *1"    concrete
hs31007106  18.94840  6  *2"    concrete
```

```
hs31007107  18.99920  7  *4"    concrete
hs31007108  19.10080  8  *8"    concrete
hs31007109  19.30400  9  *16"   concrete
hs31007110  19.71040 10  *32"   concrete
hs31007111  19.9644  11  *42"   concrete
hs31007200  -1
hs31007201  carbon-steel          3
hs31007202  concrete  10
hs31007300  0
hs31007400  1  310  int  0.0  0.0
hs31007500  1.0  37.7952  5.6622
hs31007600  0
hs31007800  -1
hs31007801  308.15  11
*
**************************************************************
*   hs31006xnn - wetwell-wall-air
*                same as 31007
*                begins at elevation = 111' 7 1/6" = 34.015 m
*                ends at elevation = 135' 4" = 41.2496 m
**************************************************************
*
hs31006000  11  2  -1  0
hs31006001  wetwell-wall-air
hs31006002  34.015  1.0
hs31006003  1.0
hs31006100  31007  1  18.8976
hs31006200  31007
hs31006300  0
hs31006400  1  310  int  1.0  1.0
hs31006500  1.0  37.7952  7.2346
hs31006600  0
hs31006800  31007
*
*******************************************************************
*   hs31011 - drywell wall - pool side
*             begins at elevation = 93' 0 1/4" = 28.3528 m
*             ends at elevation = 117' 4" = 35.7632 m
*             ri = 36'6" = 11.1252 m
*             ro = 41'6" = 12.6492 m
*             wall thickness = 60"
*             1/4" thick steel plate on each side
*******************************************************************
*
hs31011000  17  2  0  0
hs31011001  drywell-wall-11
hs31011002  28.3528  1.0
hs31011003  1.0
hs31011100  -1  1  11.1252
hs31011102  11.12774  2  *1/10"   steel
hs31011103  11.13155  3  *1/4"    steel
hs31011104  11.13790  4  *1/2"    concrete
hs31011105  11.15060  5  *1"      concrete
hs31011106  11.20140  6  *3"      concrete
hs31011107  11.35380  7  *9"      concrete
hs31011108  11.58240  8  *18"     concrete
hs31011109  11.88720  9  *30"     concrete
hs31011110  12.19200 10  *42"     concrete
```

```
hs31011111  12.42060 11  *51"     concrete
hs31011112  12.57300 12  *57"     concrete
hs31011113  12.62380 13  *59"     concrete
hs31011114  12.63650 14  *59.5"   concrete
hs31011115  12.64290 15  *59.75"  concrete
hs31011116  12.64670 16  *59.90"  steel
hs31011117  12.64920 17  *60.0 "  steel
hs31011200  -1
hs31011201  carbon-steel            2
hs31011202  concrete  14
hs31011203  carbon-steel            16
hs31011300  0
hs31011400  1  203  int  0.5  0.5
hs31011500  1.0 22.2504  7.4104
hs31011600  1  310  ext  0.5  0.5
hs31011700  1.0  25.2984  7.4104
*hs31011800  -1
*hs31011801  315.0   17
*
*****************************************************************
*   hs31027 - suppression pool floor - wetwell side
*             ri = 12.6490 m
*             ro = 18.8976 m
*             delta r = 6.2486 m
*             begins at elevation = 83'6"
*             ends at elevation = 93'0 1/4"
*
*****************************************************************
*
hs31027000  11  1  -1  0
hs31027001  supp-pool-floor
hs31027002  25.4508  0.0
hs31027003  1.0
hs31027100  -1  1  25.4508
hs31027102  26.89860  2  *57"  concrete
hs31027103  27.62250  3  *85 1/2" concrete
hs31027104  27.98445  4  *99 3/4"  concrete
hs31027105  28.16860  5  *107"  concrete
hs31027106  28.25750  6  *110.5" concrete
hs31027107  28.30830  7  *112.5" concrete
hs31027108  28.34640  8  *114.0" concrete
hs31027109  28.3489   9  *114.1" steel
hs31027110  28.35148 10  *114.2" steel
hs31027111  28.35280 11  *114.25" steel
hs31027200  -1
hs31027201  concrete  7
hs31027202  'stainless steel'  10
hs31027300  0
hs31027400  0
hs31027600  1  310  ext  0.0  0.0
hs31027700  619.278  6.2486  2.902
hs31027800  -1
hs31027801  308.15  11
*
********************************************************************
*   hs31105 - wetwell containment wall from 135'4" to 161'6"
*             ri = 62'0"
*             ro = 65'6"
```

```
*
*********************************************************************
*
hs31105000  11  2  -1  0
hs31105001  cont-wall-cv311
hs31105002  41.2496  1.0
hs31105003  1.0
hs31105100  31007  1  18.8976
hs31105200  31007
hs31105300  0
hs31105400  1  311  int  0.0  0.0
hs31105500  1.0  37.7952  7.9756
hs31105600  0
hs31105800  31007
*
*********************************************************************
*   hs31204 - wetwell containment wall from 161'6" to 184'6"
*             (49.2252 m to 56.2356 m)
*
*********************************************************************
hs31204000  11  2  -1  0
hs31204001  cont-wall-cv312
hs31204002  49.2252  1.0
hs31204003  1.0
hs31204100  31007  1  18.8976
hs31204200  31007
hs31204300  0
hs31204400  1  312  int  0.0  0.0
hs31204500  1.0  37.7952  7.0104
hs31204600  0
hs31204800  31007
*
*********************************************************************
*    hs31602 - dome portion of well containment wall
*              thickness = 2'6"
*              begins at elevation =243'6"
*        -radius of 62' based on elevation = 237'9"
*********************************************************************
*
hs31602000  10  5  -1  0
hs31602001  cont-wall-dome
hs31602002  74.2188
hs31602003  1.0
hs31602100  -1  1  17.1450
hs31602102  17.14754  2  *1/10" steel
hs31602103  17.15008  3  *2/10" steel
hs31602104  17.15516  4  *1/4 " steel
hs31602105  17.17040  5  *1"    concrete
hs31602106  17.19580  6  *2"    concrete
hs31602107  17.24660  7  *4"    concrete
hs31602108  17.34820  8  *8"    concrete
hs31602109  17.55140  9  *16"   concrete
hs31602110  17.9070 10  *30"   concrete
hs31602200  -1
hs31602201  carbon-steel     3
hs31602202  concrete  9
hs31602300  0
hs31602400  1  316  int  0.0  0.0
```

```
hs31602500  1.0  17.1450  17.1450
hs31602600  1  399  ext  0.0  0.0
hs31602700  1.0  17.1450  17.1450
hs31602800  -1
hs31602801  308.15  10
*
*********************************************************************
*   hs31703 - wetwell containment wall from 208'10" to 226'2"
*             (63.6524 m to 68.9356 m)
*
*********************************************************************
*
hs31703000  11  2  -1  0
hs31703001  cont-wall-cv317
hs31703002  63.6524  1.0
hs31703003  1.0
hs31703100  31007  1  18.8976
hs31703200  31007
hs31703300  0
hs31703400  1  317  int  0.0  0.0
hs31703500  1.0  37.7952 5.2832
hs31703600  1  399  ext  0.0  0.0
hs31703700  1.0  39.9288 5.2832
hs31703800  31007
*
*********************************************************************
*   hs31802 - wetwell containment wall from 226'2" to 243'6"
*             (68.6524 m to 74.2188 m)
*
*********************************************************************
*
hs31802000  11  2  -1  0
hs31802001  cont-wall-cv318
hs31802002  68.6524  1.0
hs31802003  1.0
hs31802100  31007  1  18.8976
hs31802200  31007
hs31802300  0
hs31802400  1  318  int  0.0 0.0
hs31802500  1.0  37.7952  5.2832
hs31802600  1  399  ext  0.0  0.0
hs31802700  1.0  39.9288  5.2832
hs31802800  31007
*
**********************************************************************
*   hs31504 - polar crane between volumes 315 and 316 (dome)
*           - located between elev. 74 and 75 m
*
**********************************************************************
hs31504000  5  1  0  0
hs31504001  polar-crane-317
hs31504002  74.21 0.0
hs31504003  1.0
hs31504100  -1  1  74.21
hs31504102  74.214   2
hs31504103  74.218   3
hs31504104  74.222   4
hs31504105  74.2253  5
```

```
hs31504200  -1
hs31504201  carbon-steel   4
hs31504300  0
hs31504400  1   315   int  1.0  1.0
hs31504500  2105.4   2.0  0.0153
hs31504600  1   316   ext  1.0  1.0
hs31504700  2105.4   2.0  0.0153
*
**********************************************************************
*   concrete   degassing input
*   degassing values provided by c.r. hyman (etd, ornl) 10-26-89
**********************************************************************
hsdg000110     -20215      14    h2o-vap    * 360.8-378 k
hsdg000120     -20215      14    h2o-vap   * 378-793 k
hsdg000130     -20215      14    co2          * 823-1073 k
hsdg000111     59.68     2.258e6      360.8      378.0
hsdg000121     44.27     6.065e6      378.0      793.0
hsdg000131     473.06    4.157e6      823.0      1073.0
**********************************************************************
hsdg000210     20226      11    h2o-vap    * 360.8-378 k
hsdg000220     20226      11    h2o-vap   * 378-793 k
hsdg000230     20226      11    co2          * 823-1073 k
hsdg000211     59.68     2.258e6      360.8      378.0
hsdg000221     44.27     6.065e6      378.0      793.0
hsdg000231     473.06    4.157e6      823.0      1073.0
**********************************************************************
hsdg000310     -20228      14    h2o-vap    * 360.8-378 k
hsdg000320     -20228      14    h2o-vap   * 378-793 k
hsdg000330     -20228      14    co2          * 823-1073 k
hsdg000311     59.68     2.258e6      360.8      378.0
hsdg000321     44.27     6.065e6      378.0      793.0
hsdg000331     473.06    4.157e6      823.0      1073.0
**********************************************************************
*
* ------------------------------------------------------------------
* tabular function for pressure vessel temperatures vs time
* ------------------------------------------------------------------
*
*
*  the values of temperature vs time were taken from the bwr sar srv run
*    of october 10, 1989. the steam/h2 temperature vs time in the srv
*    file was used as the basis of the pressure vessel temperature . the
*    inside surface of the pressure vessel is set equal to the control
*    fun. see hs 20527xnn, hs20524xnn, hs20526xnn for use of cf 890
*
*
*
*
* ---------------------------------------------------------------------
* tabular function input for vessel insulation
* ---------------------------------------------------------------------
*
tf12000   'htc out vess'      2         1.0       0.0
tf12010                       273.15    1.0      5000.0     1.0
**********************************************************************
* ---------------------------------------------------------------------
* tabular function input for thermal conductivity, heat capacity, and
* density of heat structure materials
```

```
* ---------------------------------------------------------------------
**********************************************************************
* carbon-steel
mpmat10000 carbon-steel
mpmat10001 thc 100
mpmat10002 cps 101
mpmat10003 rho 102
*
tf10000   'thc carbon-steel'  10        1.0       0.0
tf10010                       273.15    55.0      373.15    52.0
tf10011                       473.15    48.0      573.15    45.0
tf10012                       673.15    42.0      873.15    35.0
tf10013                      1073.15    31.0     1273.15    29.0
tf10014                      1473.15    31.0     9973.15    31.0
*
tf10100   'cp carbon-steel '  2         1.0       0.0
tf10110                       273.15    0.465e3   5000.0    0.465e3
*
tf10200   'rho carbon-steel'  2         1.0       0.0
tf10210                       273.15    7833.0    5000.0    7833.0
********************************************************************
* drywell head air space gap properties
mpmat20000   'air gap 1'
mpmat20001   thc  200
mpmat20002   cps  201
mpmat20003   rho  202
*
tf20000      'thc air gap 1'   2     1.0    0.0
tf20011          273.15     17.0        10000.0      17.0
*
tf20100      'cps air gap 1'   2     1.0    0.0
tf20111          273.15    1005.0       10000.0     1005.0
*
tf20200      'rho air gap 1'   2     1.0    0.0
tf20211          273.15    1.18         10000.0      1.18
********************************************************************
* thermal properties for limestone / common sand concrete
mpmat30000   concrete
mpmat30001   thc  300
mpmat30002   cps  301
mpmat30003   rho  302
*
tf30000      'thc concrete'    2     1.0     0.0
tf30011          273.15     1.3       10000.0      1.3
*
tf30100      'cps concrete'    2     1.0     0.0
tf30111          273.15   1200.0      10000.0     1200.0
*
tf30200      'rho concrete'    2     1.0     0.0
tf30211          273.15    2340.0     10000.0      2340.0
********************************************************************
cf31100   ww-dw-dp  add  2  1.  0.
cf31101   0.
cf31110   1.  0.  cvh-p.310
cf31111  -1.  0.  cvh-p.204
*
cf31200   max-dp  max  2  1.  0.
cf31201   0.
```

```
cf31210   1.  0.  cfvalu.311
cf31211   1.  0.  cfvalu.312
*
cf31300   max-ww-p  max  2  1.  0.
cf31301   0.
cf31310   1.   0.   cvh-p.310
cf31311   1.   0.   cfvalu.313
*
cf31400   max-ww-t  max  2  1.  0.
cf31401   0.
cf31410   1.   0.   cvh-tvap.310
cf31411   1.   0.   cfvalu.314
*
**********************************************************************
**********************************************************************
*    3 spray headers at elevations 294' 0", 282' 10", and 264' 0"
*    with a total flow rate of 5650 gpm (0.3565 m**3/sec)
*    all 3 headers located in cv 316
*    based on a mean drop fall height of 65.5 m, an elevation of
*    208'10" + 65.5' = 274'4" is used
*
********************************************************************
*
*   sprays inactive for case 1
*
*sprsr0100  cont-spray  316  83.6168  333
*sprsr0101  335.93  0.3565
*sprsr0102  2.30e-04   1.0
*sprjun01  316  315  0.6
*sprjun02  316  318  0.4
*sprjun03  315  314  1.0
*sprjun04  318  317  1.0
*sprjun05  314  313  1.0
*sprjun06  317  319  1.0
*sprjun07  319  312  1.0
*sprjun08  312  311  1.0
*sprjun09  311  310  1.0
*sprsump0   310
*
*cf33300    spray-start  l-gt  2  1.  0.
*cf33301    .false.
*cf33305    latch
*cf33310    1.  0.  time
*cf33311    0. 4.5e2 time     * sprays active at ads for case 1
*
**********************************************************************
**********************************************************************
*
* burn package set to default values
* ignitors off for case 1 (on card  bur000, 0=active,1=inactive)
*
bur000    1
*          xh2ign   xcoign   xh2igy   xcoigy   xo2ig  xmsig
bur001       0.10    0.167    0.070    0.129    0.05    0.55
bur002       0.14     0.09     0.3
*          xh2cc  xcocc   xh2pup   xcopup
bur003   0.08    0.148    0.041    0.125    0.06    0.138    0.09    0.150
*          icvnum   igntr  cdim   tfrac
```

```
bur101     311        -776
bur102     312        -776
bur103     207        -776
bur104     204        -776
bur105     206        -776
bur106     317        -776
bur107     319        -776
bur108     320        -776
bur109     321        -776
bur110     322        -776
bur111     323        -776
bur112     324        -776
bur113     325        -776
bur114     326        -776
bur115     327        -776
burcc00  -1  0
burfs00  -1  0 *use default value of flame speed
*                  flame speed
*sc00001    2200       4.5        1
*sc00002    2200       0.         2
*
*
*  control function  to turn ignitors on/off
*
cf77600 ignitors-start l-a-ifte 3 1.0 0.0
cf77610  1.0  0.0  cfvalu.777
cf77611  0.0  0.0  time
cf77612  0.0  0.0  time
*
cf77700 ignitors-start  l-gt  2  1.0  0.0
cf77710  1.0  0.0   time
cf77711  0.0  0.0   time
*
*****
*****
***** control functions for maximum temperatures and pressures
*****
*
*>>>>>>>>>>>>>>>>>>>>>>>>>  wetwell <<<<<<<<<<<<<<<<<<<<<<<<<<<
*
*
cf04500   check-maxt-311   l-gt   2   1.  0.
cf04501   .false.
cf04510   1.  0.  cvh-tvap.311
cf04511   1.  0.  cfvalu.722
*
cf04600   maxt-time-311   l-a-ifte    3   1.  0.  * time of max 311 temp
cf04610   1.  0.  cfvalu.045
cf04611   1.  0.  time
cf04612   1.  0.  cfvalu.046
*
cf72200   max-t-311  max  2  1.  0.
cf72201   0.
cf72210   1.  0.  cfvalu.722
cf72211   1.  0.  cvh-tvap.311
*
cf04700   check-maxp-311   l-gt   2   1.  0.
cf04701   .false.
```

```
cf04710   1.  0.  cvh-p.311
cf04711   1.  0.  cfvalu.723
*
cf04800   maxp-time-311   l-a-ifte    3   1.   0.   * time of max 311 pres
cf04810   1.  0.  cfvalu.047
cf04811   1.  0.  time
cf04812   1.  0.  cfvalu.048
*
cf72300   max-p-311  max  2  1.  0.
cf72301   0.
cf72310   1.  0.  cfvalu.723
cf72322   1.  0.  cvh-p.311
*
*
cf05700   check-maxt-317   l-gt   2   1.   0.
cf05701   .false.
cf05710   1.  0.  cvh-tvap.317
cf05711   1.  0.  cfvalu.728
*
cf05800   maxt-time-317   l-a-ifte    3   1.   0.   * time of max 317 temp
cf05810   1.  0.  cfvalu.057
cf05811   1.  0.  time
cf05812   1.  0.  cfvalu.058
*
cf72800   max-t-317  max  2  1.  0.
cf72801   0.
cf72810   1.  0.  cfvalu.728
cf72811   1.  0.  cvh-tvap.317
*
cf05900   check-maxp-317   l-gt   2   1.   0.
cf05901   .false.
cf05910   1.  0.  cvh-p.317
cf05911   1.  0.  cfvalu.729
*
cf06000   maxp-time-317   l-a-ifte    3   1.   0.   * time of max 317 pres
cf06010   1.  0.  cfvalu.059
cf06011   1.  0.  time
cf06012   1.  0.  cfvalu.060
*
cf72900   max-p-317  max  2  1.  0.
cf72901   0.
cf72910   1.  0.  cfvalu.729
cf72911   1.  0.  cvh-p.317
*
cf06100   check-maxt-310   l-gt   2   1.   0.
cf06101   .false.
cf06110   1.  0.  cvh-tvap.310
cf06111   1.  0.  cfvalu.730
*
cf06200   maxt-time-310   l-a-ifte    3   1.   0.   * time of max 310 temp
cf06210   1.  0.  cfvalu.061
cf06211   1.  0.  time
cf06212   1.  0.  cfvalu.062
*
cf73000   max-t-310  max  2  1.  0.
cf73001   0.
cf73010   1.  0.  cfvalu.730
cf73011   1.  0.  cvh-tvap.310
```

```
*
cf06300   check-maxp-310   l-gt   2   1.   0.
cf06301   .false.
cf06310   1.   0.   cvh-p.310
cf06311   1.   0.   cfvalu.731
*
cf06400   maxp-time-310   l-a-ifte    3   1.   0.   * time of max 310 pres
cf06410   1.   0.   cfvalu.063
cf06411   1.   0.   time
cf06412   1.   0.   cfvalu.064
*
cf73100   max-p-310  max  2  1.  0.
cf73101   0.
cf73110   1.   0.   cfvalu.731
cf73111   1.   0.   cvh-p.310
*
cf06500   check-maxt-312   l-gt   2   1.   0.
cf06501   .false.
cf06510   1.   0.   cvh-tvap.312
cf06511   1.   0.   cfvalu.732
*
cf06600   maxt-time-312   l-a-ifte    3   1.   0.   * time of max 312 temp
cf06610   1.   0.   cfvalu.065
cf06611   1.   0.   time
cf06612   1.   0.   cfvalu.066
*
cf73200   max-t-312  max  2  1.  0.
cf73201   0.
cf73210   1.   0.   cfvalu.732
cf73211   1.   0.   cvh-tvap.312
*
cf06700   check-maxp-312   l-gt   2   1.   0.
cf06701   .false.
cf06710   1.   0.   cvh-p.312
cf06711   1.   0.   cfvalu.733
*
cf06800   maxp-time-312   l-a-ifte    3   1.   0.   * time of max 312 pres
cf06810   1.   0.   cfvalu.067
cf06811   1.   0.   time
cf06812   1.   0.   cfvalu.068
*
cf73300   max-p-312  max  2  1.  0.
cf73301   0.
cf73312   1.   0.   cfvalu.733
cf73311   1.   0.   cvh-p.312
*
cf07300   check-maxt-325   l-gt   2   1.   0.
cf07301   .false.
cf07312   1.   0.   cvh-tvap.325
cf07311   1.   0.   cfvalu.736
*
cf07400   maxt-time-325   l-a-ifte    3   1.   0.   * time of max 325 temp
cf07410   1.   0.   cfvalu.073
cf07411   1.   0.   time
cf07412   1.   0.   cfvalu.074
*
cf73600   max-t-325  max  2  1.  0.
cf73601   0.
```

