Bottom Head (BH) Package
Users' Guide

The Bottom Head (BH) package calculates the thermal response of the lower plenum debris, the heatup of the reactor vessel bottom head, and the release of core and structural materials from the reactor vessel to the containment. Calculations are initiated when sufficient solid debris mass has accumulated to form the foundation of a debris bed. Material subsequently relocated downward from the core region (solids and liquids) is added to the upper surface of the bed. Potential debris bed/water pool interactions can be evaluated subsequent to the initiation of the package. Materials released from the lower plenum via penetration failures or bottom head creep rupture are transferred to the containment.

These models were originally developed by Larry J. Ott at Oak Ridge National Laboratory (ORNL) for use with the Boiling Water Reactor Severe Accident Response (BWRSAR) Code. In this form, they have been applied in accident analyses for the Containment Performance Improvement (CPI) Program and the Mark I shell survivability study, and in assessments of candidate accident management strategies (NUREG/CR-5869, see the BH Package Reference Manual). Subsequently, these models have been modified first to operate independently and then to operate while driven directly by MELCOR in an interactive mode. When exercised with MELCOR, these are the central algorithms of the BH package.

This document provides information concerning the user input necessary for running MELGEN and MELCOR with the BH package activated. Detailed information concerning the package organization including the arrangement of subroutines and commons and the interface with MELCOR is provided in Section 8 of the BH Package Reference Manual. Supporting interface model descriptions are presented in Section 9 of the Reference Manual.

The BH Package Reference Manual also provides a detailed discussion of the physics models and the numerical solution schemes employed by the package. Some examples of the printed output generated by the BH package are shown in Section 6 of the Reference Manual.

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1. Introduction

The Bottom Head (BH) package is intended for use in MELCOR BWR (Boiling Water Reactor) and PWR (Pressurized Water Reactor) calculations for which a large debris bed remains after dryout of the reactor vessel lower plenum. Accident sequences producing such conditions include BWR Station Blackout, for which the water of the lower plenum is boiled away by both quenching of debris falling from the core region and the subsequent decay heat release. Although penetration integrity is not expected to be threatened while water remains, and penetration failures and debris relocation from the BWR reactor vessel are unlikely to occur before lower plenum dryout, transition to the BH package is initiated on the arrival of "sufficient" fuel mass in the lower plenum, as described below.

BH package modeling enhancements permit use of this package for analysis of certain Loss of Coolant Accident (LOCA) sequences in which core material is relocated to the lower plenum. For such cases, calculations of lower plenum debris/bottom head response by the COR package are continued until such time that sufficient solid debris has accumulated within the lower plenum to adequately define the initial debris bed structure as required by the BH package. (Should penetration failure and debris relocation to the containment be predicted by the COR package to the extent that sufficient lower plenum mass to initiate the BH debris bed models is never accumulated, then BH package operation will be precluded.)

Once sufficient solid debris mass has accumulated in the lower plenum, the COR package calculation of lower plenum debris and bottom head interactions is bypassed and the BH package representation of such interactions begins. Also, COR package fission product release calculations for debris located in the lower plenum are replaced by BH package calculations.

Previous bottom head models provided for the reflooding of the lower plenum by direct ejection into the BH model. This provision has been removed so that water can be introduced into the lower plenum only through the usual MELCOR sources. The models that provide for the interaction of water with core debris in the lower plenum remain intact.

This Users' Guide provides all of the instructions necessary for preparation of the MELGEN input that will be used by the lower plenum debris bed and bottom head response models of the BH package. Since one of the purposes of this package is to specifically consider the curvature of the vessel bottom head and its effect upon the shape of the debris bed control volume boundaries, more detail with respect to the bottom head configuration is required to be input when the BH package is utilized.

Another important function of the BH package is to adequately represent the large amount of stainless steel present within the reactor vessel lower plenum. This steel structure, which is distributed to a good approximation evenly across the lower plenum in the form of control rod guide tubes, instrument guide tubes, and shroud support structures, would be surrounded by the debris relocated from the core region. So that this stainless steel can be properly subsumed into the surrounding debris as the bed height increases, the MELGEN input for the BH package includes a detailed table of solid structural stainless steel volume versus height.

The BH package considers that the lower plenum debris bed is comprised of a set of materials that can melt, relocate, and refreeze either independently or as constituents of eutectic mixtures. Here the term "eutectic mixture" is applied loosely to mean any combination of constituents whose melting temperature is lower than the melting temperature of any individual constituent. The characteristics of the eutectic mixtures (if any) to be considered in the calculation must be supplied as part of the MELGEN input.