```
cf73610   1.  0.  cfvalu.736
cf73611   1.  0.  cvh-tvap.325
*
cf07500   check-maxp-325   l-gt   2   1.  0.
cf07501   .false.
cf07510   1.  0.  cvh-p.325
cf07511   1.  0.  cfvalu.737
*
cf07600   maxp-time-325   l-a-ifte    3   1.  0.  * time of max 325 pres
cf07610   1.  0.  cfvalu.075
cf07611   1.  0.  time
cf07612   1.  0.  cfvalu.076
*
cf73700   max-p-325  max  2  1.  0.
cf73701   0.
cf73710   1.  0.  cfvalu.737
cf73711   1.  0.  cvh-p.325
*
*
cf00500   check-maxt-319   l-gt   2   1.  0.
cf00501   .false.
cf00510   1.  0.  cvh-tvap.319
cf00511   1.  0.  cfvalu.702
*
cf00600   maxt-time-319   l-a-ifte    3   1.  0.  * time of max 319 temp
cf00610   1.  0.  cfvalu.005
cf00611   1.  0.  time
cf00612   1.  0.  cfvalu.006
*
cf70200   max-t-319  max  2  1.  0.
cf70201   0.
cf70210   1.  0.  cfvalu.702
cf70211   1.  0.  cvh-tvap.319
*
cf00700   check-maxp-319   l-gt   2   1.  0.
cf00701   .false.
cf00710   1.  0.  cvh-p.319
cf00711   1.  0.  cfvalu.703
*
cf00800   maxp-time-319   l-a-ifte    3   1.  0.  * time of max 319 pres
cf00810   1.  0.  cfvalu.007
cf00811   1.  0.  time
cf00812   1.  0.  cfvalu.008
*
cf70300   max-p-319  max  2  1.  0.
cf70301   0.
cf70310   1.  0.  cfvalu.703
cf70311   1.  0.  cvh-p.319
*
cf00900   check-maxt-320   l-gt   2   1.  0.
cf00901   .false.
cf00910   1.  0.  cvh-tvap.320
cf00911   1.  0.  cfvalu.704
*
cf01000   maxt-time-320   l-a-ifte    3   1.  0.  * time of max 320 temp
cf01010   1.  0.  cfvalu.009
cf01011   1.  0.  time
cf01012   1.  0.  cfvalu.010
```

```
*
cf70400   max-t-320  max  2  1.  0.
cf70401   0.
cf70410   1.  0.  cfvalu.704
cf70411   1.  0.  cvh-tvap.320
*
cf01100   check-maxp-320   l-gt   2   1.  0.
cf01101   .false.
cf01110   1.  0.  cvh-p.320
cf01111   1.  0.  cfvalu.705
*
cf01200   maxp-time-320   l-a-ifte    3   1.  0.  * time of max 320 pres
cf01210   1.  0.  cfvalu.011
cf01211   1.  0.  time
cf01212   1.  0.  cfvalu.012
*
cf70500   max-p-320  max  2  1.  0.
cf70501   0.
cf70510   1.  0.  cfvalu.705
cf70511   1.  0.  cvh-p.320
*
*
*
cf75900   max-t-torrm  max  6  1.  0.
cf75901   0.
cf75910   1.  0.  cfvalu.759
cf75918   1.  0.  cvh-tvap.311
cf75919   1.  0.  cvh-tvap.312
cf75920   1.  0.  cvh-tvap.310
cf75921   1.  0.  cvh-tvap.317
cf75923   1.  0.  cvh-tvap.319
*
*
cf76000   max-p-torrm  max 6  1.  0.
cf76001   0.
cf76010   1.  0.  cfvalu.760
cf76018   1.  0.  cvh-p.310
cf76019   1.  0.  cvh-p.311
cf76020   1.  0.  cvh-p.312
cf76021   1.  0.  cvh-p.317
cf76023   1.  0.  cvh-p.319
*
*
******* >>>>>>>>>>>>  drywell   <<<<<<<<<<<<< *******
*
*
cf01300   check-maxt-201   l-gt   2   1.  0.
cf01301   .false.
cf01310   1.  0.  cvh-tvap.201
cf01311   1.  0.  cfvalu.706
*
cf01400   maxt-time-201   l-a-ifte    3   1.  0.  * time of max 201 temp
cf01410   1.  0.  cfvalu.013
cf01411   1.  0.  time
cf01412   1.  0.  cfvalu.014
*
cf70600   max-t-201  max  2  1.  0.
cf70601   0.
```

```
cf70610   1.  0.  cfvalu.706
cf70611   1.  0.  cvh-tvap.201
*
cf01500   check-maxp-201   l-gt   2   1.  0.
cf01501   .false.
cf01510   1.  0.  cvh-p.201
cf01511   1.  0.  cfvalu.707
*
cf01600   maxp-time-201   l-a-ifte   3   1.   0.  * time of max 201 pres
cf01610   1.  0.  cfvalu.015
cf01611   1.  0.  time
cf01612   1.  0.  cfvalu.016
*
cf70700   max-p-201  max  2  1.  0.
cf70701   0.
cf70710   1.  0.  cfvalu.707
cf70711   1.  0.  cvh-p.201
*
cf01700   check-maxt-202   l-gt   2   1.  0.
cf01701   .false.
cf01710   1.  0.  cvh-tvap.202
cf01711   1.  0.  cfvalu.708
*
cf01800   maxt-time-202   l-a-ifte   3   1.   0.  * time of max 202 temp
cf01810   1.  0.  cfvalu.017
cf01811   1.  0.  time
cf01812   1.  0.  cfvalu.018
*
cf70800   max-t-202  max  2  1.  0.
cf70801   0.
cf70810   1.  0.  cfvalu.708
cf70811   1.  0.  cvh-tvap.202
*
cf01900   check-maxp-202   l-gt   2   1.  0.
cf01901   .false.
cf01910   1.  0.  cvh-p.202
cf01911   1.  0.  cfvalu.709
*
cf02000   maxp-time-202   l-a-ifte   3   1.   0.  * time of max 202 pres
cf02010   1.  0.  cfvalu.019
cf02011   1.  0.  time
cf02012   1.  0.  cfvalu.020
*
cf70900   max-p-202  max  2  1.  0.
cf70901   0.
cf70910   1.  0.  cfvalu.709
cf70911   1.  0.  cvh-p.202
*
cf02100   check-maxt-204   l-gt   2   1.  0.
cf02101   .false.
cf02110   1.  0.  cvh-tvap.204
cf02111   1.  0.  cfvalu.710
*
cf02200   maxt-time-204   l-a-ifte   3   1.   0.  * time of max 204 temp
cf02210   1.  0.  cfvalu.021
cf02211   1.  0.  time
cf02212   1.  0.  cfvalu.022
*
```

```
cf71000   max-t-204  max  2  1.  0.
cf71001   0.
cf71010   1.  0.  cfvalu.710
cf71011   1.  0.  cvh-tvap.204
*
cf02300   check-maxp-204   l-gt   2   1.  0.
cf02301   .false.
cf02310   1.  0.  cvh-p.204
cf02311   1.  0.  cfvalu.711
*
cf02400   maxp-time-204   l-a-ifte    3   1.  0.  * time of max 204 pres
cf02410   1.  0.  cfvalu.023
cf02411   1.  0.  time
cf02412   1.  0.  cfvalu.024
*
cf71100   max-p-204  max  2  1.  0.
cf71101   0.
cf71110   1.  0.  cfvalu.711
cf71111   1.  0.  cvh-p.204
*
cf02500   check-maxt-205   l-gt   2   1.  0.
cf02501   .false.
cf02510   1.  0.  cvh-tvap.205
cf02511   1.  0.  cfvalu.712
*
cf02600   maxt-time-205   l-a-ifte    3   1.  0.  * time of max 205 temp
cf02610   1.  0.  cfvalu.025
cf02611   1.  0.  time
cf02612   1.  0.  cfvalu.026
*
cf71200   max-t-205  max  2  1.  0.
cf71201   0.
cf71210   1.  0.  cfvalu.712
cf71211   1.  0.  cvh-tvap.205
*
cf02700   check-maxp-205   l-gt   2   1.  0.
cf02701   .false.
cf02710   1.  0.  cvh-p.205
cf02711   1.  0.  cfvalu.713
*
cf02800   maxp-time-205   l-a-ifte    3   1.  0.  * time of max 205 pres
cf02810   1.  0.  cfvalu.027
cf02811   1.  0.  time
cf02812   1.  0.  cfvalu.028
*
cf71300   max-p-205  max  2  1.  0.
cf71301   0.
cf71310   1.  0.  cfvalu.713
cf71311   1.  0.  cvh-p.205
*
cf02900   check-maxt-206   l-gt   2   1.  0.
cf02901   .false.
cf02910   1.  0.  cvh-tvap.206
cf02911   1.  0.  cfvalu.714
*
cf03000   maxt-time-206   l-a-ifte    3   1.  0.  * time of max 206 temp
cf03010   1.  0.  cfvalu.029
cf03011   1.  0.  time
```

```
cf03012   1.  0.  cfvalu.030
*
cf71400   max-t-206  max  2  1.  0.
cf71401   0.
cf71410   1.  0.  cfvalu.714
cf71411   1.  0.  cvh-tvap.206
*
cf03100   check-maxp-206   l-gt   2   1.  0.
cf03101   .false.
cf03110   1.  0.  cvh-p.206
cf03111   1.  0.  cfvalu.715
*
cf03200   maxp-time-206   l-a-ifte    3   1.  0.  * time of max 206 pres
cf03210   1.  0.  cfvalu.031
cf03211   1.  0.  time
cf03212   1.  0.  cfvalu.032
*
cf71500   max-p-206  max  2  1.  0.
cf71501   0.
cf71510   1.  0.  cfvalu.715
cf71511   1.  0.  cvh-p.206
*
cf03300   check-maxt-207   l-gt   2   1.  0.
cf03301   .false.
cf03310   1.  0.  cvh-tvap.207
cf03311   1.  0.  cfvalu.716
*
cf03400   maxt-time-207   l-a-ifte    3   1.  0.  * time of max 207 temp
cf03410   1.  0.  cfvalu.033
cf03411   1.  0.  time
cf03412   1.  0.  cfvalu.034
*
cf71600   max-t-207  max  2  1.  0.
cf71601   0.
cf71610   1.  0.  cfvalu.716
cf71611   1.  0.  cvh-tvap.207
*
cf03500   check-maxp-207   l-gt   2   1.  0.
cf03501   .false.
cf03510   1.  0.  cvh-p.207
cf03511   1.  0.  cfvalu.717
*
cf03600   maxp-time-207   l-a-ifte    3   1.  0.  * time of max 207 pres
cf03610   1.  0.  cfvalu.035
cf03611   1.  0.  time
cf03612   1.  0.  cfvalu.036
*
cf71700   max-p-207  max  2  1.  0.
cf71701   0.
cf71710   1.  0.  cfvalu.717
cf71711   1.  0.  cvh-p.207
*
cf03700   check-maxt-208   l-gt   2   1.  0.
cf03701   .false.
cf03710   1.  0.  cvh-tvap.208
cf03711   1.  0.  cfvalu.718
*
cf03800   maxt-time-208   l-a-ifte    3   1.  0.  * time of max 208 temp
```

```
cf03810   1.  0.  cfvalu.037
cf03811   1.  0.  time
cf03812   1.  0.  cfvalu.038
*
cf71800   max-t-208  max  2  1.  0.
cf71801   0.
cf71810   1.  0.  cfvalu.718
cf71811   1.  0.  cvh-tvap.208
*
cf03900   check-maxp-208   l-gt   2   1.  0.
cf03901   .false.
cf03910   1.  0.  cvh-p.208
cf03911   1.  0.  cfvalu.719
*
cf04000   maxp-time-208   l-a-ifte    3   1.  0.  * time of max 208 pres
cf04010   1.  0.  cfvalu.039
cf04011   1.  0.  time
cf04012   1.  0.  cfvalu.040
*
cf71900   max-p-208  max  2  1.  0.
cf71901   0.
cf71910   1.  0.  cfvalu.719
cf71911   1.  0.  cvh-p.208
*
cf04100   check-maxt-209   l-gt   2   1.  0.
cf04101   .false.
cf04110   1.  0.  cvh-tvap.209
cf04111   1.  0.  cfvalu.720
*
cf04200   maxt-time-209   l-a-ifte    3   1.  0.  * time of max 209 temp
cf04210   1.  0.  cfvalu.041
cf04211   1.  0.  time
cf04212   1.  0.  cfvalu.042
*
cf72000   max-t-209  max  2  1.  0.
cf72001   0.
cf72010   1.  0.  cfvalu.720
cf72011   1.  0.  cvh-tvap.209
*
cf04300   check-maxp-209   l-gt   2   1.  0.
cf04301   .false.
cf04310   1.  0.  cvh-p.209
cf04311   1.  0.  cfvalu.721
*
cf04400   maxp-time-209   l-a-ifte    3   1.  0.  * time of max 209 pres
cf04410   1.  0.  cfvalu.043
cf04411   1.  0.  time
cf04412   1.  0.  cfvalu.044
*
cf72100   max-p-209  max  2  1.  0.
cf72101   0.
cf72110   1.  0.  cfvalu.721
cf72111   1.  0.  cvh-p.209
*
*
cf75500   max-t-dw  max  9  1.  0.
cf75501   0.
cf75510   1.  0.  cfvalu.755
```

```
cf75511   1.  0.  cvh-tvap.201
cf75512   1.  0.  cvh-tvap.202
cf75513   1.  0.  cvh-tvap.204
cf75514   1.  0.  cvh-tvap.205
cf75515   1.  0.  cvh-tvap.206
cf75516   1.  0.  cvh-tvap.207
cf75517   1.  0.  cvh-tvap.208
cf75518   1.  0.  cvh-tvap.209
*
*
cf75600   max-p-dw  max  9  1.  0.
cf75601   0.
cf75610   1.  0.  cfvalu.756
cf75611   1.  0.  cvh-p.201
cf75612   1.  0.  cvh-p.202
cf75613   1.  0.  cvh-p.204
cf75614   1.  0.  cvh-p.205
cf75615   1.  0.  cvh-p.206
cf75616   1.  0.  cvh-p.207
cf75617   1.  0.  cvh-p.208
cf75618   1.  0.  cvh-p.209
*
*
*
**********************************************************************
**********************************************************************
*     transfer process input
**********************************************************************
**********************************************************************
*
*
*   activate fdi for the pedestal cavity 202
*
*fdi1000   202   01  102  101
*fdi1001   pedestal cavity
*fdi1002  27.8892  36.9951
*
***** tp input *****
*        nmsim  nthrm
tpin10100   6      9   * core
*
*
*            nmsot  npotoi  iotmtx
tpot10200     5     101      uin.103
*
*
*           nrow   ncol
tpm1030000    5      6
*                      nrow/ncol    value        material
tpm1030001                1/1         1.0          * uo2 mass
tpm1030002                2/2         1.0          *  zr mass
tpm1030003                3/3         1.0          *  steel mass
tpm1030004                4/4         1.0          *   zro2 mass
tpm1030005                5/5         1.0          * steel oxide mass
*
*         radionuclide transfer processes
*
tpin60100   16   1
```

```
*
tpot60200   16   601  def.1
*
**********************************************************************
**     dw cavity input
**********************************************************************
**********************************************************************
*
*
* -- Grand Gulf Cavity:
*                     O.D.  = 32' 8" = 9.9562 m,  radius= 4.9784 m
*                     I.D.  = 21' 2" = 6.4516 m,  radius= 3.2258
*                     Approximate cavity volume  =  254.648 m**3
*                     Sidewall thickness = 5' 9" = 1.7526 m
*                     Floor thickness = 11' 0" = 3.3528 m
*
*
*
cav0100    202    dw-cavity    *  drywell inpedestal cavity
*
*
*********************************************************************
*
*     cavity concrete properties
*
*********************************************************************
*
*
*   limestone / common sand concrete (mix446) with 0.135 kg/kg rebar
cav01c0   user-input
cav01c1   sio2      0.38300       tio2     0.00073
cav01c2   mno       0.00028       mgo      0.10000
cav01c3   cao       0.18700       na2o     0.00330
cav01c4   k2o       0.00829       fe2o3    0.01180
cav01c5   al2o3     0.05052       cr2o3    0.00011
cav01c6   co2       0.20500       h2oevap  0.02870
cav01c7   h2ochem   0.02130
cav01c8   fe        0.13500   * 0.135 kg/kg rebar
cav01ca   densct    2340.0    * density
cav01cb   tsolct    1420.0    * solidus temperature
cav01cc   tliqct    1670.0    * liquidus temperature
cav01cd   tablct    1503.0    * ablation temperature
cav01ce   tinct      310.0    * initial temperature
cav01cf   emisct       0.82   * emissivity
*
cav01g0   corcon  2            *  flat bottom cylinder geometry
*
*         nrays   r0   z0
cav01g1    55     0.   0.6
*         zt   rad     hit     radc    rw    hbb       nbot  ncorn
cav01g2   0.0  3.2258  2.9210  0.01  4.9784   3.3528   32     3
*
cav01tp        102             *  transfer process number
*
*
*
. ** end of file*
```

Appendix B

BEST-ESTIMATE DECK, BH INPUT

The model of this input file is described in Sect. 4.4. The file of this Appendix B, together with the file of Appendix A are required for the "best-estimate" deck of the Grand Gulf Nuclear Station.

```
*
*
*  ORNL BOTTOM HEAD INPUT
BH0000   'GRAND GULF LOW PRESSURE, SHORT TERM STATION BLACKOUT SEQUENCE'
*
*          HBSB       NA     NPS   IEUTEC NMELTX   TMLTBD
BH0100     3.512      26     26      4      0       2672.
*HBSB at bottom of downcomer
*
*          AMTMEL     AMMLWT     AMLAMF
*           (K)                  (J/KG)
BH0201     2124.8     91.22     2.51208E5   *  ZR
BH0202     1808.0     55.847    2.72142E5   *  FE
BH0203     2130.0     51.996    3.16336E5   *  CR
BH0204     1728.0     58.700    3.00054E5   *  NI
BH0205        0.0      0.0      0.0         *  c -> blank
BH0206        0.0      0.0      0.0         *  b -> blank
BH0207        0.0      0.0      0.0         *  u -> blank
BH0208        0.0      0.0      0.0        *
BH0209        0.0      0.0      0.0        *
BH0210     2727.6     55.260    1.89336E6   *  B4C
BH0211     2977.6    123.220    7.07104E5   *  ZRO2
BH0212     1649.8     71.850    4.41940E5   *  FEO
BH0213     1733.2    159.690    5.25676E5   *  FE2O3
BH0214     1838.7    231.540    5.95456E5   *  FE3O4
BH0215     2572.0    152.02     6.88496E5   *  CR2O3
BH0216     2244.3     74.710    6.79192E5   *  NIO
BH0217     2727.6     69.620    3.44248E5   *  B2O3
BH0218     3010.9    270.070    2.74468E5   *  UO2
BH0219        0.0      0.0      0.0        *
BH0220        0.0      0.0      0.0        *
*
*Volume Tables*
*          HH          VCORE       VSHRD
*          (M)         (M**3)      (M**3)
BH0301    0.0          0.0          0.0
BH0302    .127         .147         0.0
BH0303    .254         .583         0.0
BH0304    .381        1.297         0.0
BH0305    .508        2.279         0.0
BH0306    .762        5.010         0.0
BH0307   1.107       10.237         0.0
BH0308   1.290       14.006         0.0
BH0309   1.651       22.499         0.0
BH0310   2.019       32.007         0.0
BH0311   2.261       39.047         0.0
BH0312   2.540       47.199         0.0
BH0313   2.794       54.610         0.0
BH0314   3.048       62.021         0.0
BH0315   3.254       68.024         0.0
BH0316   3.512       75.550         0.0        * bottom of downcomer
BH0317   3.823       81.636         2.219
BH0318   3.988       84.883         3.648
BH0319   4.234       89.728         5.780
BH0320   4.343       91.876         6.721
BH0321   4.470       94.360         7.826
BH0322   4.620       97.291         9.130
BH0323   4.724       99.294        10.102
```

```
BH0324  4.862   101.962       11.160
BH0325  5.004   104.648       12.257
BH0326  5.217   108.677       13.903
*
*          HPS         VPS
*          (M)        (M**3)
BH0401   0.0        0.0
BH0402   .127       .027
BH0403   .254       .105
BH0404   .381       .232
BH0405   .508       .404
BH0406   .762       .874
BH0407  1.107      1.584
BH0408  1.290      1.945
BH0409  1.651      2.587
BH0410  2.019      3.947
BH0411  2.261      4.610
BH0412  2.540      5.377
BH0413  2.794      6.075
BH0414  3.048      6.772
BH0415  3.254      7.337
BH0416  3.512      8.041     * bottom of downcomer
BH0417  3.823      8.727
BH0418  3.988      9.091
BH0419  4.234      9.634
BH0420  4.343      9.875
BH0421  4.470     10.155
BH0422  4.620     10.485
BH0423  4.724     10.715
BH0424  4.862     10.945
BH0425  5.004     11.259
BH0426  5.217     11.729
*
*      PORBOX  PORBM DTHEAD  H1MAX   HD1D2
BH0500  0.4     0.32  60.0   0.6096  2.018
*
*       HSKIRT   THKCRS    THKHD1     THKHD2     THK6   THK60
BH0600 1.524    0.0508    0.241      0.210     1672.0  1560.9
*
*---------+---------+---------+---------+---------+---------+---------+--
*    IMWDEB  SFCRDB  FZRMX1  FZRMX2  DRXID  TFAIL2   HCYL    RCYL
BH0700 1      4.0     1.0     1.0     6.960  1523.0   2.018   3.188
*
*     TMLIEU  IEUKEY  FRCKEY
BH0801   1523.0   2      .65970 0.0
BH0802   1700.0   3      .19152 0.0
BH0803   1873.2  18      .10000 0.0
BH0804   2573.2  11      .75000 0.0
*
*      IEU(J,II) 1.LE.J.LE.20, 1.LE.II.LE.IEUTEC, 1.LE.K.LE.4
*          PURE SPECIES INDEX:J
*          /1  2  3  4  5 = / ZR    FE    CR    NI    -
*           6  7  8  9 10 =   -     -     -     -     B4C
*          11 12 13 14 15 =   ZRO2  FEO   FE2O3 FE3O4 CR2O3
*          16 17 18 19 20/=   NIO   B2O3  UO2   -     - /
*
*      IEU(J,II)=0 MEANS THAT SPECIES J IS NOT IN EUTECTIC II
*               =1 MEANS THAT SPECIES J IS IN EUTECTIC II
```

```
*BH09IIK
*       II=EUTECTIC INDEX
*        J=PURE SPECIES INDEX
*        K=CARD COUNTER
* EUTECTIC 1
BH09011  1  1  1  1  0
BH09012  0  0  0  0  0
BH09013  0  0  0  0  0
BH09014  0  0  0  0  0
* EUTECTIC 2
BH09021  0  1  1  1  0
BH09022  0  0  0  0  0
BH09023  0  0  0  0  0
BH09024  0  0  0  0  0
* EUTECTIC 3
BH09031  1  0  1  0  0
BH09032  0  0  0  0  0
BH09033  0  0  0  0  0
BH09034  0  0  1  0  0
* EUTECTIC 4
BH09041  0  0  0  0  0
BH09042  0  0  0  0  0
BH09043  1  0  0  0  0
BH09044  0  0  1  0  0
*
*BH10IIK
*       II=EUTECTIC INDEX
*        J=PURE SPECIES INDEX
*        K=CARD COUNTER
*        XRNKEY(J,II)  1.LE.J.LE.20, 1.LE.II.LE.IEUTEC, 1.LE.K.LE.4
* EUTECTIC 1
BH10011  0.100   0.6597 0.1724 0.0679 0.0
BH10012  0.0     0.0    0.0    0.0    0.0
BH10013  0.0     0.0    0.0    0.0    0.0
BH10014  0.0     0.0    0.0    0.0    0.0
* EUTECTIC 2
BH10021  0.0     .73308 .19152 .07540 0.0
BH10022  0.0     0.0    0.0    0.0    0.0
BH10023  0.0     0.0    0.0    0.0    0.0
BH10024  0.0     0.0    0.0    0.0    0.0
* EUTECTIC 3
BH10031  .300    0.0    0.6    0.0    0.0
BH10032  0.0     0.0    0.0    0.0    0.0
BH10033  0.0     0.0    0.0    0.0    0.0
BH10034  0.0     0.0    0.1    0.0    0.0
* EUTECTIC 4
BH10041  0.0     0.0    0.0    0.0    0.0
BH10042  0.0     0.0    0.0    0.0    0.0
BH10043  .75     0.0    0.0    0.0    0.0
BH10044  0.0     0.0    .25    0.0    0.0
*
*         ---- NPIPES----  DPIPES    HPIPES       TABLAT
*         (1)   (2)   (3)   (M)       (W/M**2-K)   (K)
BH1100    19    19    20   .038      1.0214E3    1756.
*
*         CVH VOLUME            CVH VOLUME
*         REPRESENT.            REPRESENT.
*          JET PUMP               D W S
```

```
BH1200      105                  205
*
*
*
*       user controlled
*       print frequency
*      for bottom head
*         DTPNTB(sec)       dbdrpr(kg/sec)
BH1300     300.0              2000.0
*
*
* core shroud to vessel wall thermal radiation model input
*      nshrd      nvwall
BH1400   11         2
*
*   enter the core shroud heat structure numbers
*   nshrd entries required
*   II is the card counter
*BH141II
BH14101  10004  10005  10006  10107
BH14102  10108  10109  10110  10111
BH14103  10112  10113  10301
*
*   enter the vessel wall heat structure numbers
*   nvwall entries required
*   JJ is the card counter
*BH142JJ
BH14201  20501  20502
*
*    enter the view factors for each vessel wall structure
*    identified by the jj index (1.le.jj.le.nwall)
*    nshrd entries required for each wall structure
*    KK is the card counter
*BH14JJKK
BH140101  0.23 0.02  0.01  0.01  0.01  0.00
BH140102  0.00 0.00  0.00  0.00  0.00
BH140201  0.77 0.98  0.99  0.99  0.99  1.00
BH140202  1.00 1.00  1.00  1.00  1.00
*
**
*BH15CC heat transfer characteristics of bottom head
* external surface
*       ibcbh(jj) iflobh(jj)   fcrtr(pool,jj) fcrtr(atm,jj)
BH1501     1         1          0.5            0.5
BH1502     1         1          0.5            0.5
BH1503     1         1          0.5            0.5
BH1504     1         1          0.5            0.5
BH1505     1         1          0.5            0.5
BH1506     1         1          0.5            0.5
BH1507     1         1          0.5            0.5
BH1508     1         1          0.5            0.5
BH1509     1         1          0.5            0.5
BH1510     1         1          0.5            0.5
BH1511     1         1          0.5            0.5
BH1512     1         1          0.5            0.5
BH1513     1         1          0.5            0.5
BH1514     1         1          0.5            0.5
BH1515     1         1          0.5            0.5
```

```
BH1516     1          1           0.5             0.5
BH1517     1          1           0.5             0.5
BH1518     1          1           0.5             0.5
*
*BH16 series: deactivate heat structures in bottom head
BH1600 5
BH1601  10001
BH1602  10002
BH1603  10003
BH1604  20500
BH1605  20501
*
* input HS wall structures interfaced with BH
*      IHSBOT  IHSTOP
BH1700  20501  20502
*
* input for the BH package lower plenum debris to overlying
* structure radiation model (BH18... series)
*     NSHDLP   TFAILS  NHSOF2
BH1800  3      1700.0     14
*          ISHDLP(i) 1.le.i.le.nshdlp
BH1801   10011  10004 10005
*
*          IHSOF2(i) 1.le.i.le.nhsof2
BH18101  10011  10004  10005  10006  10107
BH18102  10108  10109  10110  10111
BH18103  10112  10113  10301  10302  10303
*
*degassing input
*
HSDG100110  -10011  4  SS
HSDG100111  7930.0   268000.0  1695.0  1705.0
HSDG100040  -10004  4  SS
HSDG100041  7930.0  268000.0  1695.0  1705.0
HSDG100050  -10005  4  SS
HSDG100051  7930.0   268000.0  1695.0  1705.0
HSDG100060  -10006  4  SS
HSDG100061  7930.0  268000.0  1695.0  1705.0
HSDG101070  -10107  4  SS
HSDG101071  7930.0   268000.0  1695.0  1705.0
HSDG101080  -10108  4  SS
HSDG101081  7930.0  268000.0  1695.0  1705.0
HSDG101090  -10109  4  SS
HSDG101091  7930.0   268000.0  1695.0  1705.0
HSDG101100  -10110  4  SS
HSDG101101  7930.0  268000.0  1695.0  1705.0
HSDG101110  -10111  4  SS
HSDG101111  7930.0  268000.0  1695.0  1705.0
HSDG101120  -10112  4  SS
HSDG101121  7930.0   268000.0  1695.0  1705.0
HSDG101130  -10113  4  SS
HSDG101131  7930.0  268000.0  1695.0  1705.0
HSDG103010  -10301  4  SS
HSDG103011  7930.0   268000.0  1695.0  1705.0
HSDG103020  -10302  4  SS
HSDG103021  7930.0  268000.0  1695.0  1705.0
HSDG103030  -10303  4  SS
HSDG103031  7930.0  268000.0  1695.0  1705.0
```

```
*
*BH18JJKK record
*   where JJ is 1.le.JJ.le.(1+NSHDLP+NRAD) index of overlying structure
*          kk is the card counter associated with the JJ index
*   information entered sequentially on the BH18JJKK record
*   is VIEW2(ii,JJ) where:
*          ii is the lower plenum debris bed upper surface radial index
*             (1.le.ii.le.5)
*          JJ is overlying structure index(1.le.JJ.le.(1+nshdlp+nrad))
*             NRAD is from the COR package
*debris surface index i
* use default values
*---JJ--   i=1     =2     =3     =4     =5
*BH180101  0.135  0.154  0.191  0.376  0.564  * JJ=01:exposed vessel
wall
*BH180201  0.062  0.080  0.118  0.220  0.219  * JJ=02:JP baffle
*BH180301  0.290  0.285  0.262  0.121  0.049  * JJ=03:shroud 10014
*BH180401  0.110  0.101  0.086  0.046  0.024  * JJ=04:shroud 10004
*BH180501  0.031  0.031  0.031  0.022  0.006  * JJ=05:COR ring 4
*BH180601  0.032  0.032  0.032  0.022  0.007  * JJ=06:COR ring 3
*BH180701  0.051  0.051  0.048  0.036  0.013  * JJ=07:COR ring 2
*BH180801  0.283  0.259  0.225  0.152  0.098  * JJ=08:COR ring 1
*          -----  -----  -----  -----  -----
* sum    = 0.994  0.993  0.993  0.995  0.980
*
* bh lp water pool and abrk control functions
BH1900  201  202  203
*
CF20400 'L P POOL CHECK' L-GT  2  1.0  0.0
CF20401  .TRUE. * initialize
CF20405  'ONE-SHOT'
CF20410  1.0  0.0  CVH-MASS.1.100
CF20420  0.0  0.1  TIME
*
CF20500 'DRYOUT TIME' L-A-IFTE  3  1.0  0.0
CF20501  1.0E6  * initialize
CF20510  1.0  0.0  CFVALU.204
CF20520  1.0  0.0  CFVALU.205
CF20530  1.0  0.0  TIME
*
CF20000  'FLOW ON'        L-GE     2  1.0  0.0
CF20001  .FALSE.  * initialize
CF20010  1.0  0.0     TIME         * current time
CF20020  0.0 27100.0 TIME  * time of injection (sec)
*
CF20100  'LP MASS SOURCE'    L-A-IFTE   3  1.0  0.0
CF20101   0.0  * initialize
CF20110   1.0   0.0  CFVALU.200 * if true flow in
CF20120   0.0  10.0 TIME *  flow rate ( kg/sec)
CF20130   0.0   0.0 TIME *  no flow rate
*
CF20200  'LP SOURCE TEMP'    L-A-IFTE   3  1.0  0.0
CF20201   0.0  * initialize
CF20210   1.0  0.0  CFVALU.200
CF20220   0.0  300.0 TIME *  temp (k)
CF20230   0.0    0.0 TIME *  temp (k)
*
CF20300  'BH BREAK AREA'    EQUALS  1    1.0  0.0
```

```
CF20301   0.0  * initialize
CF20310   0.0  0.0100  TIME * area=0.01 m**2 before injectiom
*                              area=0.0005 m2 after injection
*
BHRN101    8  7 7 7  0    0  0 0 0 13    8 7  7 7 7  7 13 10 0 0
*
*
.
```

Appendix C

BEST-ESTIMATE DECK, MELGEN INPUT

This MELCOR file is to be used with the MELGEN input files of Appendix A and B to run the "best estimate" station blackout transient of the Grand Gulf Nuclear Station. This file ends the calculation at 170,000 s (47.2 h).

```
title  gg-stsb-w-ads
restartf   gg2.rst
diagf dia2
messagef mes2
cpulim  99400.0
cpuleft  10.0
outputf  mel2out
plotf plot2
time1     0    1.0  0.00001   1720.0 30.0   1720.0
time2  400.0  1.0  0.001  1800.0  50.0  1800.0
time3  1720.0 5.0 0.001   8000.0 300.0   8000.0
time4  7192.0  5.0 0.001  15000.0 500.0 15000.0
time5 11000.0 1.0 0.001 15000.0 10.0  15000.0
time6 11100.0 1.0 0.0001 4000.0 300.0 10000.0
time7 12000.0  10.0 0.0001 10000.0  300.0 10000.0
time8 30000.0  5.0 0.0001 10000.0  300.0 10000.0
time9 31200.0 5.0 0.001 10000.0  300.0 10000.0
tend 170000.0
************************************************
sc00001   4203   1.0   1
cav01rr  -2
.
```

Appendix D

NUREG-1150 DECK, MELGEN INPUT

The model for this input is described in Sect. 5. The MELCOR input for this run is listed in Appendix E.

```
***********************************************************************
*
*      Reactor:       Grand Gulf (NUREG-1150 DECK)
*      Sequence:      Station Blackout - Low Pressure (ADS depressurized)
*                     Containment failure pressure added (55 psig)
*                     Ignitors deactivated --  ORNL -  Dec 1993.
*                     Initial Conditions at 1720s in LTAS run
*      Nodalization  RPV(6), Cont(7), Sec(1)
*
***********************************************************************
*
TITLE     GGSB7
JOBID     GGSB7
*
RESTARTF GGSB7REST
OUTPUTF  GGSB7GOUT
DIAGF    GGSB7GDIAG
CRTOUT
*DTTIME    0.1
*
***********************************************************************
*
*     NCG INPUT
*
***********************************************************************
*
NCG004    N2  4  * NITROGEN
NCG005    O2  5  * OXYGEN
NCG006    H2  6  * HYDROGEN
NCG007    CO  7  * CARBON MONOXIDE
NCG008    CO2 8  * CARBON DIOXIDE
NCG009    CH4 9  * METHANE
*
***********************************************************************
*     CVH INPUT
***********************************************************************
*
CV10000   LOWER-PLENUM      2  2  1
CV100A0   3
CV100A1   PVOL   6.960E6
CV100A2   TPOL   558.39 ZPOL  5.2845
CV100B1   0.0       0.0
CV100B2   3.3400   68.2720
CV100B3   5.2845  100.1268
*
CV10100   CHANNEL           2  2  1
CV101A0   3
CV101A1   PVOL   6.931E6  RHUM  1.0
CV101A2   ZPOL   9.3043   VFOG  0.0
CV101B1   5.2845    0.0000
CV101B2   5.4938    2.2880
CV101B3   9.3038   35.1852
CV101B4   9.6629   38.2859
*
CV10200   BYPASS            2  2  1
CV102A0   3
CV102A1   PVOL   6.931E6  RHUM  1.0
CV102A2   ZPOL   9.3043   VFOG  0.0
```

```
CV102B1   5.2845    0.0000
CV102B2   5.4938    1.3503
CV102B3   9.3038   23.2537
CV102B4   9.6629   25.3184
*
CV10300   UPPER-PLENUM/SEP  2  2  1
CV103A0   3
CV103A1   PVOL  6.931E6  RHUM  1.0
CV103A2   VPOL  0.0      VFOG 0.0
CV103B1    9.6629    0.0
CV103B2    9.9313    7.3664
CV103B3   11.1920   26.9522
CV103B4   13.0555   38.2789
CV103B5   15.4304   65.1035
*
CV10400   DRYER/STEAM-DOME  2  2  1
CV104A0   3
CV104A2   PVOL  6.929E6  RHUM  1.0
CV104A3   VPOL  0.0      VFOG  0.0
CV104B1   15.4304    0.0
CV104B2   16.4389   23.3210
CV104B3   17.0180   77.8790
CV104B4   22.2276  191.4439
*
CV10500   DOWN/RECIRC-2    2  2  1
CV105A0   3
CV105A1   PVOL  6.931E6  RHUM  1.0
CV105A2   ZPOL  9.3038   VFOG  0.0
CV105B1    3.3400     0.0
CV105B2    8.2488    93.2635
CV105B3   13.0555   162.9992
CV105B4   15.4304   228.1555
*
CV20100   'DRYWELL'           2  2  2
CV201A1   PVOL   1.073E5   TATM   343.5  RHUM  0.9
CV201A2   MLFR.4 0.79      MLFR.5 0.21
CV201A3   ZPOL   -6.73
CV201B1   -6.73      0.
CV201B2   -1.68   1165.
*CV201B3   24.36   7554.
CV201B3   24.36   6554.
*
CV20200   'WEIR WALL'         2  2  2
CV202A1   PVOL   1.073E5   TATM   343.5  RHUM  0.9
CV202A2   MLFR.4 0.79      MLFR.5 0.21
CV202A3   ZPOL   -3.145    TPOL   320.8
CV202B1   -9.09      0.
CV202B2   -5.44    269.6     * INCLUDES VENTS
CV202B3   -1.68    462.5
CV202B4   12.56   1462.5
*
CV20400   PEDESTAL            2  2  2
CV204A1   PVOL   1.073E5   TATM   343.5  RHUM  0.9
CV204A2   MLFR.4 0.79      MLFR.5 0.21
CV204A3   ZPOL   -8.64
CV204B1   -8.64      0.
CV204B2   -2.63    196.4
CV204B3   -2.26    207.2
```

```
*CV204B4   -0.44    244.5
CV204B4    3.34    244.5
*
CV30100   'DOME'              2  2  3
CV301A1   PVOL   1.071E5   TATM   307.6  RHUM  1.
CV301A2   MLFR.4 0.79      MLFR.5 0.21
CV301A3   ZPOL   25.91     TPOL  307.6
CV301B1   13.61      0.
CV301B2   26.26   1780.
CV301B3   53.92  25463.
*
CV30200   'EQUIP HATCH'       2  2  3
CV302A1   PVOL   1.071E5   TATM   307.6  RHUM  1.
CV302A2   MLFR.4 0.79      MLFR.5 0.21
CV302A3   ZPOL    3.71
CV302B1    3.71      0.
CV302B2   26.26   1654.
*
CV30300   'UPPER ANN'         2  2  3
CV303A1   PVOL   1.071E5   TATM   307.6  RHUM  1.
CV303A2   MLFR.4 0.79      MLFR.5 0.21
CV303A3   ZPOL   11.63
CV303B1   11.63      0.
CV303B2   26.26   4480.
*
CV30400   'LOWER ANN'         2  2  3
CV304A1   PVOL   1.071E5   TATM   307.6  RHUM  1.
CV304A2   MLFR.4 0.79      MLFR.5 0.21
CV304A3   ZPOL    3.71
CV304B1    3.71      0.
CV304B2   11.63   3278.
*
CV30500   'WETWELL'           2  2  3
CV305A1   PVOL   1.071E5   TATM   307.6  RHUM  1.
CV305A2   MLFR.4 0.79      MLFR.5 0.21
CV305A3   ZPOL   -3.145    TPOL   320.8
CV305B1   -9.09      0.
CV305B2    3.71   7783.
*
* ENVIRONMENT
CV40000    ENVIRONMENT  1  2  6
CV400A1     PVOL  1.013E5    RHUM  0.5   TATM   300.0    TPOL   300.0
CV400A2     VPOL  0.
CV400A3     MLFR.4  0.79    MLFR.5  0.21
CV400B1       -12.44       0.0
CV400B2        62.56       1.0E7
*
***********************************************************************
*
*    FLOW PATH INPUT
*
***********************************************************************
*
FL03100   'VESSEL BREACH'  100  204  0.    -0.2254
FL03101   0.1   0.2254  0.0               * INITIALLY CLOSED
FL03102   0  0  0  0
FL03103   1.0     1.0
FL031S0   0.1   0.2254  0.1128
```