Finally, it is important to recognize that a major purpose of MELCOR is to serve as a vehicle for parametric variation studies. To this end, most of the BH package input variables are applied in a manner that permits their values to be changed upon a MELCOR restart. This capability and the means for its use are described in Section 2.14 of this manual.

2. MELGEN Input Requirements

This section describes the special input requirements for the BH package, including a brief discussion of the characteristics of the user-supplied quantities with their units and default values, if any. A detailed description of the manner in which these input variables are employed in the lower plenum debris bed and bottom head response calculations can be found in the BH Package Reference Manual.

Input record identifiers for the BH package all begin with the character string "BH." Record identifiers between BH0000 and BH0500 are used to specify the reactor vessel lower plenum geometry, the material species from which the debris bed is composed, bed characteristics such as porosity and particle size, and the arrangement of stainless steel structures within the lower plenum (steel volume versus height). Input records BH0600 and BH0700 provide information concerning the structure of the reactor vessel bottom head wall and metal/water reaction parameters.

Records BH1800, BH18JJ, BH18JJKK, and BH181KK provide input for the interface modeling of the thermal response for selected structures overlying the lower plenum debris bed. This interface modeling thermally couples the debris bed surfaces of the BH package, the lower core boundary sections modeled by the HS package, and the radial core plate sections modeled by the COR package. Phenomena represented in this debris-to-overlying structure interface model include:

(1) heatup, failure, and melting of the lower core boundary below the core plate;

(2) gross collapse of the remaining core upon lower core boundary failure; and

(3) gross downward movement of the upper core boundary toward the lower plenum as the core boundary melts and relocates into the debris bed.

An important component in this interface modeling is the radiative heat transfer from the outer surfaces of the failed core boundary to the relatively cool massive heat sinks typically represented by the reactor vessel wall. Prior to core boundary failure, this radiative heat transfer is calculated by the BH package structure-to-structure radiation model. After core boundary failure, however, this radiative heat transfer is calculated by the BH interface model. The radiative heat sinks for this model are identified by input records BH1400 and BH142JJ.

The parameters necessary for the calculation of material ablation in the lower portion of the debris bed and in the vessel wall are provided by input record BH1100. The MELCOR control volumes representing the downcomer region and the containment are identified by input record BH1200. The print edit interval for the BH package is specified on input record BH1300, as is the maximum rate of debris transfer to the lower plenum from the core region.

The information necessary to specify the type of heat transfer boundary condition to be used for the calculation of the localized heat transfer coefficient along the external surface of the bottom head wall is specified on input record BH15CC. Information is entered on records BH1600 and BH16LL to identify the HS package heat structure numbers (modeling the lower head portion of the reactor vessel wall) to be deactivated once the BH package is initiated. Input record BH1700 identifies the HS package lower vessel wall structures that are specifically considered in the BH package interface with the HS package of MELCOR.

A model has also been developed for calculating interactions between the lower plenum debris bed and a potential overlying water pool. This pool might be created either by the presence of water in the lower plenum at the time of arrival of core debris, or by water injected after initiation of the BH package. A lower plenum water pool may arise only from systems' interactions such as pressurizer and accumulator discharge or by source term injections into the CVH volume associated with the lower plenum. The user can no longer limit the rate at which water from the CVH lower plenum pool is added to the BH debris bed/water pool model. This was previously prescribed via sensitivity coefficient 5010, which has now been removed. The bottom head package now "sees" all coolant inventory present in the lower plenum as it arrives from source terms.

Fission product release is calculated and is based upon COR package modeling. Most of the input for the release modeling is taken from COR package input with the exception of the RN class associations for the BH materials being volatilized. The RN classes into which the released BH materials are grouped are specified by the user on input record BHRN10K.

Many of the input variables utilized by the BH package can be adjusted upon a MELCOR restart. These are listed in Section 2.14, where the limitations (if any) as to the amount of change allowed are discussed.

The flow of gas and water from the lower plenum to the containment is calculated by the MELCOR/BH interface during the interval between calculation of penetration failure and calculation of gross bottom head failure. The flow leaving the lower plenum atmosphere is modified appropriately before entering the containment to reflect heat transfer and chemical reaction with any zirconium present in the lower plenum debris bed. The user controls the size of the break area by specifying the number of a real valued control function (whose value is the break area) on input record BH1900.

After the occurrence of gross bottom head failure either through creep rupture or ablation, BH calculation of this gas flow is terminated, and the value of the BH-FFLAG control function variable is changed from 0.0 to 1.0. Modeling of gas exchange between the lower plenum and the containment after this time can only be represented by an appropriate FL package flow path whose area fraction is controlled by a control function based on the value of BH-FFLAG. (See FL package input record FLnnnVk.)