```
FL031V0   -1  130  130
*
CF13000   'VESSEL BREACH'  DIVIDE  2  1.0  0.0
CF13010   0.0  0.1   COR-ABRCH
CF13011   1.0  0.0   COR-ABRCH
*
*****    Pump Seal Leakage Taken From Downcomer (45%)
FL37000  LEAKAGE-DOWN   105  201  6.838    6.838
FL37001  2.783E-6   0.15   1.0
FL37002  3  0  0  0
FL37003  1.0  1.0
FL370S1  2.783E-6   0.15   0.001631
*
*****    CRD Seal Leakage Taken From Lower Plenum (55%)
FL37100  LEAKAGE-LP   100  204    0.1      -0.44
FL37101  3.399E-6   0.15   1.0
FL37102  0  0  0  0
FL37103  1.0  1.0
FL371S1  3.399E-6   0.15   0.001804
*
FL01100   CHAN-IN            100  101  5.2845   5.2845
FL01101   7.95     4.65215 0.61748   0.1     0.1
FL01102   0  0  0  0
FL01103   11.95    15.
FL011S1   7.95     4.65215  0.01359   5.E-6
FL011V0   -1   118  118
*
CF00100  SET-TS1  L-GT  2  1.  0.
CF00101  .FALSE.
CF00105  LATCH
CF00110  1.  0.  COR-TSS.105
CF00111  0.  1273.  TIME
*
CF00500  FL-A-1   MIN   2  1.  0.
CF00502  3  0.  2.96
CF00510  1.  0.     COR-AFLMIN.105.113
CF00511  0.  2.96   TIME
*
CF00900  SP1-OPEN   L-A-IFTE   3   1.   0.
CF00901  0.0
CF00902  3  0.   4.794
CF00911  1.   0.    CFVALU.1
CF00912  0.   0.4794 TIME
CF00913  1.   0.    CFVALU.5
*
CF00200  SET-TS2  L-GT  2  1.  0.
CF00201  .FALSE.
CF00205  LATCH
CF00210  1.  0.  COR-TSS.105
CF00211  0.  1273.  TIME
*
CF00600  FL-A-2   MIN   2  1.  0.
CF00602  3  0.  .795
CF00610  1.  0.     COR-AFLMIN.205.213
CF00611  0.  0.795  TIME
*
CF01000  SP2-OPEN   L-A-IFTE   3   1.   0.
CF01001  0.0
```

```
CF01002  3  0.   1.288
CF01011  1.   0.    CFVALU.2
CF01012  0.   0.1288 TIME
CF01013  1.   0.    CFVALU.6
*
CF00300  SET-TS3  L-GT  2  1.  0.
CF00301  .FALSE.
CF00305  LATCH
CF00310  1.  0.  COR-TSS.305
CF00311  0.  1273.  TIME
*
CF00700  FL-A-3   MIN   2  1.  0.
CF00702  3  0.  .565
CF00710  1.  0.     COR-AFLMIN.305.313
CF00711  0.  0.565  TIME
*
CF01100  SP3-OPEN   L-A-IFTE   3   1.   0.
CF01101  0.0
CF01102  3  0.   0.914
CF01111  1.   0.    CFVALU.3
CF01112  0.   0.0914 TIME
CF01113  1.   0.    CFVALU.7
*
CF00400  SET-TS4  L-GT  2  1.  0.
CF00401  .FALSE.
CF00405  LATCH
CF00410  1.  0.  COR-TSS.405
CF00411  0.  1273.  TIME
*
CF00800  FL-A-4   MIN   2  1.  0.
CF00802  3  0.  .589
CF00810  1.  0.     COR-AFLMIN.405.413
CF00811  0.  0.589  TIME
*
CF01200  SP4-OPEN   L-A-IFTE   3   1.   0.
CF01201  0.0
CF01202  3  0.   0.954
CF01211  1.   0.    CFVALU.4
CF01212  0.   0.0954 TIME
CF01213  1.   0.    CFVALU.8
*
CF01700  FLAREA      ADD  4  1.0  0.0
CF01711  1.0  0.0      CFVALU.9
CF01712  1.0  0.0      CFVALU.10
CF01713  1.0  0.0      CFVALU.11
CF01714  1.0  0.0      CFVALU.12
*
CF11800  'FRAC-AREA'  DIVIDE  2  1.0  0.0
CF11801  0.61748
*CF11802  3   0.03    1.
CF11802  3   0.003    1.
CF11810  0.0  7.95     CFVALU.17
CF11811  1.0  0.0      CFVALU.17
*
FL01200   BYPASS-INLET      100  102  5.2845  5.2845
FL01201   6.04785  4.65215  0.01289  .1    .1
FL01202   0  0  0  0
FL01203   0.8055   4.97
```

```
FL012S1   6.04785  4.65215  0.05841   5.E-6
*
FL01300   CORE-OUTLET       101  103   9.6629  9.6629
FL01301   7.95     4.96806  0.67561  .1     .1
FL01302   0  0  0  0
FL01303   12.55    12.55
FL013S1   7.95     4.96806  0.01359   5.E-6
*
FL01400   BYPASS-OUTLET     102  103   9.6629   9.6629
FL01401   6.2128   4.96806  1.0   .1     .1
FL01402   0  0  0  0
FL01403   0.5      0.5
FL014S1   6.2128   4.96806  0.05841   5.E-6
*
FL01500   UPPER-PLENUM-OUT  103  104  15.4304   15.4304
FL01501   4.19318  6.3123   1.0         .1    .1
FL01502   0  0  0  0
FL01503   9.09     2.84
FL015S1   4.19318  6.3123   0.00878   5.E-6
*
FL01600   DOME-DOWNCOMER    104  105  15.4304   15.4304
FL01601   13.90015 9.29442  1.0         .1905 .1905
FL01602   0  0  0  0
FL01603   0.11     0.11
FL016S1   13.90015 9.29442  0.73944   5.E-6
*
*  LIQUID RETURN PATH FROM SEPARATORS - CURRENTLY CLOSED OFF
FL01700   SEP-DRAIN         103  105 13.05553 13.05553
*FL01701   10.53660  2.      1.0
FL01701   10.53660  2.      0.0
FL01702   2 0 0 0 * LIQUID ONLY VERTICAL FLOW PATH
FL01703   2.        2.
FL017S1   10.53660 .01      1.
FL017V0   -1   105   105
*
CF10500   SEP-DRAIN-VALVE   EQUALS  1   0.   0.
*CF10501   1.
CF10501   0.
CF10510   0.   1.   TIME
*
FL01800   JET-PUMP-SUCTION  105  100   8.24883  3.26383
*FL01801   0.32948  2.40335  1.0  .1     .1
FL01801   0.32948  7.715    1.0  .1     .1
FL01802   0  0  0  0
FL01803   0.157    17.8
*FL018S1   0.32948  2.40335  0.27783   5.E-6
FL018S1   0.32948  7.715    0.27783   5.E-6
FL018V0   -1   19  19
*
CF01800   'LP-LEV-TEST'  L-GT  2  1.0  0.0
CF01801   .TRUE.
CF01810   1.0  0.0      CVH-LIQLEV.100
CF01811   0.0  3.32     TIME
*
CF01900   'JET-PUMP-AFRAC'  L-A-IFTE  3  1.0  0.0
CF01901   1.
CF01910   1.0  0.0      CFVALU.18
CF01911   0.0  1.0      TIME
```

```
CF01912  0.0  0.0      TIME
*
FL01900  VES-BRCH-DC       105  201   10.  10.
FL01901  0.1      0.2254   0.0  .1    .1
FL01902  0  0  0  0
FL01903  1.0      1.0
FL019S1  0.1      0.2254   0.1128
FL019V0  -1   106  106
*
CF10600  VES-BRCH-VALVE    EQUALS  1   1.   0.
CF10601  0.
CF10610  0.   0.   TIME
*
FL02100  STEAM-LINE-SRV    104  305  16.4592   -7.41
FL02101  1.10555  41.3122  0.0 .5842 .5842 * INITIALLY CLOSED
FL02102  0 0 0 1 * VERTICAL FLOW PATH, ACTIVE, DEF, SPARC
FL02103  3.5       3.5
FL021V0  -1  100  100
FL021S1  1.10555  41.3122  0.5842    5.E-6
*
*        CONTROL FUNCTIONS FOR SRVs
*
CF10000  'SRV'  HYST  1  0.16933  0.0  * SCALE FACTOR GIVES FULL-OPEN
*                                        VALVE AREA OF 0.1872 M**2
CF10003  -1  -2                    * LOAD, UNLOAD TABULAR FUNCTION NUMBERS
CF10010  1.0  0.0  CVH-P.104
*
TF00100  'SRV-LOAD-AREA'  12  1.0  0.0
*        PRESSURE  FRACTION-OPEN
TF00111  7.1140E6  0.0
TF00112  7.1141E6  0.055556
TF00113  7.3888E6  0.055556
TF00114  7.3889E6  0.111111
TF00115  7.6636E6  0.111111
TF00116  7.6637E6  0.333333
TF00117  7.7323E6  0.333333
TF00118  7.7324E6  0.555556
TF00119  7.8010E6  0.555556
TF00120  7.8011E6  0.777778
TF00121  7.8698E6  0.777778
TF00122  7.8699E6  1.0
*
TF00200  'SRV-UNLOAD-AREA'  12  1.0  0.0
*        PRESSURE  FRACTION-OPEN
TF00211  6.3582E6  0.0
TF00212  6.3583E6  0.055556
TF00213  6.5643E6  0.055556
TF00214  6.5644E6  0.111111
TF00215  6.7017E6  0.111111
TF00216  6.7018E6  0.388889
TF00217  7.0453E6  0.388889
TF00218  7.0454E6  0.555556
TF00219  7.1140E6  0.555556
TF00220  7.1141E6  0.777778
TF00221  7.1827E6  0.777778
TF00222  7.1828E6  1.0
*
*  ADS  ADDED  -  DEC-1993- ORNL
```

```
*
FL02200   ADS 104 305  16.4592  -7.41
FL02201   0.09496   41.3122  0.0
FL02202   0 0 0 1
FL02203   3.5  3.5
FL022V0   -1  22  22
FL022S1   0.09496  41.3122  0.5842  5.0e-6
*
CF02200   OPEN-ADS   L-A-IFTE   3  1.0  0.0
CF02201   0.0
CF02205   'NORMAL'
CF02210   1.0  0.0  CFVALU.23
CF02211   0.0  0.0  TIME
CF02212   0.0  1.0  TIME
*
CF02300   VESSEL-LEVEL   L-GT  2  1.0  0.0
CF02301   .TRUE.
CF02305   'LATCH'
CF02306   2  'CORE WATER LEVEL AT 1/3 ACH'
CF02310   1.0  0.0  CVH-CLIQLEV.101          *measured in CORE volume
CF02311   0.0  6.7638   TIME                 * 1/3 ACH per Rev.3 EPGs
*
*  END  OF  ADS
*
FL30100   DOME-HATCH         301  302  26.46  26.26
FL30101   74.3     12.5   1.0   .2  .2
FL30102   0 0 0 0
FL30103   0.75       0.75
FL301S1   74.3    .001  1.
*
FL30200   DOME-UPPERANN      301  303  26.46  26.26
FL30201   152.1    10.5   1.0   .2  .2
FL30202   0 0 0 0
FL30203   1.5        1.5
FL302S1   152.1  .001  1.
*
FL30300   HATCH-UPPANN       302  303  18.95  18.95
FL30301   135.64  15.8   1.0   1.  1.
FL30302   3 0 0 0
FL30303   1.5        1.5
FL303S1   135.64 .001  1.
*
FL30400   HATCH-LOWANN       302  304   7.67   7.67
FL30401   157.     15.8   1.0   1.  1.
FL30402   3 0 0 0
FL30403   1.5        1.5
FL304S1   157.    .001  1.
*
FL30500   HATCH-WW           302  305   3.91   3.71
FL30501   62.4     7.39   1.0   .2  .2
FL30502   0 0 0 0
FL30503   0.75       0.75
FL305S1   62.4    .001  1.
*
FL30600   UPP-LOW-ANN        303  304  11.83  11.63
FL30601   228.8    5.56   1.0   .2  .2
FL30602   0 0 0 0
FL30603   1.5        1.5
```

```
FL306S1   228.8  .001  1.
*
FL30700   LOWANN-WW          304  305   3.91   3.71
FL30701   144.4   3.81   1.0   .2  .2
FL30702   0 0 0 0
FL30703   1.5       1.5
FL307S1   144.4  .001  1.
*
FL20100   WW-DW-VB           301  201  26.46  24.36
FL20101   .051    1.     0.0   .1  .1
FL20102   0 0 0 0
FL20103   1.19      1.19
FL201S1   .051   .001  1.
FL201V0   -1  305   305
*
*CF30500   'VAC-BRK' TAB-FUN  1  1.0  0.0
* CLOSED OFF FOR BLACKOUT CALC
CF30500   'VAC-BRK' TAB-FUN  1  0.0  0.0
CF30503   11  * TABULAR FUNCTION NUMBER
CF30510   1.0  0.0  CFVALU.301
*
CF30100   'VAC-BRK-DP' ADD 3  1.0  0.0
CF30110   1.0  0.0  CVH-P.301
CF30111   -1.0  0.0  CVH-P.201
CF30113   323.7 0.0  CVH-RHOA.201
*
TF01100   'VAC-BRK-AREA' 2  1.0  0.0
*         DELTA-P   FRACTION-OPEN
TF01111      0.0    0.0
TF01112    100.0    1.0
*
FL20200   WW-DW-LEAK         302  201  7.56   7.56
FL20201   .0929   1.     0.017 .1  .1
FL20202   3 0 0 0
FL20203   1.        1.
FL202S1   .0929   .001  1.
FL202V0   -1  107  107
*
CF10700   DW-LK-FRAC         EQUALS  1   1.    0.
CF10701   0.017
CF10710   0.   0.017    TIME
*
FL20300   DW-WEIR-WAT        201  202  -1.68  -1.68
FL20301   51.4    1.     1.0   .1  .1
FL20302   0 0 0 0
FL20303   .1        .1
FL203S1   51.4   .001  1.
*
FL20400   DW-WEIR-GAS        201  202   8.32   8.32
FL20401   51.4    1.     1.0   .1  .1
FL20402   0 0 0 0
FL20403   .5        .5
FL204S1   51.4   .001  1.
*
FL20500   DW-PED-GAS         201  204  -4.65  -4.65
FL20501   1.95   1.75    1.0   2.13   2.13
FL20502   3 0 0 0
FL20503   1.        1.
```

```
FL205S1   1.95   .001  1.28
*
*FL20600   DW-PED-DRAIN      201  204  -6.73  -8.64
FL20600   DW-PED-DRAIN      201  204  -6.73  -7.
* JUST PUT IN DUMMY NUMBER FOR AREA
*FL20601   10.     1.     1.0   .1  .1
FL20601    5.     1.     1.0   .1  .1
FL20602   0 0 0 0
FL20603   .5        .5
FL206S1   10.    .001  1.
*
FL21100   TOP-SP-VENTS      202  305  -5.64  -5.64
FL21101   17.9    1.52   1.0   .36 .36
FL21102   3 0 1 1
FL21103   4.        4.
FL211S1   17.9   .001  1.
*
FL21200   MID-SP-VENTS      202  305  -6.91  -6.91
FL21201   17.9    1.52   1.0   .36 .36
FL21202   3 0 1 1
FL21203   4.        4.
FL212S1   17.9   .001  1.
*
FL21300   BOT-SP-VENTS      202  305  -8.18  -8.18
FL21301   17.9    1.52   1.0   .36 .36
FL21302   3 0 1 1
FL21303   4.        4.
FL213S1   17.9   .001  1.
*
*   CONTAINMENT  FAILURE  AT  55 PSIG ( 4.81E5  PA)  PER  NUREG-1150
*   MODIFIED AT  ORNL -  DEC-1193
*
FL10000      'CONT-FAIL'        301   400     40.   40.
FL10001      10.            0.1   0.0
FL10002      3
FL10003      1.   1.
FL100S0      10.            0.001   1.0
FL100V0      150   145   145
*
CF14500      CONT-FAIL-FRAC   EQUALS   1   1.   0.01
CF14510      0.   0.   TIME
*
CF15000      CONT-FAIL-THRESH T-O-F    1   1.   0.
CF15003      -1.E9    4.81E5
CF15010      1.   0.   CVH-P.301
*
CF15100     CONT-FAIL-MES  L-GT  2  1.0  0.0
CF15101     .FALSE.
CF15106     2  'CONTAINMENT  FAILED'
CF15111     1.0  0.0  CVH-P.301
CF15112     0.0  4.81E5  TIME
*
***********************************************************************
*
*     CORE INPUT
*
***********************************************************************
*
```

```
*   INCREASE ZR MELTING TEMPERATURE TO DELAY RELOCATION
*
MPMAT00500  ZIRCALOY
MPMAT00501  ENH  281
MPMAT00503  TMP  283
*
MPMAT00550  MLT  2498.0
*
TF28100  'EZIRC'  16  1.0
TF28111    300.0        0.0
TF28112    400.0    21915.0
TF28113    640.0   105110.0
TF28114   1090.0   263960.0
TF28115   1093.0   265275.5
TF28116   1113.0   276195.5
TF28117   1133.0   288245.5
TF28118   1153.0   301585.5
TF28119   1173.0   316935.5
TF28120   1193.0   332795.5
TF28121   1213.0   346685.5
TF28122   1233.0   357565.5
TF28123   1248.0   363753.0
TF28124   2498.0   808753.0
TF28125   2498.01 1033753.0
TF28126   3598.0  1425353.0
*
TF28300  'TZIRC'  16  1.0
TF28311   0.0          300.0
TF28312   21915.0      400.0
TF28313   105110.0     640.0
TF28314   263960.0     1090.0
TF28315   265275.5     1093.0
TF28316   276195.5     1113.0
TF28317   288245.5     1133.0
TF28318   301585.5     1153.0
TF28319   316935.5     1173.0
TF28320   332795.5     1193.0
TF28321   346685.5     1213.0
TF28322   357565.5     1233.0
TF28323   363753.0     1248.0
TF28324   808753.0     2498.0
TF28325   1033753.0    2498.01
TF28326   1425353.0    3598.0
*
*         GENERAL CORE INPUT
*         NRAD      NAXL      NTLP      NCVOL     NLH       NPNTOT
COR00000  4         13        5         3         5         4
*
*         RFUEL      RCLAD      DRGAP      PITCH      DXCAN      DXSS   DXLH
COR00001  .0052067   .0061338   .0001143   .0162252   .0025399   .0014  .2254
*
*         IRTYP     MCRP
COR00002  BWR       B4C
*
*         FCNCL     FSSCN     FCELR     FCELA     FLPUP
*COR00003  0.10      0.95      0.90      1.00      0.60
*COR00003  0.10      0.95      0.15      1.00      0.40
COR00003  0.10      0.95      0.01      1.00      0.40
```

```
*
*          NTPCOR
COR00004   101
*
*          HFRZFU   HFRZZR   HFRZSS   HFRZZX   HFRZSX   HFRZCP
*COR00005   1000.    1000.    1000.    1000.    1000.    1000.
COR00005   3000.    3000.    3000.    3000.    3000.    3000.
*
*          MTUOZR   MTZXZR   MTSXSS   MTCPSS   FUOZR    FZXZR    FSXSS    FCPSS
COR00007   1        2        2        2        0.2      1.0      1.0      0.0
*
*          DRCLMN   DRSSMN
COR00008   0.0001   0.0001
*
*          HDBPN    HDBLH    TPFAIL   CDISPN
COR00009   500.0    500.0    1273.15  1.0
*          XFE      XCR      XNI      XCAR
COR00010   0.74     0.18     0.08     0.0
*
*          CELL ELEVATIONS AND POROSITIES
*          Z        DZ         PORIN    PORDP    *  Z,IN     DZ,IN
CORZ1301   9.3038   0.3591     0.0      0.3      * 366.31     14.14
CORZ1201   8.6688   0.6350     0.9      0.3      * 341.31     25.0
CORZ1101   8.0338   0.6350     0.9      0.3      * 316.31     25.0
CORZ1001   7.3988   0.6350     0.9      0.3      * 291.31     25.0
CORZ0901   6.7638   0.6350     0.9      0.3      * 266.31     25.0
CORZ0801   6.1288   0.6350     0.9      0.3      * 241.31     25.0
CORZ0701   5.4938   0.6350     0.9      0.3      * 216.31     25.0
CORZ0601   5.2845   0.2093     0.9      0.3      * 208.07      8.24
*CORZ0501   5.2147   0.0698     0.0      0.3      * 205.32      2.75
CORZ0501   5.2147   0.0698     0.99     0.3      * 205.32      2.75
CORZ0401   4.5766   0.6381     0.0      0.3      *
CORZ0301   1.2762   3.3004     0.0      0.3      *
CORZ0201   0.6381   0.6381     0.0      0.3      *  25.125   25.125
CORZ0101   0.0      0.6381     0.0      0.3      *  0.0      25.125
*
*          BOUNDARY HEAT STRUCTURES
CORZ0102   10001
CORZ0202   10002
CORZ0302   10003
CORZ0402   10004
CORZ0502   10005    11
CORZ0602   10206
CORZ0702   10207
CORZ0802   10208
CORZ0902   10209
CORZ1002   10210
CORZ1102   10211
CORZ1202   10212
CORZ1302   10213
*
CORR0102   10302
CORR0202   10302
CORR0302   10302
CORR0402   10302
*
*          CELL CROSS-SECTIONAL BOUNDARY AREAS
*          ASCELA
```

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CORR0101 10.682808
CORR0201  2.879713
CORR0301  2.043667
CORR0401  2.136561
*         IREFN   ICVHC   ICVHB
COR11301      107
COR11201      107
COR11101      107
COR11001      107
COR10901      107
COR10801      107
COR10701      -1  101  102
COR10601      107
COR10501      101
COR10401      101
COR10301      101
COR10201      101
COR10101      -1  100  100
*  RING 2
COR21301      207
COR21201      207
COR21101      207
COR21001      207
COR20901      207
COR20801      207
COR20701      -1  101  102
COR20601      207
COR20501      201
COR20401      201
COR20301      201
COR20201      201
COR20101      -1  100  100
*  RING 3
COR31301      307
COR31201      307
COR31101      307
COR31001      307
COR30901      307
COR30801      307
COR30701      -1  101  102
COR30601      307
COR30501      301
COR30401      301
COR30301      301
COR30201      301
COR30101      -1  100  100
*  RING 4
COR41301      407
COR41201      407
COR41101      407
COR41001      407
COR40901      407
COR40801      407
COR40701      -1  101  102
COR40601      407
COR40501      401
COR40401      401
COR40301      401
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COR40201      401
COR40101       -1  100  100
*****  CELL COMPONENT MASSES
* TOTAL OF ALL RINGS ********** NEEDS TO BE UPDATED ***************
* AXIAL                     MASS BY AXIAL NODE, KG
* NODE        UO2    ZR-CLAD         SS        B4C   ZR-CAN         TOTAL
*    13      0.00    3444.79    6670.47       0.00  2428.87      10115.26
*    12  26453.17    6281.56    1645.96     145.87  4294.32      34526.56
*    11  26453.17    6281.56    1645.96     145.87  4294.32      34526.56
*    10  26453.17    6281.56    1645.96     145.87  4294.32      34526.56
*     9  26453.17    6281.56    1645.96     145.87  4294.32      34526.56
*     8  26453.17    6281.56    1645.96     145.87  4294.32      34526.56
*     7  26453.17    6281.56    1645.96     145.87  4294.32      34526.56
*     6      0.00     862.68    6247.65       0.00   551.39       7110.33
*     5      0.00       0.00   10659.32       0.00     0.00      10659.32
*     4      0.00       0.00    2394.20       0.00     0.00       2394.20
*     3      0.00       0.00   22193.71       0.00     0.00      22193.71
*     2      0.00       0.00    2922.77       0.00     0.00       2922.77
*     1      0.00       0.00    3948.79       0.00     0.00       3948.79
*TOTAL 158719.02   41996.83   64912.67     875.22 28746.18     261222.46
*TOTAL ZR          70743.01
*
*
***** RING 1 MASSES - VOLUME FRACTION=0.603
*                           MASS BY AXIAL NODE, KG
*                 UO2    ZR-CLAD         SS        B4C   ZR-CAN         TOTAL
COR11302         0.00    2175.09    4211.81       0.00  1533.62   *   7920.52
COR11202     16702.89    3966.26    1039.29      92.10  2711.49   *  24512.03
COR11102     16702.89    3966.26    1039.29      92.10  2711.49   *  24512.03
COR11002     16702.89    3966.26    1039.29      92.10  2711.49   *  24512.03
COR10902     16702.89    3966.26    1039.29      92.10  2711.49   *  24512.03
COR10802     16702.89    3966.26    1039.29      92.10  2711.49   *  24512.03
COR10702     16702.89    3966.26    1039.29      92.10  2711.49   *  24512.03
COR10602         0.00     544.71    3944.86       0.00   348.16   *   4837.73
COR10502         0.00       0.00    6730.44       0.00     0.00   *   6730.44
COR10402         0.00       0.00    3790.93       0.00     0.00   *   3790.93
COR10302         0.00       0.00   11734.21       0.00     0.00   *  11734.21
COR10202         0.00       0.00    1845.48       0.00     0.00   *   1845.48
COR10102         0.00       0.00    2493.32       0.00     0.00   *   2493.32
*  TOTAL    100217.34   26517.36   40986.79     552.60 18150.72     186424.81
*  TOTAL ZR             44668.08
*
***** RING 2 MASSES - VOLUME FRACTION=0.162
*                           MASS BY AXIAL NODE, KG
*                 UO2    ZR-CLAD         SS        B4C   ZR-CAN         TOTAL
COR21302         0.00     584.36    1131.54       0.00   412.02   *   2127.92
COR21202      4487.34    1065.56     279.21      24.74   728.46   *   6585.31
COR21102      4487.34    1065.56     279.21      24.74   728.46   *   6585.31
COR21002      4487.34    1065.56     279.21      24.74   728.46   *   6585.31
COR20902      4487.34    1065.56     279.21      24.74   728.46   *   6585.31
COR20802      4487.34    1065.56     279.21      24.74   728.46   *   6585.31
COR20702      4487.34    1065.56     279.21      24.74   728.46   *   6585.31
COR20602         0.00     146.34    1059.81       0.00    93.54   *   1299.69
COR20502         0.00       0.00    1808.18       0.00     0.00   *   1808.18
COR20402         0.00       0.00    1018.46       0.00     0.00   *   1018.46
COR20302         0.00       0.00    3152.47       0.00     0.00   *   3152.47
COR20202         0.00       0.00     495.80       0.00     0.00   *    495.80
COR20102         0.00       0.00     669.84       0.00     0.00   *    669.84
```

* TOTAL	26924.04	7124.06	11011.36	148.44	4876.32		50084.22
* TOTAL ZR		12000.38					

*

***** RING 3 MASES - VOLUME FRACTION=0.115

* MASS BY AXIAL NODE, KG

*	UO2	ZR-CLAD	SS	B4C	ZR-CAN		TOTAL
COR31302	0.00	414.82	803.26	0.00	292.48	*	1510.56
COR31202	3185.46	756.42	198.21	17.57	517.12	*	4674.78
COR31102	3185.46	756.42	198.21	17.57	517.12	*	4674.78
COR31002	3185.46	756.42	198.21	17.57	517.12	*	4674.78
COR30902	3185.46	756.42	198.21	17.57	517.12	*	4674.78
COR30802	3185.46	756.42	198.21	17.57	517.12	*	4674.78
COR30702	3185.46	756.42	198.21	17.57	517.12	*	4674.78
COR30602	0.00	103.88	752.34	0.00	66.40	*	922.62
COR30502	0.00	0.00	1283.58	0.00	0.00	*	1283.58
COR30402	0.00	0.00	722.97	0.00	0.00	*	722.97
COR30302	0.00	0.00	2237.87	0.00	0.00	*	2237.87
COR30202	0.00	0.00	351.96	0.00	0.00	*	351.96
COR30102	0.00	0.00	475.51	0.00	0.00	*	475.51
* TOTAL	19112.76	5057.22	7816.75	105.42	3461.60		35553.75
* TOTAL ZR		8518.82					

*

***** RING 4 MASSES - VOLUME FRACTION=0.120

* MASS BY AXIAL NODE, KG

*	UO2	ZR-CLAD	SS	B4C	ZR-CAN		TOTAL
COR41302	0.00	432.85	838.17	0.00	305.19	*	1576.21
COR41202	3323.96	789.31	206.83	18.32	539.60	*	4878.02
COR41102	3323.96	789.31	206.83	18.32	539.60	*	4878.02
COR41002	3323.96	789.31	206.83	18.32	539.60	*	4878.02
COR40902	3323.96	789.31	206.83	18.32	539.60	*	4878.02
COR40802	3323.96	789.31	206.83	18.32	539.60	*	4878.02
COR40702	3323.96	789.31	206.83	18.32	539.60	*	4878.02
COR40602	0.00	108.40	785.05	0.00	69.29	*	962.74
COR40502	0.00	0.00	1339.39	0.00	0.00	*	1339.39
COR40402	0.00	0.00	754.41	0.00	0.00	*	754.41
COR40302	0.00	0.00	2335.17	0.00	0.00	*	2335.17
COR40202	0.00	0.00	367.26	0.00	0.00	*	367.26
COR40102	0.00	0.00	496.18	0.00	0.00	*	496.18
* TOTAL	19943.76	5277.11	8156.61	109.92	3612.08		37099.48
* TOTAL ZR		8889.19					

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COR11304    0.014   0.0191   0.005   0.1513   0.1570
COR10704    0.014   0.1238   0.005   0.1513   0.1570
COR10604    0.014   0.1016   0.005   0.1513   0.1570
COR10504    0.014   0.0564   0.005   0.1513   0.1570
COR10404    0.014   0.0381   0.005   0.1513   0.1570
COR10304    0.014   0.2601   0.005   0.1513   0.1570
COR10104    0.014   0.1460   0.005   0.1513   0.1570
* RING 2
COR21304    0.014   0.0191   0.005   0.1513   0.1570
COR20704    0.014   0.1238   0.005   0.1513   0.1570
COR20604    0.014   0.1016   0.005   0.1513   0.1570
COR20504    0.014   0.0564   0.005   0.1513   0.1570
COR20404    0.014   0.0381   0.005   0.1513   0.1570
COR20304    0.014   0.2601   0.005   0.1513   0.1570
COR20104    0.014   0.1460   0.005   0.1513   0.1570
* RING 3
COR31304    0.014   0.0191   0.005   0.1513   0.1570
COR30704    0.014   0.1238   0.005   0.1513   0.1570
COR30604    0.014   0.1016   0.005   0.1513   0.1570
COR30504    0.014   0.0564   0.005   0.1513   0.1570
COR30404    0.014   0.0381   0.005   0.1513   0.1570
COR30304    0.014   0.2601   0.005   0.1513   0.1570
COR30104    0.014   0.1460   0.005   0.1513   0.1570
* RING 4
COR41304    0.014   0.0191   0.005   0.1513   0.1570
COR40704    0.014   0.1238   0.005   0.1513   0.1570
COR40604    0.014   0.1016   0.005   0.1513   0.1570
COR40504    0.014   0.0564   0.005   0.1513   0.1570
COR40404    0.014   0.0381   0.005   0.1513   0.1570
COR40304    0.014   0.2601   0.005   0.1513   0.1570
COR40104    0.014   0.1460   0.005   0.1513   0.1570
*
*****     RADIAL BOUNDARY, CHANNEL AND BYPASS FLOW AREAS
*          ASCELR       AFLOWC     AFLOWB
*RING 1
COR11305   4.16067      5.207      3.467
COR10705   7.35735      5.207      3.467
COR10605   2.42503      6.592      3.890
COR10505   0.80873      1.1525     0.0
COR10405   7.56938      4.5622     0.0
COR10305  38.06356      4.5622     0.0
COR10105   7.39327      8.8302     0.0
*RING 2
COR21305   4.68803      1.399      0.931
COR20705   8.28989      1.399      0.931
COR20605   2.73240      1.7718     1.045
COR20505   0.91124      0.3096     0.0
COR20405   8.52880      1.2256     0.0
COR20305  42.88811      1.2256     0.0
COR20105   8.33036      2.3723     0.0
*RING 3
COR31305   5.02885      0.993      0.661
COR30705   8.89257      0.993      0.661
COR30605   2.93105      1.257      0.742
COR30505   0.97748      0.2198     0.0
COR30405   9.14884      0.8701     0.0
COR30305  46.00607      0.8701     0.0
COR30105   8.93598      1.6840     0.0
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*RING4
COR41305   5.36205     1.036     0.690
COR40705   9.48176     1.036     0.690
COR40605   3.12525     1.312     0.774
COR40505   1.04225     0.2293    0.0
COR40405   9.75502     0.9079    0.0
COR40305  49.05431     0.9079    0.0
COR40105   9.52805     1.7572    0.0
*
*****  SURFACE AREAS
* TOTAL OF ALL RINGS  ***** NEEDS TO BE UPDATED FOR NEW TOTALS *****
* AXIAL             SURFACE AREA BY AXIAL NODE   M2
* NODE      UO2   ZR-CLAD       SS   ZR-CAN       TOTAL
*   13    0.000   537.710  175.648  147.129     860.487
*   12  983.975  1420.182  114.863  260.128    2779.148
*   11  983.975  1420.182  114.863  260.128    2779.148
*   10  983.975  1420.182  114.863  260.128    2779.148
*    9  983.975  1420.182  114.863  260.128    2779.148
*    8  983.975  1420.182  114.863  260.128    2779.148
*    7  983.975  1420.182  114.863  260.128    2779.148
*    6    0.000    27.870  131.261    5.203     164.334
*    5    0.000     0.000    9.722    0.000       9.722
*    4    0.000     0.000    6.968    0.000       6.968
*    3    0.000     0.000  603.474    0.000     603.474
*    2    0.000     0.000   54.165    0.000      54.165
*    1    0.000     0.000   55.852    0.000      55.852
*TOTAL 5903.850  9086.672 1726.268 1713.100   18429.890
*
***** RING 1 SURFACES - VOLUME FRACTION=0.603
*                SURFACE AREA BY AXIAL NODE   M2
*                UO2   ZR-CLAD       SS   ZR-CAN         TOTAL
COR11306     0.000   339.515  110.904   92.902  *  543.321
COR11206   621.292   896.718   72.529  164.251  * 1754.790
COR11106   621.292   896.718   72.529  164.251  * 1754.790
COR11006   621.292   896.718   72.529  164.251  * 1754.790
COR10906   621.292   896.718   72.529  164.251  * 1754.790
COR10806   621.292   896.718   72.529  164.251  * 1754.790
COR10706   621.292   896.718   72.529  164.251  * 1754.790
COR10606     0.000    17.596   82.883    3.287  *  103.766
*COR10506     0.000     0.000    6.138    0.000  *    6.138
COR10506     0.000     0.000    61.38    0.000  *    6.138
COR10406     0.000     0.000   66.375    0.000  *   66.375
COR10306     0.000     0.000  319.066    0.000  *  319.066
COR10206     0.000     0.000   34.199    0.000  *   34.199
COR10106     0.000     0.000   35.266    0.000  *   35.266
*TOTAL    3727.752  5737.419 1090.005 1081.695   11636.876
*
***** RING 2  SURFACES - VOLUME FRACTION=0.162
*                SURFACE AREA BY AXIAL NODE   M2
*                UO2   ZR-CLAD       SS   ZR-CAN         TOTAL
COR21306     0.000    91.214   29.798   24.958  *  145.970
COR21206   166.915   240.910   19.485   44.127  *  471.437
COR21106   166.915   240.910   19.485   44.127  *  471.437
COR21006   166.915   240.910   19.485   44.127  *  471.437
COR20906   166.915   240.910   19.485   44.127  *  471.437
COR20806   166.915   240.910   19.485   44.127  *  471.437
COR20706   166.915   240.910   19.485   44.127  *  471.437
COR20606     0.000     4.728   22.266    0.883  *   27.877
```

```
*COR20506    0.000     0.000     1.649    0.000  *    1.649
COR20506    0.000     0.000     16.49    0.000  *    1.649
COR20406    0.000     0.000    17.833    0.000  *   17.833
COR20306    0.000     0.000    85.719    0.000  *   85.719
COR20206    0.000     0.000     9.189    0.000  *    9.189
COR20106    0.000     0.000     9.474    0.000  *    9.474
*TOTAL   1001.490  1541.402   292.838  290.603     3126.333
*
***** RING 3 SURFACES - VOLUME FRACTION=0.115
*                 SURFACE AREA BY AXIAL NODE   M2
*               UO2   ZR-CLAD        SS   ZR-CAN         TOTAL
COR31306    0.000    64.751    21.152   17.717  *  103.620
COR31206  118.489   171.017    13.831   31.325  *  334.662
COR31106  118.489   171.017    13.831   31.325  *  334.662
COR31006  118.489   171.017    13.831   31.325  *  334.662
COR30906  118.489   171.017    13.831   31.325  *  334.662
COR30806  118.489   171.017    13.831   31.325  *  334.662
COR30706  118.489   171.017    13.831   31.325  *  334.662
COR30606    0.000     3.356    15.806    0.626  *   19.788
*COR30506    0.000     0.000     1.171    0.000  *    1.171
COR30506    0.000     0.000     11.71    0.000  *    1.171
COR30406    0.000     0.000    12.658    0.000  *   12.658
COR30306    0.000     0.000    60.851    0.000  *   60.851
COR30206    0.000     0.000     6.523    0.000  *    6.523
COR30106    0.000     0.000     6.726    0.000  *    6.726
*TOTAL    710.934  1094.209   207.873  206.293     2219.309
*
***** RING 4 SURFACES - VOLUME FRACTION=0.120
*                 SURFACE AREA BY AXIAL NODE   M2
*               UO2   ZR-CLAD        SS   ZR-CAN         TOTAL
COR41306    0.000    67.565    22.071   18.487  *  108.123
COR41206  123.641   178.452    14.434   32.686  *  349.213
COR41106  123.641   178.452    14.434   32.686  *  349.213
COR41006  123.641   178.452    14.434   32.686  *  349.213
COR40906  123.641   178.452    14.434   32.686  *  349.213
COR40806  123.641   178.452    14.434   32.686  *  349.213
COR40706  123.641   178.452    14.434   32.686  *  349.213
COR40606    0.000     3.502    16.493    0.653  *   20.648
*COR40506    0.000     0.000     1.222    0.000  *    1.222
COR40506    0.000     0.000     12.22    0.000  *    1.222
COR40406    0.000     0.000    13.208    0.000  *   13.208
COR40306    0.000     0.000    63.496    0.000  *   63.496
COR40206    0.000     0.000     6.806    0.000  *    6.806
COR40106    0.000     0.000     7.018    0.000  *    7.018
*TOTAL    741.846  1141.779   216.918  215.256     2315.799
*
******      LOWER HEAD INPUT
*         IRS IRE     XMLH       TLH     ASLH    ICVLH ICVCAV
CORLHD01    1   1  21331.04    561.0 11.7675    100    204
CORLHD02    2   2   6632.15    561.0  3.6587    100    204
CORLHD03    3   3   5029.00    561.0  2.7743    100    204
CORLHD04    4   4   5608.43    561.0  3.0940    100    204
*TOTALS            38600.62           21.2944
********************************************************************
*      LOWER HEAD PENETRATIONS INPUT
* ALL PENETRATIONS ARE CRD HOUSINGS AND STUB TUBES
* MASS AND AREAS REDUCED TO 1% OF VALUES TO AVOID DOUBLE ACCOUNTING
*          IPNREF  IRP  XMPN     TPN     ASPN     AXPN    DFLPN
```