There are several special MELGEN input requirements for other packages when the BH package is used, since the RN1, COR, HS, CAV, CVH, and DCH packages are also active. For the CVH package, a single control volume must be used to model the lower plenum. Therefore, the finer nodalization scheme used for natural circulation enhancement may not be utilized beyond the bottom of the fuel. Also, the region representing the downcomer is assumed to be a single control volume.

Special coding has been implemented into the COR package (CORPSE routine) for use during calculations that utilize the BH package. For these calculations, a pseudo COR package water height is determined for each CVH volume interfaced with the COR package. This pseudo water pool height is a primary interface variable between the COR and CVH packages. It is used to determine core cell atmosphere fractions and the axial segment adjacent to the liquid level. As a result, it identifies the axial boundary below which certain phenomena such as radiative heat transfer and oxidation are not evaluated.

Care must be taken when developing input for the CVH volumes, specifically if coarse segmentation is used in defining the CVH altitude versus volume table**. For the CVH volumes representing the core region, including the lower plenum, the user must ensure that the following two criteria are met:**

(1) the CVH hydrodynamic fluid volume is identical to the fluid volume defined in the COR package and

(2) each core cell channel CVH volume is paired with a unique core cell bypass CVH volume.

For example, in a BWR, if one CVH volume is used to represent all of the core cell channel volumes, then one and only one bypass CVH volume may be used. Likewise, if five CVH volumes are used to represent the core cell channel volumes, a set of five corresponding core cell bypass CVH volumes must be used. For the channel and bypass volumes, the input in both the COR and CVH package should be identical in both total fluid volume as well as axial distribution. If the channel/bypass volume-pairing criterion is not met, then an error message is printed on the first restart timestep from the CORPSE routine, and if the calculation is continued, unphysical results may occur.

Also, the user may note in the CVH package output that the swollen water elevation is inconsistent with that indicated in the COR package output. This difference is the result of the pseudo water height being calculated in the COR package.

2.1 Lower Plenum Geometry and Debris Bed Materials

BH0000 – Calculation Title
Required

This record provides an identification title for the lower plenum debris bed/bottom head response calculation, which can differ from the overall MELCOR calculation title.

The title should be enclosed in quotation marks and comprise not more than 80 characters.

BHTITL - Title for the lower plenum/bottom head response calculation.
(type = Character * 80, default = none)

<u>Initialization Characteristics of BH</u>
The presence of this input record in MELGEN processing acts as a flag to activate the BH package. The BH package may be used for the reactor types BWR, SBWR, or PWR as identified on COR package input record COR00002. Special provisions for the SBWR and PWR are described in Sections 10 and 12, respectively, of the BH Package Reference Manual. If BH0000 is entered, then all remaining BH input is processed. In this case, BH will override the COR package models in the lower plenum once the following conditions are met: (a) the lower plenum is dry, and (b) there is sufficient solid debris to fill the lower plenum to at least a depth of H1MAX (see card BH0500).

Prior to meeting these conditions, the original COR package models are used to determine the lower plenum debris bed/bottom head response and to calculate boiloff of the lower plenum water pool. Significant uncertainties exist in the determination of heat transfer from falling debris to a surrounding water pool and in the debris-to-water heat transfer once the debris has formed a well-defined bed in the lower plenum. Modeling of these processes is described in the COR Package Reference Manual. Significant user control of the calculation of these processes has been provided via COR package and sensitivity coefficient input (specifically input records COR00009 and COR00012, plus sensitivity coefficients 1020 and 1244).

Inappropriate input for these COR package debris-to-water heat transfer models may lead to unintended results for users attempting to employ the BH package. For instance, if the debris quenching heat transfer coefficient (input record COR00012, entry 1) is too large, then the calculated pressure pulse produced immediately after core plate failure may lead to vessel failure by overpressure prior to BH package initiation. On the other hand, insufficient heat transfer from the debris to the water would not only prevent (or inordinately delay) lower plenum dryout, but may also lead to COR package calculation of thermal failure of the bottom head penetrations prior to BH package initiation. Thus, judicious use of COR package input is required to calculate the initial conditions acceptable for the BH package.

Mitigation of the calculated pressure spike may be gained by decreasing the debris quenching heat transfer coefficient (COR00012, entry 1), by increasing the time constants associated with the radial spreading of solid and molten debris (sensitivity coefficient 1020 entries 1 and 2 respectively), and by increasing the minimum debris bed porosity allowed in the calculation of the dryout heat flux from the Lipinski debris bed correlation (sensitivity coefficient 1244, entry 3).

Experience has shown that large variations in the timing of lower plenum dryout may be calculated depending on the values of these input parameters. To give the user some guidance however, reasonable estimates of these input parameters include:

(1) 750 W/m^2-K for the debris quenching heat transfer coefficient,

(2) 360.0 s time constant for the radial spreading of solid debris,

(3) 60.0 s time constant for the radial spreading of molten debris, and

(4) 0.4 for the minimum porosity used in the evaluation of the Lipinski debris bed heat flux.

(See also Section 8.2.3 of the BH Package Reference Manual.)

To preclude calculation of bottom head penetration failure by the COR package prior to lower plenum dryout and BH package initiation, the user should enter an artificially high failure temperature (e.g., 10000.0 K) on COR package input record COR00009. Such is the recommended procedure for a BWR station blackout calculation for which the debris would be expected to quench during its relocation from the core region into the lower plenum and underwater penetration failures are considered unrealistic.

For accident sequences such as bottom head LOCA, the user should provide best-estimate data for COR package input records COR00009, CORLHDii, and CORPENNN. In these cases, lower plenum dryout may occur prior to the accumulation of significant debris mass within the lower plenum. If this occurs, the COR package may calculate failure of the lower head penetrations and the initial period of debris relocation from the vessel to the containment floor. Whether or not the BH package is eventually exercised in this calculation depends on the instantaneous solid debris mass present in the lower plenum. If debris melts and is relocated to the containment faster than it accumulates within the lower plenum, then the BH package will not be exercised. If, on the other hand, sufficient solid debris mass does accumulate, then the BH package will be initialized and exercised for the remainder of the calculation.

Finally, do not include the BH0000 input record if the user wishes to use the original COR package modeling throughout the calculation. In this case, the user should again provide best-estimate data for COR package input records COR00009, CORLHDii, and CORPENnn. The remainder of BH package input is ignored and the BH package will remain inactive. (See discussion in Section 8.2.4 of the BH Package Reference Manual.)

BH0100 – Lower Plenum Geometry and Treatment of Debris Melting
Required

This record provides information concerning the reactor vessel lower plenum dimensions and the method of material melting to be considered during the heatup of the lower plenum debris. The following four fields must be present.

(1) HBSB - For a BWR, HBSB represents the bottom of the shroud baffle and corresponds to the elevation of the lower surface of the downcomer baffle plate. This elevation also defines the lowermost boundary of the BH wall node NWALL at the interface with wall node NWALL - 1.

For a PWR, this input field is ignored, and HBSB is computed internally based on the value of DRXID (HBSB = DRXID/2 – 0.076) entered on record BH0700. The computed value, as is the case for BWRs, defines the interface elevation between wall nodes NWALL and NWALL - 1. For both BWR and PWR applications, see the relationship between HBSB and DRXID on input record BH0700.
(type = real, default = none, units = m)

(2) NA - Number of corresponding height and volume entries [HH(I), VCORE(I), VSHRD(I) (input record BH03LL)] that describe the free volume versus height relationship within the reactor vessel lower plenum (maximum = 100).
(type = integer, default = none, units = none)

(3) NPS - Number of table entries describing the relationship of structural (stainless steel) solid volume to height above vessel zero (input record BH04LL) (maximum = 30).
(type = integer, default = none, units = none)

(4) IEUTEC - Number of debris eutectic mixtures to be considered (input record BH08LL) (maximum = 10).
(type = integer, default = none, units = none)

The number of line entries in the VCORE versus HH and VPS versus HPS tables (NA and NPS respectively) must each be greater than 2 to preclude code interrupt. These entries form tables that are intended to provide detailed information describing the configuration of the lower plenum as a function of elevation. It is perhaps easiest to prepare input such that the HH and HPS elevations coincide, but this is not required. At any rate, it is recommended that at least 20 entries for VCORE and 10 entries for VPS be provided. It is particularly important to adequately represent the effects of curvature at the lower elevations, where the variations of volume with height are the greatest.