```
CORPEN01  -1      1  23.8112  561.0  0.33679  0.008301   0.1
CORPEN02  -1      2   6.3970  561.0  0.09048  0.002230   0.1
CORPEN03  -1      3   4.5411  561.0  0.06423  0.001583   0.1
CORPEN04  -1      4   4.7385  561.0  0.06702  0.001652   0.1
*TOTALS             39.4879          0.55852  0.013766
*
*          CONTROL VOLUME INLET TEMPERATURE INPUT
*          IVOL   ITIN
CORTIN00   100    100
CORTIN01   102    100
CORTIN02   101    100
**********************************************************************
*
*     TRANSFER PROCESS INPUT
*
**********************************************************************
*
*   'IN' TRANSFER PROCESS FOR CORE PACKAGE
*           NMSIN   NTHRM
TPIN10100   6       9
*
*    'OUT' TRANSFER PROCESS FOR CAVITY PACKAGE
*           NMSOT   NPOTOI  IOTMTX
TPOT10200   5       101     UIN.103
*
*     COR-CAV TRANSLATION MATRIX
*     *** NOTE *** CONTROL POISON MASS IS NOT CONSERVED
*           NROW    NCOL
TPM1030000  5       6
*           NROW/NCOL  VALUE
TPM1030001  1/1        1.0     * UO2 MASS
TPM1030002  2/2        1.0     * ZRO2 MASS
TPM1030003  3/3        1.0     * STEEL MASS
TPM1030004  4/4        1.0     * ZR MASS
TPM1030005  5/5        1.0     * STEEL OXIDE MASS
*     TRANSFER PROCESSES FOR RADIONUCLIDE TRANSFER
TPIN60100   16      1
TPOT60200   16      601    DEF.1
*
**********************************************************************
*
*     DECAY HEAT INPUT
*
**********************************************************************
*
DCHREACTOR   BWR
DCHSHUT      -1   -1720.
DCHDECPOW    TF-77
*
TF07700   DECAY-HEAT  44   3833.E6  0.
*               TIME    NORMALIZED POWER
TF07710  0.            .06           1.00000E+00  5.71500E-02
TF07711  1.50000E+00  5.55200E-02
TF07712  2.00000E+00  5.43700E-02
TF07713  3.00000E+00  5.20400E-02
TF07714  4.00000E+00  5.04000E-02
TF07715  6.00000E+00  4.80700E-02
TF07716  8.00000E+00  4.61900E-02
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TF07717  1.00000E+01  4.47300E-02
TF07718  1.50000E+01  4.20500E-02
TF07719  2.00000E+01  4.01500E-02
TF0771A  3.00000E+01  3.75600E-02
TF0771B  4.00000E+01  3.57200E-02
TF0771C  6.00000E+01  3.31300E-02
TF0771D  8.00000E+01  3.13700E-02
TF0771E  1.00000E+02  3.00000E-02
TF0771F  1.50000E+02  2.77700E-02
TF0771G  2.00000E+02  2.61900E-02
TF0771H  3.00000E+02  2.42800E-02
TF0771I  4.00000E+02  2.29300E-02
TF0771J  6.00000E+02  2.10200E-02
TF0771K  8.00000E+02  1.96500E-02
TF0771L  1.00000E+03  1.85900E-02
TF0771M  1.50000E+03  1.66200E-02
TF0771N  2.00000E+03  1.52200E-02
TF0771O  3.00000E+03  1.35400E-02
TF0771P  4.00000E+03  1.23500E-02
TF0771Q  6.00000E+03  1.06700E-02
TF0771R  8.00000E+03  9.81500E-03
TF0771S  1.00000E+04  9.15200E-03
TF0771T  1.50000E+04  8.19300E-03
TF0771U  2.00000E+04  7.51200E-03
TF0771V  3.00000E+04  6.76400E-03
TF0771W  4.00000E+04  6.23200E-03
TF0771X  6.00000E+04  5.48400E-03
TF0771Y  8.00000E+04  5.03900E-03
TF0771Z  1.00000E+05  4.69300E-03
TF07720  1.50000E+05  4.14100E-03
TF07721  2.00000E+05  3.74900E-03
TF07722  3.00000E+05  3.27500E-03
TF07723  4.00000E+05  2.94000E-03
TF07724  6.00000E+05  2.46600E-03
TF07725  8.00000E+05  2.18700E-03
TF07726  1.00000E+06  1.97100E-03
*
***********************************************************************
*
*     RADIONUCLIDE INPUT
*
***********************************************************************
*
RN1000 0
RN1001 5 1 16 14 13 0 0
RN1100 1.0E-6 50.E-6 1000.
*
* USE DEFAULT RADIONUCLIDES PLUS CSI CLASS 16
*
DCHDEFCLS0 ALL
*
* CSI CLASS
*
DCHNEM0100 CI 1.0E-6
DCHNEM0101    0. 5.0211E5    6.12 4.0919E5    11.88 3.8675E5    18. 3.5494E5
DCHNEM0102    29.88 3.1747E5      61.2 2.8612E5     118.8 2.4439E5
DCHNEM0103    241.2 2.3141E5      612. 2.1557E5     1188. 1.9989E5
DCHNEM0104    3600. 1.5937E5     5400. 1.3421E5     7200. 1.2565E5
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DCHNEM0105  14400. 8.3485E4   21600. 6.8352E4   28800. 5.8241E4
DCHNEM0106  36000. 5.1511E4   43200. 4.3972E4   54000. 3.8938E4
DCHNEM0107  72000. 3.1424E4   86400. 2.6405E4  129600. 1.7206E4
DCHNEM0108 172800. 1.3019E4  259200. 8.8273E3  345600. 6.4804E3
DCHNEM0109 518400. 4.5686E3  691200. 3.5628E3  864000. 3.0797E3
DCHCLS0160 CSI
DCHCLS0161 CI
*
DCHCLSNORM YES
*
RNCLS0100 16
RNCLS0101 2 1.0 *CS
RNCLS0102 4 0.5 *I2
*
*  VANESA TO CLASS MAP
*
RNVNCL01  25 16
*
* CORE FISSION PRODUCT INVENTORIES
*
* BASED ON 3578 MW(T) BWR INVENTORIES
*
RNFP000 -2   * MODIFIED CORSOR
*
*  THE DISTRIBUTION OF FISSION PRODUCTS
*  AMONG INDIVIDUAL CORE CELLS IS BASED
*  ON THE DATA FROM COMMONWEALTH EDISON
*  REFERENCE THEIR LETTER DATED 9/10/87
*  FOR LASALLE
*
*** RING 1
RNFPN11301   0   0.000   0.000
RNFPN11201   0   0.140   0.694
RNFPN11101   0   0.171   0.694
RNFPN11001   0   0.177   0.694
RNFPN10901   0   0.183   0.694
RNFPN10801   0   0.188   0.694
RNFPN10701   0   0.140   0.694
RNFPN10601   0   0.000   0.000
*** RING 2
RNFPN21301   0   0.000   0.000
RNFPN21201   0   0.140   0.170
RNFPN21101   0   0.171   0.170
RNFPN21001   0   0.177   0.170
RNFPN20901   0   0.183   0.170
RNFPN20801   0   0.188   0.170
RNFPN20701   0   0.140   0.170
RNFPN20601   0   0.000   0.000
******************************
*** RING 3
RNFPN31301   0   0.000   0.000
RNFPN31201   0   0.140   0.094
RNFPN31101   0   0.171   0.094
RNFPN31001   0   0.177   0.094
RNFPN30901   0   0.183   0.094
RNFPN30801   0   0.188   0.094
RNFPN30701   0   0.140   0.094
RNFPN30601   0   0.000   0.000
```

```
******************************
*** RING 4
RNFPN41301   0   0.000   0.000
RNFPN41201   0   0.140   0.042
RNFPN41101   0   0.171   0.042
RNFPN41001   0   0.177   0.042
RNFPN40901   0   0.183   0.042
RNFPN40801   0   0.188   0.042
RNFPN40701   0   0.140   0.042
RNFPN40601   0   0.000   0.000
*
*   GAP
*  THE GAP FRACTIONS ARE TAKEN FROM PAGE
*  5-7 OF BMI-2104 VOLUME 2
*
RNGAP10700 1173.
RNGAP10701 2 .05       1.0  *CS
RNGAP10702 4 .017      1.0  *I
RNGAP10703 1 .03       1.0  *XE
RNGAP10704 5 .0001     1.0  *TE
RNGAP10705 3 .000001   1.0  *BA,SR
*
RNGAP10600 1173.
RNGAP10601 -107  1.0  1.0
RNGAP10800 1173.
RNGAP10801 -107  1.0  1.0
RNGAP10900 1173.
RNGAP10901 -107  1.0  1.0
RNGAP11000 1173.
RNGAP11001 -107  1.0  1.0
RNGAP11100 1173.
RNGAP11101 -107  1.0  1.0
RNGAP11200 1173.
RNGAP11201 -107  1.0  1.0
RNGAP11300 1173.0
RNGAP11301 -107  1.0  1.0
*
RNGAP20600 1173.
RNGAP20601 -107  1.0  1.0
RNGAP20700 1173.
RNGAP20701 -107  1.0  1.0
RNGAP20800 1173.
RNGAP20801 -107  1.0  1.0
RNGAP20900 1173.
RNGAP20901 -107  1.0  1.0
RNGAP21000 1173.
RNGAP21001 -107  1.0  1.0
RNGAP21100 1173.
RNGAP21101 -107  1.0  1.0
RNGAP21200 1173.
RNGAP21201 -107  1.0  1.0
RNGAP21300 1173.
RNGAP21301 -107  1.0  1.0
*
RNGAP30600 1173.
RNGAP30601 -107  1.0  1.0
RNGAP30700 1173.
RNGAP30701 -107  1.0  1.0
```

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RNGAP30800 1173.
RNGAP30801 -107  1.0  1.0
RNGAP30900 1173.
RNGAP30901 -107  1.0  1.0
RNGAP31000 1173.
RNGAP31001 -107  1.0  1.0
RNGAP31100 1173.
RNGAP31101 -107  1.0  1.0
RNGAP31200 1173.
RNGAP31201 -107  1.0  1.0
RNGAP31300 1173.
RNGAP31301 -107  1.0  1.0
*
RNGAP40600 1173.
RNGAP40601 -107  1.0  1.0
RNGAP40800 1173.
RNGAP40801 -107  1.0  1.0
RNGAP40900 1173.
RNGAP40901 -107  1.0  1.0
RNGAP41000 1173.
RNGAP41001 -107  1.0  1.0
RNGAP41100 1173.
RNGAP41101 -107  1.0  1.0
RNGAP41200 1173.
RNGAP41201 -107  1.0  1.0
RNGAP41300 1173.0
RNGAP41301 -107  1.0  1.0
*
* AEROSOL COEFFICIENTS
*
*R*I*F UD3:[SWWEBB]ACOEFF.DAT
RNACOEF 1
*
*  DEFAULT VALUES FOR THE AEROSOL
*  PARAMETERS ARE USED
*
*  DEPOSITION SURFACES
*
RNDS001  10001   LHS  FLOOR
*
*  SETTLING AREAS
*
*          FR   TO     ELEV     AREA
*
RNSET001  101  100    5.2845    4.9090         * FL011
RNSET002  102  100    5.2845    0.0780         * FL012
RNSET003  103  101    9.6629    5.3711         * FL013
RNSET004  103  102    9.6629    6.2128         * FL014
RNSET005  104  103   15.4304    4.19318        * FL015
RNSET006  104  105   15.4304   13.90015        * FL016
RNSET007  105  100    3.3400    0.32948        * FL018
*                                              *
*  FL017 SEPARATOR DRAIN AND FL021 STEAM FLOW  *
*  LINE SRV ARE NOT LIKELY TO BE SETTLING FLOW *
*  PATHS                                       *
*                                              *
RNSET008  201  202    -1.68     51.4           * DW - WEIR ANN
RNSET016  301  302    26.26     74.3
```

```
RNSET017  301  303    26.26    152.1
RNSET018  302  305     3.71     62.4
RNSET019  303  304    11.63    228.8
RNSET020  304  305     3.71    144.4
*                                                            *
*  FOR VOLUME 400 A SETTLING FLOW PATH FROM 400             *
*  TO 400 IS USED INSTEAD OF HAVING A HORIZONTAL            *
*  HEAT SLAB                                                 *
*                                                            *
RNSET010   400   400   -12.44  10.00                         *
*
**  THIS IS A TEMPORARY FIX FOR SETTLING IN CV100
*   A HORIZONTAL DEPOSITION SURFACE WAS INPUT INSTEAD.  CONCERNED
*   ABOUT POTENTIAL FOR SETTLING OUT AEROSOLS TO DW BEFORE
*   THE VESSEL BREACHES
*
*RNSET011   100   204    0.     .01
*
*** WE MAY NOT WANT TO DO THESE THIS WAY - JUST TRYING IT OUT
RNSET013   202   202    -7.44  50.
RNSET014   204   204    -7.44  50.
RNSET015   305   305    -7.44  50.
*
************************************************************************
*
*     CAVITY INPUT
*
************************************************************************
*
CAV0000          204              *  CONTROL VOLUME NUMBER
*
*   LIMESTONE / COMMON SAND CONCRETE (MIX446) WITH 0.135 KG/KG REBAR
CAV00C0   USER-INPUT
CAV00C1   SIO2       0.38300       TIO2      0.00073
CAV00C2   MNO        0.00028       MGO       0.10000
CAV00C3   CAO        0.18700       NA2O      0.00330
CAV00C4   K2O        0.00829       FE2O3     0.01180
CAV00C5   AL2O3      0.05052       CR2O3     0.00011
CAV00C6   CO2        0.20500       H2OEVAP   0.02870
CAV00C7   H2OCHEM    0.02130
CAV00C8   FE         0.13500    * 0.135 KG/KG REBAR
CAV00CA   DENSCT     2340.0     * DENSITY
CAV00CB   TSOLCT     1420.0     * SOLIDUS TEMPERATURE
CAV00CC   TLIQCT     1670.0     * LIQUIDUS TEMPERATURE
CAV00CD   TABLCT     1503.0     * ABLATION TEMPERATURE
CAV00CE   TINCT       310.0     * INITIAL TEMPERATURE
CAV00CF   EMISCT        0.82    * EMISSIVITY
*
CAV00G0   CORCON  2              *  FLAT BOTTOM CYLINDER GEOMETRY
*
*         NRAYS   R0    Z0
CAV00G1    55      0.   0.5
*         ZT   RAD   HIT   RADC    RW    HBB  NBOT  NCORN
CAV00G2   1.  3.226  2.921  0.1  4.978   2.0   25     3
*
CAV00TP        102               *  TRANSFER PROCESS NUMBER
*
************************************************************************
```

```
*
* HEAT STRUCTURE INPUT
*
***********************************************************************
*
* REACTOR VESSEL HEAT STRUCTURES
*
***********************************************************************
* SECTION OF VESSEL LOWER HEAD AROUND AXIAL NODE 1 (CR HOUSINGS & STUBS)
HS10001000        5    2    0    0
HS10001001     'LOWER HEAD 1     '
HS10001002        0.00         1.00
HS10001003         1.0
HS10001100       -1           1        2.17209
HS10001102      2.216538      2
HS10001103      2.260986      3
HS10001104      2.305433      4
HS10001105      2.349881      5
HS10001200     -1
HS10001201     'CARBON STEEL               '       4
HS10001300     0
HS10001400        1       100      'INT'      0.50      0.50
HS10001500         8.71         1.00          0.64
HS10001600     5120       204      'EXT'      1.00      1.00
HS10001700         9.42         0.20          0.64
HS10001800     -1
HS10001801      560.0        5
***********************************************************************
* SECTION OF VESSEL LOWER HEAD AROUND AXIAL NODE 2 (CR HOUSINGS)
HS10002000        5    2    0    0
HS10002001     'LOWER HEAD 2     '
HS10002002        0.6381       1.00
HS10002003         1.0
HS10002100       -1           1        2.17209
HS10002102      2.216538      2
HS10002103      2.260986      3
HS10002104      2.305433      4
HS10002105      2.349881      5
HS10002200     -1
HS10002201     'CARBON STEEL               '       4
HS10002300     0
HS10002400        1       100      'INT'      0.50      0.50
HS10002500         8.71         1.00          0.64
HS10002600     5120       204      'EXT'      1.00      1.00
HS10002700         9.42         0.20          0.64
HS10002800     -1
HS10002801      560.0        5
***********************************************************************
* SECTION OF VESSEL LOWER HEAD AROUND AXIAL NODE 3 (CR GUIDE TUBES)
HS10003000        5    2    0    0
HS10003001     'LOWER HEAD 3     '
HS10003002        1.276        1.00
HS10003003         1.0
HS10003100       -1           1        2.17209
HS10003102      2.216538      2
HS10003103      2.260986      3
HS10003104      2.305433      4
HS10003105      2.349881      5
```

```
HS10003200     -1
HS10003201     'CARBON STEEL              '        4
HS10003300      0
HS10003400        1        100      'INT'       0.50       0.50
HS10003500        28.16            1.00            2.06
HS10003600      5120       204      'EXT'       1.00       1.00
HS10003700        30.47            0.20            2.06
HS10003800      -1
HS10003801       560.0        5
*************************************************************************
* LOWER PLENUM SHROUD AXIAL NODE 3 (CR GUIDE TUBES)
HS10014000        5    2    0    0
HS10014001     'LP SHROUD 3       '
HS10014002        3.34          1.00
HS10014003         1.0
HS10014100       -1             1          2.57956
HS10014102       2.592259      2
HS10014103       2.604959      3
HS10014104       2.617658      4
HS10014105       2.630358      5
HS10014200     -1
HS10014201     'STAINLESS STEEL           '        4
HS10014300      0
HS10014400        1        100      'INT'       0.50       0.50
HS10014401     0.7000     'EQUIV BAND'      0.20
HS10014500         1.             0.20            1.222
HS10014600        1        105      'INT'       0.50       0.50
HS10014601     0.7000     'EQUIV BAND'      0.20
HS10014700         1.             0.20            1.222
HS10014800      -1
HS10014801       560.0        5
*************************************************************************
* CORE SHROUD AROUND AXIAL NODE 4
HS10004000        5    2    0    0
HS10004001     'LP SHROUD 4       '
HS10004002        4.5615        1.00
HS10004003         1.0
HS10004100       -1             1          2.57956
HS10004102       2.592259      2
HS10004103       2.604959      3
HS10004104       2.617658      4
HS10004105       2.630358      5
HS10004200     -1
HS10004201     'STAINLESS STEEL           '        4
HS10004300      0
HS10004400        1        100      'INT'       0.50       0.50
HS10004500         1.             0.01            0.6532
HS10004600        1        105      'INT'       0.50       0.50
HS10004601     0.7000     'EQUIV BAND'      0.20
HS10004700         1.             0.20            0.6532
HS10004800      -1
HS10004801       560.0        5
*************************************************************************
* CORE SHROUD AROUND AXIAL NODE 5 (CORE SUPPORT PLATE)
HS10005000        5    2    0    0
HS10005001     'LP SHROUD 5       '
HS10005002        5.2147        1.00
HS10005003         1.0
```

```
HS10005100        -1            1        2.57956
HS10005102       2.592259       2
HS10005103       2.604959       3
HS10005104       2.617658       4
HS10005105       2.630358       5
HS10005200     -1
HS10005201     'STAINLESS STEEL            '       4
HS10005300      0
HS10005400        1       100     'INT'       0.50       0.50
HS10005500         1.13          0.01          0.0698
HS10005600        1       105     'INT'       0.50       0.50
HS10005601     0.7000     'EQUIV BAND'      0.20
HS10005700         1.15          0.20          0.0698
HS10005800      -1
HS10005801       560.0       5
************************************************************************
* CORE SHROUD AROUND AXIAL NODE 6 (ASSEMBLY NOSE PIECES)
HS10206000        5    2    0    0
HS10206001     'CORE SHROUD 6    '
HS10206002        5.2845       1.00
HS10206003         1.0
HS10206100        -1            1        2.57956
HS10206102       2.592259       2
HS10206103       2.604959       3
HS10206104       2.617658       4
HS10206105       2.630358       5
HS10206200     -1
HS10206201     'STAINLESS STEEL            '       4
HS10206300      0
HS10206400        1       102     'INT'       0.50       0.50
HS10206500         3.39          0.20          0.2093
HS10206600        1       105     'INT'       0.50       0.50
HS10206601     0.7000     'EQUIV BAND'      0.20
HS10206700         3.46          0.20          0.2093
HS10206800      -1
HS10206801       560.0       5
************************************************************************
* CORE SHROUD AROUND AXIAL NODE 7 (BOTTOM OF ACTIVE FUEL)
HS10207000        5    2    0    0
HS10207001     'CORE SHROUD 7    '
HS10207002        5.494        1.00
HS10207003         1.0
HS10207100        -1            1        2.57956
HS10207102       2.592259       2
HS10207103       2.604959       3
HS10207104       2.617658       4
HS10207105       2.630358       5
HS10207200     -1
HS10207201     'STAINLESS STEEL            '       4
HS10207300      0
HS10207400        1       102     'INT'       0.50       0.50
HS10207500        10.29          0.20          0.635
HS10207600        1       105     'INT'       0.50       0.50
HS10207601     0.7000     'EQUIV BAND'      0.20
HS10207700        10.49          0.20          0.635
HS10207800      -1
HS10207801       560.0       5
************************************************************************
```

```
* CORE SHROUD AROUND AXIAL NODE 8 (ACTIVE FUEL)
HS10208000        5    2    0    0
HS10208001      'CORE SHROUD 8    '
HS10208002        6.129        1.00
HS10208003         1.0
HS10208100       -1            1        2.57956
HS10208102      2.592259       2
HS10208103      2.604959       3
HS10208104      2.617658       4
HS10208105      2.630358       5
HS10208200     -1
HS10208201      'STAINLESS STEEL         '       4
HS10208300      0
HS10208400        1       102     'INT'      0.50       0.50
HS10208500        10.29          0.20          0.635
HS10208600        1       105     'INT'      0.50       0.50
HS10208601     0.7000     'EQUIV BAND'     0.20
HS10208700        10.49          0.20          0.635
HS10208800      -1
HS10208801      560.0       5
**************************************************************************
* CORE SHROUD AROUND AXIAL NODE 9 (ACTIVE FUEL)
HS10209000        5    2    0    0
HS10209001      'CORE SHROUD 9    '
HS10209002        6.764        1.00
HS10209003         1.0
HS10209100       -1            1        2.57956
HS10209102      2.592259       2
HS10209103      2.604959       3
HS10209104      2.617658       4
HS10209105      2.630358       5
HS10209200     -1
HS10209201      'STAINLESS STEEL         '       4
HS10209300      0
HS10209400        1       102     'INT'      0.50       0.50
HS10209500        10.29          0.20          0.635
HS10209600        1       105     'INT'      0.50       0.50
HS10209601     0.7000     'EQUIV BAND'     0.20
HS10209700        10.49          0.20          0.635
HS10209800      -1
HS10209801      560.0       5
**************************************************************************
* CORE SHROUD AROUND AXIAL NODE 10 (ACTIVE FUEL)
HS10210000        5    2    0    0
HS10210001      'CORE SHROUD 10   '
HS10210002        7.399        1.00
HS10210003         1.0
HS10210100       -1            1        2.57956
HS10210102      2.592259       2
HS10210103      2.604959       3
HS10210104      2.617658       4
HS10210105      2.630358       5
HS10210200     -1
HS10210201      'STAINLESS STEEL         '       4
HS10210300      0
HS10210400        1       102     'INT'      0.50       0.50
HS10210500        10.29          0.20          0.635
HS10210600        1       105     'INT'      0.50       0.50
```

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HS10210601     0.7000     'EQUIV BAND'     0.20
HS10210700        10.49           0.20          0.635
HS10210800      -1
HS10210801       560.0       5
***************************************************************************
* CORE SHROUD AROUND AXIAL NODE 11 (ACTIVE FUEL)
HS10211000         5    2    0    0
HS10211001     'CORE SHROUD 11  '
HS10211002        8.034        1.00
HS10211003          1.0
HS10211100        -1           1        2.57956
HS10211102       2.592259      2
HS10211103       2.604959      3
HS10211104       2.617658      4
HS10211105       2.630358      5
HS10211200     -1
HS10211201     'STAINLESS STEEL          '       4
HS10211300      0
HS10211400         1       102     'INT'      0.50       0.50
HS10211500        10.29           0.20          0.635
HS10211600         1       105     'INT'      0.50       0.50
HS10211601     0.7000     'EQUIV BAND'     0.20
HS10211700        10.49           0.20          0.635
HS10211800      -1
HS10211801       560.0       5
***************************************************************************
* CORE SHROUD AROUND AXIAL NODE 12 (TOP OF ACTIVE FUEL)
HS10212000         5    2    0    0
HS10212001     'CORE SHROUD 12  '
HS10212002        8.669        1.00
HS10212003          1.0
HS10212100        -1           1        2.57956
HS10212102       2.592259      2
HS10212103       2.604959      3
HS10212104       2.617658      4
HS10212105       2.630358      5
HS10212200     -1
HS10212201     'STAINLESS STEEL          '       4
HS10212300      0
HS10212400         1       102     'INT'      0.50       0.50
HS10212500        10.29           0.20          0.635
HS10212600         1       105     'INT'      0.50       0.50
HS10212601     0.7000     'EQUIV BAND'     0.20
HS10212700        10.49           0.20          0.635
HS10212800      -1
HS10212801       560.0       5
***************************************************************************
* CORE SHROUD AROUND AXIAL NODE 13 (FUEL ROD UPPER PLENUMS & STRUCTURES)
HS10213000         5    2    0    0
HS10213001     'CORE SHROUD 13  '
HS10213002        9.3038       1.00
HS10213003          1.0
HS10213100        -1           1        2.57956
HS10213102       2.592259      2
HS10213103       2.604959      3
HS10213104       2.617658      4
HS10213105       2.630358      5
HS10213200     -1
```

```
HS10213201     'STAINLESS STEEL          '        4
HS10213300      0
HS10213400         1       102     'INT'      0.50       0.50
HS10213500          5.82           0.20           0.3591
HS10213600         1       105     'INT'      0.50       0.50
HS10213601     0.7000     'EQUIV BAND'      0.20
HS10213700          5.94           0.20           0.3591
HS10213800      -1
HS10213801     560.0   5
*************************************************************************
*
*DT/DZ INPUT
*
HS10001004   401  0
HS10002004   402  0
HS10003004   403  0
HS10004004   404  0
HS10005004   405  0
HS10206004   406  0
HS10207004   407  0
HS10208004   408  0
HS10209004   409  0
HS10210004   410  0
HS10211004   411  0
HS10212004   412  0
HS10213004   413  0
*
**************************************************************
* UPPER PLENUM SHROUD
HS10301000         5    2    0    0
HS10301001      'UP SHROUD          '
HS10301002         9.6629       1.00
HS10301003          1.0
HS10301100        -1            1         2.79386
HS10301102       2.806559       2
HS10301103       2.819259       3
HS10301104       2.831958       4
HS10301105       2.844658       5
HS10301200      -1
HS10301201      'STAINLESS STEEL          '        4
HS10301300       0
HS10301400          1       103     'INT'      0.50       0.50
HS10301401      0.7000     'EQUIV BAND'      0.80
HS10301500         14.05           0.80           0.80
HS10301600          1       105     'INT'      0.50       0.50
HS10301601      0.7000     'EQUIV BAND'      0.20
HS10301700         14.30           0.20           0.80
HS10301800       -1
HS10301801        560.0       5
*************************************************************************
* UPPER PLENUM SHROUD DOME
HS10302000         5    1    0    0
HS10302001      'UP SHROUD DOME   '
HS10302002        10.46          0.00
HS10302003          1.0
HS10302100        -1            1         0.00000
HS10302102       0.012700       2
HS10302103       0.025399       3
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HS10302104       0.038099      4
HS10302105       0.050798      5
HS10302200      -1
HS10302201      'STAINLESS STEEL           '       4
HS10302300       0
HS10302400         1       103      'INT'      1.00       1.00
HS10302500         21.60           0.60          4.65
HS10302600         1       105      'INT'      1.00       1.00
HS10302601      0.7000      'EQUIV BAND'     0.10
HS10302700         21.60           0.10          4.65
HS10302800      -1
HS10302801       560.0       5
**********************************************************************
* STEAM SEPARATORS
HS10303000         5    1    0    0
HS10303001      'SEPARATORS        '
HS10303002        10.46          1.00
HS10303003          1.0
HS10303100        -1             1         0.00000
HS10303102       0.003960      2
HS10303103       0.007920      3
HS10303104       0.011880      4
HS10303105       0.015840      5
HS10303200      -1
HS10303201      'STAINLESS STEEL           '       4
HS10303300       0
HS10303400         1       103      'INT'      0.50       0.50
HS10303401      0.7000      'EQUIV BAND'     0.20
HS10303500        520.00           0.20          4.97
HS10303600         1       105      'INT'      0.50       0.50
HS10303601      0.7000      'EQUIV BAND'     0.20
HS10303700        520.00           0.20          4.97
HS10303800      -1
HS10303801       560.0       5
**********************************************************************
* STEAM DRYERS
HS10401000         5    1    0    0
HS10401001      'DRYERS            '
HS10401002        15.60          1.00
HS10401003          1.0
HS10401100        -1             1         0.00000
HS10401102       0.001642      2
HS10401103       0.003284      3
HS10401104       0.004926      4
HS10401105       0.006568      5
HS10401200      -1
HS10401201      'STAINLESS STEEL           '       4
HS10401300       0
HS10401400         1       104      'INT'      0.50       0.50
HS10401401      0.7000      'EQUIV BAND'     0.40
HS10401500        697.00           0.40          2.82
HS10401600         1       104      'INT'      0.50       0.50
HS10401601      0.7000      'EQUIV BAND'     0.40
HS10401700        697.00           0.40          2.82
HS10401800      -1
HS10401801       560.0       5
**********************************************************************
* VESSEL UPPER HEAD - HEMISPHERIC SECTION
```

```
HS10402000          5    5    0    0
HS10402001       'UPPER HEAD          '
HS10402002         19.04          0.00
HS10402003           1.0
HS10402100         -1             1         3.18754
HS10402102        3.231988        2
HS10402103        3.276436        3
HS10402104        3.320883        4
HS10402105        3.365331        5
HS10402200       -1
HS10402201       'CARBON STEEL                  '        4
HS10402300        0
HS10402400          1        104      'INT'       1.00       1.00
HS10402401       0.7000      'EQUIV BAND'      3.00
HS10402500          63.84          3.00          3.19
HS10402600        5120       201      'EXT'       1.00       1.00
HS10402700          71.16          5.00          3.36
HS10402800        -1
HS10402801         560.0       5
***********************************************************************
* REACTOR VESSEL CYLINDER WALL AROUND DRYERS
HS10403000          5    2    0    0
HS10403001       'UPPER CYL          '
HS10403002         15.4304        1.00
HS10403003           1.0
HS10403100         -1             1         3.18754
HS10403102        3.231988        2
HS10403103        3.276436        3
HS10403104        3.320883        4
HS10403105        3.365331        5
HS10403200       -1
HS10403201       'CARBON STEEL                  '        4
HS10403300        0
HS10403400          1        104      'INT'       1.00       1.00
HS10403401       0.7000      'EQUIV BAND'      0.50
HS10403500          72.22          0.50          3.61
HS10403600        5120       201      'EXT'       1.00       1.00
HS10403700          76.25          0.20          3.61
HS10403800        -1
HS10403801         560.0       5
***********************************************************************
* REACTOR VESSEL WALL AROUND DOWNCOMER
HS10501000          5    2    0    0
HS10501001       'MAIN CYL          '
HS10501002          3.34          1.00
HS10501003           1.0
HS10501100         -1             1         3.18754
HS10501102        3.231988        2
HS10501103        3.276436        3
HS10501104        3.320883        4
HS10501105        3.365331        5
HS10501200       -1
HS10501201       'CARBON STEEL                  '        4
HS10501300        0
HS10501400          1        105      'INT'       0.50       0.50
HS10501401       0.7000      'EQUIV BAND'      0.50
HS10501500         242.15          0.50         12.09
HS10501600        5120       201      'EXT'       1.00       1.00
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HS10501700        255.66          0.20          12.09
HS10501800       -1
HS10501801        560.0       5
*********************************************************************
* -------------------------------------------------------------------
* CONTAINMENT HEAT STRUCTURE INPUT
* -------------------------------------------------------------------
*********************************************************************
HS30101000         10    1    -1    0
HS30101001       'CONC FLOOR        '
HS30101002         27.56          1.00
HS30101003           1.0
HS30101100          -1            1          0.00100
HS30101102        0.001749        2
HS30101103        0.003060        3
HS30101104        0.005353        4
HS30101105        0.009364        5
HS30101106        0.016381        6
HS30101107        0.028656        7
HS30101108        0.050129        8
HS30101109        0.087691        9
HS30101110        0.153400       10
HS30101200       -1
HS30101201       'CONCRETE                        '        9
HS30101300        0
HS30101400          1        301        EXT        1.00
HS30101500         297.30          6.00           5.00
HS30101600          0
HS30101800       -1
HS30101801        305.0       10
*********************************************************************
HS30102000          5    1    -1    0
HS30102001       'POOL WALLS        '
HS30102002         27.56          1.00
HS30102003           1.0
HS30102100          -1            1          0.00100
HS30102102        0.001706        2
HS30102103        0.002910        3
HS30102104        0.004965        4
HS30102105        0.008470        5
HS30102200       -1
HS30102201       'STAINLESS STEEL                 '        4
HS30102300        0
HS30102400          1        301        EXT        1.00
HS30102500         555.00          0.46           5.00
HS30102600          0
HS30102800       -1
HS30102801        305.0        5
*********************************************************************
HS30103000          5    1    -1    0
HS30103001       'CRANE             '
HS30103002         27.56          1.00
HS30103003           1.0
HS30103100          -1            1          0.00100
HS30103102        0.003835        2
HS30103103        0.014704        3
HS30103104        0.056382        4
HS30103105        0.216200        5
```

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HS30103200      -1
HS30103201      'STAINLESS STEEL          '        4
HS30103300       0
HS30103400         1        301       EXT        1.00
HS30103500       1188.00          1.00            5.00
HS30103600         0
HS30103800       -1
HS30103801       305.0        5
**************************************************************************
HS30104000         14   1    -1    0
HS30104001      'CONT WALLS       '
HS30104002        27.56         1.00
HS30104003          1.0
HS30104100        -1              1          0.00100
HS30104101       0.002709        2
HS30104102       0.007340        3
HS30104103       0.013           4
HS30104104       0.0224          5
HS30104105       0.03743         6
HS30104106       0.06148         7
HS30104107       0.100           8
HS30104108       0.1616          9
HS30104109       0.260          10
HS30104110       0.420          11
HS30104111       0.670          12
HS30104112       1.07           13
HS30104113       1.70           14
HS30104200      -1
HS30104201      'STAINLESS STEEL          '        2
HS30104202       CONCRETE                         13
HS30104300       0
HS30104400         1        301       EXT        1.00
HS30104500       3290.60         28.00            5.00
HS30104600         0
HS30104800       -1
HS30104801       305.0        14
**************************************************************************
HS30201000        14    1    -1    0
HS30201001      'CONT WALL        '
HS30201002         7.56         1.00
HS30201003          1.0
HS30201100        -1              1          0.00100
HS30201101       0.002709        2
HS30201102       0.007340        3
HS30201103       0.013           4
HS30201104       0.0224          5
HS30201105       0.03743         6
HS30201106       0.06148         7
HS30201107       0.100           8
HS30201108       0.1616          9
HS30201109       0.260          10
HS30201110       0.420          11
HS30201111       0.670          12
HS30201112       1.07           13
HS30201113       1.70           14
HS30201200      -1
HS30201201      'STAINLESS STEEL          '        2
HS30201202       CONCRETE                         13
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HS30201300       0
HS30201400         1        302        EXT        1.00
HS30201500         393.40         22.30            5.00
HS30201600         0
HS30201800       -1
HS30201801        305.0       14
*************************************************************************
HS30301000         14    1     -1     0
HS30301001       'CONT WALL          '
HS30301002         17.56         1.00
HS30301003           1.0
HS30301100         -1           1          0.00100
HS30301101        0.002709      2
HS30301102        0.007340      3
HS30301103        0.013         4
HS30301104        0.0224        5
HS30301105        0.03743       6
HS30301106        0.06148       7
HS30301107        0.100         8
HS30301108        0.1616        9
HS30301109        0.260        10
HS30301110        0.420        11
HS30301111        0.670        12
HS30301112        1.07         13
HS30301113        1.70         14
HS30301200       -1
HS30301201       'STAINLESS STEEL          '        2
HS30301202        CONCRETE                         13
HS30301300       0
HS30301400         1        303        EXT        1.00
HS30301500         950.00         14.30            5.00
HS30301600         0
HS30301800       -1
HS30301801        305.0       14
*************************************************************************
HS30302000         10    1     -1     0
HS30302001       'DW WALL            '
HS30302002         17.56         1.00
HS30302003           1.0
HS30302100         -1           1          0.00100
HS30302102        0.00229       2
HS30302103        0.005256      3
HS30302104        0.01205       4
HS30302105        0.027622      5
HS30302106        0.06333       6
HS30302107        0.145176      7
HS30302108        0.33282       8
HS30302109        0.54          9
HS30302110        0.763000     10
HS30302200       -1
HS30302201       CONCRETE        9
HS30302300       0
HS30302400         1        303        EXT        1.00
HS30302500         202.00         14.30            5.00
HS30302600         0
HS30302800       -1
HS30302801        305.0       10
*************************************************************************
```

```
HS30303000        10    1    -1    0
HS30303001      'CONC            '
HS30303002        17.56          1.00
HS30303003          1.0
HS30303100        -1            1         0.00100
HS30303102       0.001749       2
HS30303103       0.003060       3
HS30303104       0.005353       4
HS30303105       0.009364       5
HS30303106       0.016381       6
HS30303107       0.028656       7
HS30303108       0.050129       8
HS30303109       0.087691       9
HS30303110       0.153400      10
HS30303200      -1
HS30303201      'CONCRETE                     '        9
HS30303300       0
HS30303400         1       303       EXT        1.00
HS30303500       2103.00          6.00           5.00
HS30303600         0
HS30303800       -1
HS30303801       305.0       10
**********************************************************************
HS30304000         2    1    -1    0
HS30304001      'MISC STEEL      '
HS30304002        17.56          1.00
HS30304003          1.0
HS30304100        -1            1         0.0
HS30304102       0.017960       2
HS30304200      -1
HS30304201      'STAINLESS STEEL              '        1
HS30304300       0
HS30304400         1       303       EXT        1.00
HS30304500       1980.00          1.00           5.00
HS30304600         1       303       EXT        1.00
HS30304700       1980.00          1.00           5.00
HS30304800       -1
HS30304801       305.0        2
**********************************************************************
HS30401000        14    1    -1    0
HS30401001      'CONT WALL       '
HS30401002          5.56         1.00
HS30401003          1.0
HS30401100        -1            1         0.00100
HS30401101       0.002709       2
HS30401102       0.007340       3
HS30401103       0.013          4
HS30401104       0.0224         5
HS30401105       0.03743        6
HS30401106       0.06148        7
HS30401107       0.100          8
HS30401108       0.1616         9
HS30401109       0.260         10
HS30401110       0.420         11
HS30401111       0.670         12
HS30401112       1.07          13
HS30401113       1.70          14
HS30401200      -1
```

```
HS30401201      'STAINLESS STEEL          '       2
HS30401202       CONCRETE                        13
HS30401300      0
HS30401400        1       304      EXT       1.00
HS30401500        702.00          7.90          5.00
HS30401600        0
HS30401800      -1
HS30401801       305.0      14
*************************************************************************
HS30402000        10    1    -1    0
HS30402001      'DW WALL            '
HS30402002         5.56         1.00
HS30402003          1.0
HS30402100        -1            1         0.00100
HS30402102       0.00229        2
HS30402103       0.005256       3
HS30402104       0.01205        4
HS30402105       0.027622       5
HS30402106       0.06333        6
HS30402107       0.145176       7
HS30402108       0.33282        8
HS30402109       0.54           9
HS30402110       0.763000      10
HS30402200      -1
HS30402201      CONCRETE        9
HS30402300      0
HS30402400        1       304      EXT       1.00
HS30402500        487.00          7.90          5.00
HS30402600        0
HS30402800      -1
HS30402801       305.0      10
*************************************************************************
HS30403000        10    1    -1    0
HS30403001      'CONC               '
HS30403002         5.56         1.00
HS30403003          1.0
HS30403100        -1            1         0.00100
HS30403102       0.001749       2
HS30403103       0.003060       3
HS30403104       0.005353       4
HS30403105       0.009364       5
HS30403106       0.016381       6
HS30403107       0.028656       7
HS30403108       0.050129       8
HS30403109       0.087691       9
HS30403110       0.153400      10
HS30403200      -1
HS30403201      'CONCRETE                 '       9
HS30403300      0
HS30403400        1       304      EXT       1.00
HS30403500        396.00          7.00          5.00
HS30403600        0
HS30403800      -1
HS30403801       305.0      10
*************************************************************************
HS30404000         2    1    -1    0
HS30404001      'MISC STEEL         '
HS30404002         5.56         1.00
```

```
HS30404003          1.0
HS30404100        -1            1         0.
HS30404102      0.023780      2
HS30404200     -1
HS30404201     'STAINLESS STEEL            '        1
HS30404300      0
HS30404400        1        304       EXT         1.00
HS30404500      1039.50           1.00            5.00
HS30404600        1        304       EXT         1.00
HS30404700      1039.50           1.00            5.00
HS30404800      -1
HS30404801      305.0       2
**************************************************************************
HS30501000        14    1    -1    0
HS30501001     'CONT WALL         '
HS30501002        -1.44         1.00
HS30501003          1.0
HS30501100        -1            1         0.00100
HS30501101      0.002709      2
HS30501102      0.007340      3
HS30501103      0.013         4
HS30501104      0.0224        5
HS30501105      0.03743       6
HS30501106      0.06148       7
HS30501107      0.100         8
HS30501108      0.1616        9
HS30501109      0.260        10
HS30501110      0.420        11
HS30501111      0.670        12
HS30501112      1.07         13
HS30501113      1.70         14
HS30501200     -1
HS30501201     'STAINLESS STEEL            '        2
HS30501202      CONCRETE                           13
HS30501300      0
HS30501400        1        305       EXT         1.00
HS30501500         832.00          7.30            5.00
HS30501600        0
HS30501800      -1
HS30501801      305.0       14
**************************************************************************
HS30502000        10    1    -1    0
HS30502001     'DW WALL           '
HS30502002        -1.44         1.00
HS30502003          1.0
HS30502100        -1            1         0.00100
HS30502102      0.00229       2
HS30502103      0.005256      3
HS30502104      0.01205       4
HS30502105      0.027622      5
HS30502106      0.06333       6
HS30502107      0.145176      7
HS30502108      0.33282       8
HS30502109      0.54          9
HS30502110      0.763000     10
HS30502200     -1
HS30502201     CONCRETE        9
HS30502300      0
```

```
HS30502400        1       305      EXT       1.00
HS30502500      557.00          7.30           5.00
HS30502600        0
HS30502800     -1
HS30502801      305.0      10
*************************************************************************
HS30503000       10    1    -1    0
HS30503001     'CONC                 '
HS30503002       -1.44          1.00
HS30503003         1.0
HS30503100       -1             1         0.00100
HS30503102      0.001749        2
HS30503103      0.003060        3
HS30503104      0.005353        4
HS30503105      0.009364        5
HS30503106      0.016381        6
HS30503107      0.028656        7
HS30503108      0.050129        8
HS30503109      0.087691        9
HS30503110      0.153400       10
HS30503200     -1
HS30503201     'CONCRETE                       '       9
HS30503300      0
HS30503400        1       305      EXT       1.00
HS30503500      308.00          4.00           5.00
HS30503600        0
HS30503800     -1
HS30503801      305.0      10
*************************************************************************
HS30504000        2    1    -1    0
HS30504001     'MISC STEEL           '
HS30504002       -1.44          1.00
HS30504003         1.0
HS30504100       -1             1         0.0
HS30504102      0.010280        2
HS30504200     -1
HS30504201     'STAINLESS STEEL                '       1
HS30504300      0
HS30504400        1       305      EXT       1.00
HS30504500      1127.00         1.             5.00
HS30504600        1       305      EXT       1.00
HS30504700      1127.00         1.             5.
HS30504800     -1
HS30504801      305.0       2
*************************************************************************
HS20101000       10    1    -1    0
HS20101001     'SHIELD WALL          '
HS20101002        2.56          1.00
HS20101003         1.0
HS20101100       -1             1         0.0
HS20101102      0.01823         4
HS20101106      0.024           5
HS20101107      0.037           6
HS20101108      0.058           7
HS20101109      0.096           8
HS20101110      0.161           9
HS20101111      0.317          10
HS20101200     -1
```