BH02JJ – INDEPENDENT Constituents of Debris
01 ≤ JJ ≤ 20, JJ is the material identification integer
Optional

This record identifies the individual chemical species or constituents of eutectic mixtures to be considered in the calculation. The material identification integers are assigned as follows:

1	Zr	6	Ag	11	ZrO_2	16	NiO
2	Fe	7	CdIn	12	FeO	17	B_2O_3
3	Cr	8	blank	13	Fe_2O_3	18	UO_2
4	Ni	9	blank	14	Fe_3O_4	19	blank
5	blank	10	B_4C	15	Cr_2O_3	20	blank

Each of these 20 records provides the melting temperature, the molecular weight, and the heat of fusion for the pure species. Any rearrangement of the order of species would have to be supported by internal code modifications of the lower plenum model since several of the imbedded calculations make use of the fact that Zr occupies position 1 in the series, Fe occupies position 2, and UO_2 has index 18. New use of the currently blank array elements (5, 8, 9, 19, and 20) can be accomplished relatively easily, however, simply by making the associated additions to the physical properties DATA statements (see Section 2 of the BH Package Reference Manual). The following three fields must be present on each record: (Zeros should be provided for the blank species 5, 8, 9, 19, and 20.)

(1) AMTMEL - Melting temperature of debris constituent
(type = real, default = see Table 2.1, units = K)

(2) AMMLWT - Molecular weight of debris constituent
(type = real, default = see Table 2.1, units = kg/kg-mole)

(3) AMLAMF - Heat of fusion of debris constituent
(type = real, default = see Table 2.1, units = J/kg)

The user should note that the masses of debris bed species 6 (Ag) and 7 (CdIn) are calculated by partitioning the MELCOR mass of PWR poison (Ag-In-Cd) that has relocated from the core region. This calculation is necessary because the COR package tracks the Ag-In-Cd mixture mass as a single species. The mass fractions of Ag and InCd in the control rod material used in the partitioning of poison are specified via BH package sensitivity coefficient 5001.

Table 2.1 Default BH Package Material Properties

ID	Material	AMMLWT Molecular Weight (kg/kg-mole)	AMTMEL Melting Temperature (K)	AMLAMF Heat of Fusion (J/kg)
1	zr	91.220	2124.8	2.51208E+05
2	fe	55.847	1808.0	2.72142E+05
3	cr	51.996	2130.0	3.16336E+05
4	ni	58.700	1728.0	3.00054E+05
5		0.000	0.0	0.00000E+00
6	ag	107.870	1234.0	1.04796E+05
7	cdin	114.215	1200.0	3.49550E+04
8		0.000	0.0	0.00000E+00
9		0.000	0.0	0.00000E+00
10	b4c	55.260	2727.6	1.89336E+06
11	zro2	123.220	2977.6	7.07104E+05
12	feo	71.850	1649.8	4.41940E+05
13	fe2o3	159.690	1733.2	5.25676E+05
14	fe3o4	231.540	1838.7	5.95456E+05

ID	Material	AMMLWT Molecular Weight (kg/kg-mole)	AMTMEL Melting Temperature (K)	AMLAMF Heat of Fusion (J/kg)
15	cr2o3	152.020	2572.0	6.88496E+05
16	nio	74.710	2244.	6.79192E+05
17	b2o3	69.620	2727.6	3.44248E+05
18	uo2	270.070	3010.9	2.74468E+05
19		0.000	0.0	0.00000E+00
20		0.000	0.0	0.00000E+00

BH03LL – Table of Lower Plenum Free Volume Versus Height

01 ≤ LL ≤ NA, where LL is the index of the corresponding lower plenum height and cumulative free volume entries, and NA is the total number of entries (BH0100).
Required

This record type identifies the free volume versus height relationship within the portion of the lower plenum inside the shroud and the total volume-versus-height relationship within the downcomer region. The former is used to apportion the relocating debris within the bed control volumes. The entries must be in order of increasing height above vessel zero. The first record (BH0301) indicates the bottom of the vessel, where the height, free volume within the shroud, and volume outside the shroud boundary are all zero. The volume outside the shroud boundary remains zero for each record that represents a height below the bottom of the downcomer (at elevation HBSB on input record BH0100). The last record (BH03NA) represents the height of the bottom of the core plate and provides the total free volume beneath this height within the lower plenum (inside the shroud) and the total volume within the downcomer region (outside the shroud boundary). The term "free volume" is defined in the sense that the sum of VCORE, VSHRD, and the structural steel solid volume VPS (see input record BH04LL) equals the total volume enclosed within the reactor vessel wall between 0.0 and height HH. The following three fields must be provided for each record.

(1) HH - Height above vessel zero.
(type = real, default = none, units = m)

(2) VCORE - Cumulative free volume within the lower plenum (inside the shroud) between vessel zero and height HH.
(type = real, default = none, units = m^3)

(3) VSHRD - Cumulative total volume within the downcomer region (outside the shroud boundary) between HBSB (input record BH0100) and HH. For values of HH ≤ HBSB, enter values of 0.0 for VSHRD. For

PWRs, all entries of VSHRD should be zero; see Table 12.3 in the BH Package Reference Manual.
(type = real, default = none, units = m^3)

The user should be aware that the information contained in the VCORE and VSHRD versus height tables, while normally much more detailed, is redundant with the CVH volume versus height table for the CVH volumes corresponding to the lower plenum and the downcomer annulus. **The user should ensure that the information contained in the CVH volume versus height and in the BH volume versus height tables is consistent.**

BH04LL – Table of Lower Plenum Stainless Steel Volume versus Height

01 ≤ LL ≤ NPS, where LL is the index of the corresponding lower plenum height and structural stainless steel (solid) volume entries, and NPS is the total number of entries (BH0100).

Required

This record type identifies the stainless steel volume versus height relationship within the portion of the lower plenum inside the shroud. This is used to calculate the stainless steel mass to be assimilated into the surrounding debris. It is also used to determine the initial stainless steel mass of debris bed layer three after the control rod guide tubes fail (see TFAIL2 on input record BH0700). The sum of the stainless steel volume and the volumes VCORE and VSHRD (on Record BH03LL) must equal the total volume enclosed within the reactor vessel wall. The entries must be in order of increasing height above vessel zero. The first record (BH0401) indicates the inner bottom of the vessel, where the height and stainless steel volume are both zero. The last record (BH04NPS) represents the height of the bottom of the core plate and provides the total solid volume of all stainless steel beneath this point that is either within the shroud or below HBSB. The following two fields must be present for each record:

(1) HPS - Height above vessel zero.
(type = real, default = none, units = m)

(2) VPS - Volume of (solid) stainless steel (and Inconel for PWRs) inside the shroud within the lower plenum between vessel zero and height HH. (Does not represent the material volume of the downcomer structures or the shroud wall as these structures are not assimilated into the BH debris bed.)
(type = real, default = none, units = m^3)

It should be noted that separate logic exists within the code for melting of the shroud wall and entrance of the relocating liquid into the debris bed.

The stainless steel mass implied by the VPS table, while normally described in much greater detail, is redundant with the COR package input for the mass of the ISS structure for axial segments below the core plate. **The user should ensure that the steel mass information is consistent between the COR and BH packages for this region of the vessel.**

BH0500 – Porosities, Time Constant, Heights, and Debris Particle Diameter
Required

This record provides the metallic and oxidic porosities associated with the particulate debris, the time constant for movement of liquids vertically or horizontally within the bed, and the specified maximum thickness of the bottom debris layer. The following five fields must be provided:

(1) PORBOX* - Porosity of the lower plenum debris bed solid oxides.
(type = real, default = none, units = none)

(2) PORBM* - Porosity of the lower plenum debris bed solid metals.
(type = real, default = none, units = none)

(3) DTHEAD+ - Time constant for downward relocation of molten material among debris bed control volumes. Horizontal movement (when the underlying control volume has no remaining free volume) will occur at one-half the downward rate.
(type = real, default = none, units = s)

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* PORBOX and PORBM as entered here have no direct relationship to the particulate debris porosity PORDB entered on input record CORZjj01. However, the user is cautioned against inputting a value close to unity for PORBOX, PORBM, or PORDB. This is because there must be sufficient free volume below the core plate to house all of the slumped core debris regardless of its packed volume. If the user inputs a value of 0.9 for PORDB, then the packed volume of any debris slumping into the lower plenum will be a factor of 10 higher than that calculated for an input porosity of zero. Thus, for an artificially high debris porosity, insufficient free volume may exist in the lower plenum to completely house the relocating debris, and the COR package will calculate that a portion will remain above the core plate.

+ DTHEAD is used in calculating the debris flow from the lower head after penetration failure. If prior COR package penetration failure has occurred, DTHEAD can be adjusted such that a smooth, continuous flow can be maintained during initiation of the BH package. Actual release of material from the debris bed is controlled by the rate of debris melting.

(4) H1MAX** - Maximum height (above vessel zero) of the upper surface of the bottom debris layer. Enter 0.6625 for SBWR calculations.
(type = real, default = none, units = m)

(5) HD1D2 - Height above vessel zero at which the reactor vessel wall thickness changes from THKHD1 to THKHD2 (see BH0600). For PWRs with uniform bottom head thickness, set HD1D2 to any height greater than HCYL (see BH0700).
(type = real, default = none, units = m)

(6) DPART - Diameter of the lower plenum debris bed (spherical) particles. This single value, which is used for all bed control volumes, affects the metal oxidation rates, the effective bed thermal conductivities, and the interaction of the bed control volumes with any overlying water.
(type = real, default = none, units = m)