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HS20101201     'STAINLESS STEEL          '       3
HS20101202     'CONCRETE                 '       9
HS20101300      0
HS20101400        1       201      EXT       1.00
HS20101401     0.7000     'EQUIV BAND'     3.
HS20101500        465.0          10.00          5.00
HS20101600        0
HS20101800      -1
HS20101801       331.0      10
*************************************************************************
HS20102000        11    1    -1    0
HS20102001     'WEIR WALL      '
HS20102002         2.56         1.00
HS20102003           1.0
HS20102100        -1            1         0.00100
HS20102102       0.001749      2
HS20102103       0.003060      3
HS20102104       0.005353      4
HS20102105       0.009364      5
HS20102106       0.016381      6
HS20102107       0.028656      7
HS20102108       0.050129      8
HS20102109       0.087691      9
HS20102110       0.153400     10
HS20102111       0.229        11
HS20102200     -1
HS20102201     'CONCRETE                 '      10
HS20102300      0
HS20102400        1       201      EXT       1.00
HS20102401     0.9        'EQUIV BAND'     2.4
HS20102500        589.00         15.00          5.00
HS20102600        0
HS20102800      -1
HS20102801       333.0      11
*************************************************************************
HS20103000         2    1    -1    0
HS20103001     'MISC STEEL     '
HS20103002         2.56         1.00
HS20103003           1.0
HS20103100        -1            1         0.0
HS20103102       0.0092        2
HS20103200     -1
HS20103201     'STAINLESS STEEL          '       1
HS20103300      0
HS20103400        1       201      EXT       1.00
HS20103401     0.7000     'EQUIV BAND'     1.
HS20103500       2154.00         1.             5.00
HS20103600        1       201      EXT       1.00
HS20103601     0.7000     'EQUIV BAND'     1.
HS20103700       2154.00         1.             5.00
HS20103800      -1
HS20103801       337.0        2
*************************************************************************
HS20104000        13    1    -1    0
HS20104001     'DW FLOOR       '
HS20104002        -6.63         0.00
HS20104003           1.0
HS20104100        -1            1         0.00100
```

```
HS20104102        0.001749       2
HS20104103        0.003060       3
HS20104104        0.005353       4
HS20104105        0.009364       5
HS20104106        0.016381       6
HS20104107        0.028656       7
HS20104108        0.050129       8
HS20104109        0.087691       9
HS20104110        0.153400      10
HS20104111        0.3           11
HS20104112        0.6           12
HS20104113        0.9144        13
HS20104200      -1
HS20104201      'CONCRETE                     '      12
HS20104300       0
HS20104400          1        201       EXT       0.5
HS20104500         235.00           15.00           5.00
HS20104600          0
HS20104800       -1
HS20104801        333.0       13
**********************************************************************
HS20105000         12    1    -1    0
HS20105001      'DW WALL AND TOP '
HS20105002          2.56          1.00
HS20105003           1.0
HS20105100         -1              1        0.0
HS20105102        0.00634          4
HS20105106        0.012381       5
HS20105107        0.024656       6
HS20105108        0.046129       7
HS20105109        0.083691       8
HS20105110        0.149400       9
HS20105111        0.346         10
HS20105112        0.6605        11
HS20105113        0.9144        12
HS20105200      -1
HS20105201      'STAINLESS STEEL              '       3
HS20105202      'CONCRETE                     '      11
HS20105300       0
HS20105400          1        201       EXT       1.00
HS20105401      0.7000      'EQUIV BAND'      3.
HS20105500         235.0           10.00           5.00
HS20105600          0
HS20105800       -1
HS20105801        331.0       12
**********************************************************************
HS20401000         14     2     -1    0
HS20401001      'PEDESTAL'
HS20401002          -6.64          1.0
HS20401003           1.0
HS20401100         -1              1        3.226
HS20401102        3.2405         2
HS20401103        3.2761         3
HS20401104        3.3634         4
HS20401105        3.5775         5
HS20401106        4.1025         6
HS20401107        4.6275         7
HS20401108        4.8416         8
```

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HS20401109       4.9289        9
HS20401110       4.9645       10
HS20401111       4.979        11
HS20401112       4.9972       14
HS20401200      -1
HS20401201      'CONCRETE                  '       10
HS20401202      'STAINLESS STEEL           '       13
HS20401300       0
HS20401400         1       204      EXT        1.00
HS20401401      0.9000     'EQUIV BAND'      3.
HS20401500       166.3          8.204          8.204
HS20401600         1       201      EXT        1.00
HS20401601      0.7000     'EQUIV BAND'      2.4
HS20401700       256.7          8.204          8.204
HS20401800      -1
HS20401801       331.0      14
*************************************************************************
* CONCRETE DEGASSING INPUT
*************************************************************************
*HSDG000110     -20101      9     'H2O-VAP'     * 300-322 K
*HSDG000120     -20101      9     'H2O-VAP'     * 322-340 K
HSDG000130     -20101      9     'H2O-VAP'     * 340-350 K
HSDG000140     -20101      9     'H2O-VAP'     * >350 K
HSDG000150     -20101      9     'CO2'
*HSDG000111      4.48    2.378E6      300.0     322.0
*HSDG000121      8.95    2.378E6      322.0     340.0
HSDG000131     53.73     2.378E6      340.0     350.0
HSDG000141     49.84     6.067E6      350.0     750.0
HSDG000151     479.7     4.043E6      670.0     870.0
*************************************************************************
*HSDG000210     -20401     10     'H2O-VAP'     * 300-322 K
*HSDG000220     -20401     10     'H2O-VAP'     * 322-340 K
HSDG000230     -20401     10     'H2O-VAP'     * 340-350 K
HSDG000240     -20401     10     'H2O-VAP'     * >350 K
HSDG000250     -20401     10     'CO2'
*HSDG000211      4.48    2.378E6      300.0     322.0
*HSDG000221      8.95    2.378E6      322.0     340.0
HSDG000231     53.73     2.378E6      340.0     350.0
HSDG000241     49.84     6.067E6      350.0     750.0
HSDG000251     479.7     4.043E6      670.0     870.0
*************************************************************************
*HSDG000310     -20102     10     'H2O-VAP'     * 300-322 K
*HSDG000320     -20102     10     'H2O-VAP'     * 322-340 K
HSDG000330     -20102     10     'H2O-VAP'     * 340-350 K
HSDG000340     -20102     10     'H2O-VAP'     * >350 K
HSDG000350     -20102     10     'CO2'
*HSDG000311      4.48    2.378E6      300.0     322.0
*HSDG000321      8.95    2.378E6      322.0     340.0
HSDG000331     53.73     2.378E6      340.0     350.0
HSDG000341     49.84     6.067E6      350.0     750.0
HSDG000351     479.7     4.043E6      670.0     870.0
*************************************************************************
* -----------------------------------------------------------------------
* TABULAR FUNCTION INPUT FOR VESSEL INSULATION
* -----------------------------------------------------------------------
*
TF12000   'HTC OUT VESS'      2          1.0        0.0
TF12010                       273.15     10.0       5000.0     10.0
```

```
***********************************************************************
* ---------------------------------------------------------------------
* TABULAR FUNCTION INPUT FOR THERMAL CONDUCTIVITY, HEAT CAPACITY, AND
* DENSITY OF HEAT STRUCTURE MATERIALS
* ---------------------------------------------------------------------
***********************************************************************
* CARBON STEEL
MPMAT10000 'CARBON STEEL'
MPMAT10001 THC 100
MPMAT10002 CPS 101
MPMAT10003 RHO 102
*
TF10000   'THC CARBON STEEL'  10         1.0        0.0
TF10010                       273.15     55.0       373.15     52.0
TF10011                       473.15     48.0       573.15     45.0
TF10012                       673.15     42.0       873.15     35.0
TF10013                      1073.15     31.0      1273.15     29.0
TF10014                      1473.15     31.0      9973.15     31.0
*
TF10100   'CP CARBON STEEL '  2          1.0        0.0
TF10110                       273.15     0.465E3    5000.0     0.465E3
*
TF10200   'RHO CARBON STEEL'  2          1.0        0.0
TF10210                       273.15     7833.0     5000.0     7833.0
*********************************************************************
* DRYWELL HEAD AIR SPACE GAP PROPERTIES
MPMAT20000   'AIR GAP 1'
MPMAT20001   THC  200
MPMAT20002   CPS  201
MPMAT20003   RHO  202
*
TF20000      'THC AIR GAP 1'   2     1.0    0.0
TF20011          273.15     17.0         10000.0      17.0
*
TF20100      'CPS AIR GAP 1'   2     1.0    0.0
TF20111          273.15    1005.0        10000.0     1005.0
*
TF20200      'RHO AIR GAP 1'   2     1.0    0.0
TF20211          273.15    1.18          10000.0      1.18
*********************************************************************
* THERMAL PROPERTIES FOR LIMESTONE / COMMON SAND CONCRETE
MPMAT30000   'CONCRETE'
MPMAT30001   THC  300
MPMAT30002   CPS  301
MPMAT30003   RHO  302
*
TF30000      'THC CONCRETE'    2     1.0     0.0
TF30011          273.15     1.3       10000.0      1.3
*
TF30100      'CPS CONCRETE'    2     1.0     0.0
TF30111          273.15   1200.0      10000.0     1200.0
*
TF30200      'RHO CONCRETE'    2     1.0     0.0
TF30211          273.15    2340.0     10000.0      2340.0
*********************************************************************
CF31100   WW-DW-DP  ADD  2  1.  0.
CF31101   0.
CF31110   1.  0.  CVH-P.305
```

```
CF31111  -1.  0.  CVH-P.201
*
CF31200   MAX-DP  MAX  2  1.  0.
CF31201   0.
CF31210   1.  0.  CFVALU.311
CF31211   1.  0.  CFVALU.312
*
CF31300   MAX-WW-P  MAX  2  1.  0.
CF31301   0.
CF31310   1.   0.   CVH-P.305
CF31311   1.   0.   CFVALU.313
*
CF31400   MAX-WW-T  MAX  2  1.  0.
CF31401   0.
CF31410   1.   0.   CVH-TVAP.305
CF31411   1.   0.   CFVALU.314
*
**********************************************************************
SPRSR0100  CONT-SPRAY  301  33.11  319
SPRSR0101  330.37  .356  *  CAN ADD CFS FOR TEMP AND FLOW RATE
SPRSR0102  3.09E-4  .95
SPRSR0103  8.10E-4  .05
SPRJUN01   301  302  .1
SPRJUN02   301  303  .2
SPRSUMP0   305
SPRSUMP1   302  303
*
CF31900    SPRAY-START  L-GT  2  1.  0.
CF31910    1.  0.  TIME
CF31911    0. 1.E9 TIME     * SPRAYS INACTIVE
*
**********************************************************************
*BUR000   0
*   INPUT DEFAULT VALUES FOR BUR001, 2 & 3 (ORNL 5/94)
*         XH2IGN   XCOIGN   XH2IGY   XCOIGY   XO2IG  XMSIG
*BUR001      1.       1.       1.        1.      0.05   .55
*BUR002      1.       0.05     0.3
*         XH2CC     XCOCC   XH2PUP   XCOPUP
*BUR003    .08          1.      1.        1.       1.  1.  1.  1.
*   IGNITERS DEACTIVATED  FOR  STATION  BLACKOUT,  ORNL-DEC 1993
*
*         ICVNUM   IGNTR  CDIM   TFRAC
BUR101     301        0     19.    1.
BUR102     302        0     11.13  1.
BUR103     303        0     14.32  1.
BUR104     304        0      7.92  1.
BUR105     305        0      3.67  1.
BUR106     201        0     13.    1.
BUR107     202        0      3.    1.
*                   FLAME SPEED
*SC00001    2200        4.5         1
*SC00002    2200        0.          2
*
**********************************************************************
*   EXTERNAL DATA FILE INPUT
**********************************************************************
*
CF32000 INT-POL-FLO-21  INTEG  2  1.  0.
```

```
CF32001  0.
CF32011  1.  0.  FL-MFLOW.1.021
CF32012  1.  0.  TIME
*
CF32100 INT-FOG-FLO-21  INTEG  2  1.  0.
CF32101  0.
CF32111  1.  0.  FL-MFLOW.2.021
CF32112  1.  0.  TIME
*
CF32200 INT-STM-FLO-21  INTEG  2  1.  0.
CF32201  0.
CF32211  1.  0.  FL-MFLOW.3.021
CF32212  1.  0.  TIME
*
CF32300 INT-H2-FLO-21  INTEG  2  1.  0.
CF32301  0.
CF32311  1.  0.  FL-MFLOW.6.021
CF32312  1.  0.  TIME
*
CF32400 TOT-WATER-FLO-21  ADD 3  1.  0.
CF32401  0.
CF32411  1.  0.  CFVALU.320
CF32412  1.  0.  CFVALU.321
CF32413  1.  0.  CFVALU.322
*
CF32500 RATE-WAT-FLO-21  ADD  3  1.  0.
CF32501  0.
CF32511  1.  0.  FL-MFLOW.1.21
CF32512  1.  0.  FL-MFLOW.2.21
CF32513  1.  0.  FL-MFLOW.3.21
*
CF32600 RATE-WATER-H-21  MULTIPLY 2  1.  0.
CF32601  0.
CF32611  1.  0.  CFVALU.325
CF32612  1.  0.  CVH-H.3.204
*
CF32700 INT-WATER-H-21  INTEG  2  1.  0.
CF32701  0.
CF32711  1.  0.  CFVALU.326
CF32712  1.  0.  TIME
*
CF32800 RATE-H2-H-21  MULTIPLY 2  1.  0.
CF32801  0.
CF32811  1.  0.  FL-MFLOW.6.21
CF32812  1.  0.  CVH-H.6.204
*
CF32900 INT-H2-H-21  INTEG  2  1.  0.
CF32901  0.
CF32911  1.  0.  CFVALU.328
CF32912  1.  0.  TIME
*
CF33000 INT-CONT-LEAK  ADD  6  1.  0.
CF33001  0.
CF33011  1.  0.  FL-I-MFLOW.3.100
CF33012  1.  0.  FL-I-MFLOW.4.100
CF33013  1.  0.  FL-I-MFLOW.5.100
CF33014  1.  0.  FL-I-MFLOW.6.100
CF33015  1.  0.  FL-I-MFLOW.7.100
```

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CF33016  1.  0.  FL-I-MFLOW.8.100
*
CF33100 RATE-STM-H-100  MULTIPLY 2  1.  0.
CF33101  0.
CF33111  1.  0.  FL-MFLOW.3.100
CF33112  1.  -2.5291E6  CVH-H.3.301
*
CF33200 RATE-N2-H-100  MULTIPLY 2  1.  0.
CF33201  0.
CF33211  1.  0.  FL-MFLOW.4.100
CF33212  1.  -7.925E4  CVH-H.4.301
*
CF33300 RATE-O2-H-100  MULTIPLY 2  1.  0.
CF33301  0.
CF33311  1.  0.  FL-MFLOW.5.100
CF33312  1.  -1.7898E7  CVH-H.5.301
*
CF33400 RATE-H2-H-100  MULTIPLY 2  1.  0.
CF33401  0.
CF33411  1.  0.  FL-MFLOW.6.100
CF33412  1.  -1.0846E6  CVH-H.6.301
*
CF33500 RATE-CO-H-100  MULTIPLY 2  1.  0.
CF33501  0.
CF33511  1.  0.  FL-MFLOW.7.100
CF33512  1.  -6.4078E6  CVH-H.7.301
*
CF33600 RATE-CO2-H-100  MULTIPLY 2  1.  0.
CF33601  0.
CF33611  1.  0.  FL-MFLOW.8.100
CF33612  1.  -4.1275E6  CVH-H.8.301
*
CF34100 RATE-TOT-H-100  ADD  6  1.  0.
CF34101  0.
CF34111  1.  0.  CFVALU.331
CF34112  1.  0.  CFVALU.332
CF34113  1.  0.  CFVALU.333
CF34114  1.  0.  CFVALU.334
CF34115  1.  0.  CFVALU.335
CF34116  1.  0.  CFVALU.336
*
CF34200 INT-TOT-H-100  INTEG  2  1.  0.
CF34201  0.
CF34211  1.  0.  CFVALU.341
CF34212  1.  0.  TIME
*
*  EXTERNAL  FILES  DEACTIVATED  AT  ORNL- DEC 1993
*
*EDF00100   STEAM-FLOW   12   WRITE
*EDF00101   GG_SOURCE.EDF7
*EDF00102   6E12.4
*EDF00111   0.   60.                * MODIFY WRITE OUTPUT FREQUENCY
*EDF001A1   FL-MFLOW.1.021
*EDF001A2   CVH-H.1.204
*EDF001B1   FL-MFLOW.3.021
*EDF001B2   CVH-H.3.204
*EDF001C1   FL-MFLOW.6.021
*EDF001C2   CVH-H.6.204
```

```
*EDF001C3    CFVALU.324  CFVALU.323  CFVALU.327  CFVALU.329
*EDF001C4    CFVALU.330  CFVALU.342
*R*I*F UD8:[SUSAN.GG]GGCF.GEN
*R*I*F SCR:[MKCARME.GG]GGCF.GEN
.
```

Appendix E

NUREG-1150 DECK, MELCOR INPUT

This MELCOR file is to be used with the MELGEN input file of Appendix D. This file ends the calculations at 158,400 s (44.0 h).

```
*******************************************************************
TITLE     GGSB7
JOBID     GGSB7
*******************************************************************
OUTPUTF   GGSBOUT
PLOTF     GGSBPLOT
RESTARTF  GGSB7REST
MESSAGEF  GGSB7MES.DAT
DIAGF     GGSB7DIAG.DAT
*******************************************************************
*EDITCF      991
*PLOTCF      993
CRTOUT
***********
*RESTART    0
*RESTART    5076   *295    *0
*RESTART   29583
*DTTIME  0.1
TEND      158400.0
CPULIM     86000.
CPULEFT     10.   *100.
*******************************************************************
**         TIME    DTMAX      DTMIN   DTEDIT    DTPLOT   DTREST
TIME1       0.0      1.0      0.001     4850.0    20.0    4850.0 4850.
TIME2     4795.0    10.0      0.001     2080.0    90.0    7200.0 3600.
TIME3     5540.0     1.0      0.0001     4000.0   180.0    7200.0 3600.
TIME4     5700.0    10.0      0.001     4000.0   380.0    7200.0 3600.
TIME5    9000.0    30.0     0.001     6000.0   980.0    7200.0 3600.
TIME6   30000.0    30.0     0.001     7200.0   980.0    7200.0 7200.
*******************************************************************
COREDV01     1  1  1  0  0
CORTST01     0  0  0  0  0  0  1  0  0
CAV00RR   -2
CAV00RA   -2
*CORDTC01     20.  .01  8
*EDF00101    GG_SOURCE2.EDF2
BUR004  -2
*CF11802  3  0.003  1.
CF11802  3  0.      1.
***  SENSITIVITY COEFFICIENTS
*SC00001    2200   2.   1      * FLAME SPEED ADDITIVE CONSTANT
*SC00002    2200   0.   2      * FLAME SPEED MOLE FRACTION MULTIPLIER
SC00003     4203   1.0  1
*******************************************************************
.
```

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