2.2 Vessel Wall Reaction Parameters and Metal/Water

BH0600 – Skirt Height, Wall Thickness, and Creep Rupture Temperature/Time Constants Required

This record identifies the attachment point of the reactor vessel support skirt, the thickness of the crust nodes (adjacent to the vessel wall) for debris layers two and three, the thicknesses of the vessel wall in the region of the penetrations and above, and the temperature/time constants used for calculation of failure of the bottom head penetration welds. The following six fields must be present:

(1) HSKIRT - Height above vessel zero at which the reactor vessel support skirt attaches to the vessel wall. For reactor vessels without a support skirt, set HSKIRT to any value greater than HCYL (see BH0700).
(type = real, default = none, units = m)

(2) THKCRS - Thickness of debris bed control volumes (2,5) and (3,5), which are adjacent to the vessel wall.
(type = real, default = none, units = m)

** H1MAX is important to the initialization of the BH representation of the lower plenum debris bed and must lie within the range of the HH table entered on Record BH03LL. See the discussion of the initialization characteristics of BH included with input record BH0000. For the SBWR (only), the upper surface of the bottom layer corresponds to the height of the interface between the lower and upper spherical portions of the bottom head wall.

(3) THKHD1 - Vessel wall thickness in region of penetrations (below height HD1D2 [see BH0500]).
(type = real, default = none, units = m)

(4) THKHD2 - Vessel wall thickness above height HD1D2 (BH0500).
(type = real, default = none, units = m)

(5) THK6 - Temperature for creep rupture of the bottom head penetration welds in six minutes.
(type = real, default = none, units = K)

(6) THK60 - Temperature for creep rupture of the bottom head penetration welds in 60 minutes.
(type = real, default = none, units = K)

Typical values for creep rupture failure at normal BWR operating pressure, based upon data for Inconel-stainless steel welds, are THK6 = 1295 K and THK60 = 1210 K. (Differential pressure across the weld is assumed to be 7.239×10^6 Pa [Reference: Figure 2.9 of NUREG-1265.]) Higher failure temperatures should be used for cases where the reactor vessel is depressurized.

BH0700 – Metal/Water Reaction Parameters and Vessel Dimensions
Required

This record controls the extent of metal/steam reaction in the lower plenum debris bed, sets a debris temperature for collapsing the lower plenum structures (such as the BWR control rod guide tubes) and initiating formation of debris bed layer three*, and provides the dimensions of the lower plenum so that the transition point from spherical to cylindrical geometry is clearly defined. The following eleven fields must be present:

(1) IMWDEB - Flag to indicate the desired control of the metal oxidation reactions within the debris bed control volumes (see BH Package Reference Manual, Section 3.4). A value of
0 = no metal/steam reaction
1 = metal/steam reaction according to cylindrical geometry

* Although collapsing of lower plenum structures is used to initiate debris layer three, in-core components, such as the core plate, supported by the lower plenum structures are not automatically added to the debris layer three inventory.

reaction kinetics and the availability of steam
2 = SS oxidation only; no Zr oxidation
3 = Zr oxidation only; no SS oxidation.
(type = integer, default = none, units = none)

(2) SFCRDB - Shape factor used to limit the extent of zirconium oxidation to adjust for non-cylindrical geometry and the decreased surface-to-volume ratio. This can also be used to account for the effect of steam tunneling through the lower plenum debris bed. For SFCRDB greater than 1.0, the Zr/water reaction is limited to 1.0/SFCRDB of that otherwise calculated.
(type = real, default = none, units = none)

(3) SFCRSS - Same as (2), except applies to stainless steel oxidation.
(type = real, default = none, units = none)

(4) FZRMX1 - Maximum fraction of initial (at time of BH initiation) Zr metal inventory in lower plenum that can be reacted.
(type = real, default = none, units = none)

(5) FSSMX1 - Same as (4), except applies to initial inventory of stainless steel.
(type = real, default = none, units = none)

(6) DRXID - Inner diameter of spherical portion of reactor vessel bottom head. DRXID is also used in the nodalization of the bottom head wall, where the uppermost node NWALL is defined such that its interface with node NWALL - 1 is located at elevation HBSB while its upper surface is located at max (DRXID/2, HBSB + 0.076).
(type = real, default = none, units = m)

(7) TFAIL2 - Temperature flag used to initiate formation of the uppermost debris bed layer 3. Layer 3 is set up when either the debris in layer 2 exceeds TFAIL2, if there is any molten pure species or eutectic in layer 2, or if the debris layer 2 upper surface exceeds elevation HCYL. Addition of material relocating from the core region to debris bed layer 2 is closed and formation of layer 3 begins at this time.
(type = real, default = none, units = K)

(8) HCYL - Height above vessel zero at which the geometry of the vessel wall shifts from spherical to cylindrical.
(type = real, default = none, units = m)

(9) RCYL - Radius to the inner surface of the cylindrical portion of the reactor vessel wall. HCYL and RCYL are necessary for plants such as Grand Gulf where the interface between the cylindrical and spherical sections occurs before the bottom head hemisphere is complete. For other applications, HCYL and RCYL should be set equal to one-half of DRXID.
(type = real, default = none, units = m)

(10) XOZRMX - Maximum zirconium oxide thickness. Oxidation logic assumes that any oxide in excess of this thickness sloughs away. As XOZRMX is increased, the oxidation rate at the zirconium surface is decreased.
(type = real, default = none, units = m)

(11) XOSSMX - Same as (10), except applies to SS oxide layer thickness.
(type = real, default = none, units = m)

2.3 Eutectic Mixtures

BH08LL – Parameters for Eutectic Mixtures

01 ≤ LL ≤ IEUTEC, where LL is the index of the eutectic mixture and IEUTEC is the number of eutectic mixtures to be considered (BH0100).
Required if IEUTEC is greater than 0

This record type provides the melting temperature for each eutectic, identifies the "key" constituent of each eutectic mixture (see BH Package Reference Manual, Section 4.2), and establishes the mole fraction of the key constituent within each mixture. The records must be entered in the order of ascending melting temperatures and each eutectic mixture must have a unique material identification integer IEUKEY. The following four fields must be provided for each record:

(1) TMLIEU - Melting temperature of the eutectic mixture.
(type = real, default = none, units = K)

(2) IEUKEY - Material identification integer corresponding to the following FRCKEY entry. The identification integers must correspond to species in the BH data base having non-zero entries on input records BH02JJ.
(type = integer, default = none, units = none)

(3) FRCKEY - Mole fraction of the key material species that identifies eutectic mixture LL. The value of FRCKEY should be the same as the corresponding value input via Record BH10LLK.
(type = real, default = none, units = none)

(4) EKYMIN - Minimum mole fraction of key material species required for formation of eutectic where mole fraction is defined as moles of key constituent available divided by total constituent moles available to form the eutectic. (Not currently used—enter 0.0.)
(type = real, default = none, units = none)

BH09LLK – Identify Constituents of Each Eutectic Mixture
01 ≤ LL ≤ IEUTEC, LL is the index of the eutectic mixture
1 ≤ K ≤ 4, card counter
Required if IEUTEC is greater than 0

Four cards are entered for each eutectic mixture, with five fields per card. Field entries of 0 indicate that the material species is not included within the eutectic; a field entry of 1 indicates that the material species is a constituent of the eutectic.

Card Number	Material Species Represented				
LL1	Zr	Fe	Cr	Ni	-
LL2	Ag	CdIn	-	-	B_4C
LL3	ZrO_2	FeO	Fe_2O_3	Fe_3O_4	Cr_2O_3
LL4	NiO	B_2O_3	UO_2	-	-

For example, if the second eutectic mixture were to represent stainless steel, then

BH09021	0	1	1	1	0
BH09022	0	0	0	0	0
BH09023	0	0	0	0	0
BH09024	0	0	0	0	0

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

BH10LLK – Constituent Mole Fractions for Each Eutectic Mixture
01 ≤ LL ≤ IEUTEC, LL is the index of the eutectic mixture
1 ≤ K ≤ 4, card counter
Required if IEUTEC is greater than 0

Four cards are entered for each eutectic mixture, with five fields per card. Non-zero entries are made only for material species for which "1" was entered in the series BH09LLK.

Card Number	Material Species Represented				
LL1	Zr	Fe	Cr	Ni	-
LL2	Ag	CdIn	-	-	B_4C
LL3	ZrO_2	FeO	Fe_2O_3	Fe_3O_4	Cr_2O_3
LL4	NiO	B_2O_3	UO_2	-	-

Continuing the example begun in the discussion of BH09LLK, if the second eutectic mixture represents stainless steel, then

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

The sum of the individual constituent mole fractions for each eutectic mixture must equal 1.00.
(type = real, default = none, units = none)

The user should be aware that the mole fractions entered for any stainless steel eutectic should be consistent with the corresponding mass fractions entered for stainless steel on MPMATxxx99 in the MP Package User's Guide. If these numbers are not consistent, the current modeling of stainless steel eutectic in the BH package may result in unintended amounts of pure species Fe, Cr, or Ni in the bottom head debris bed.

2.4 Parameters for Material Ablation

BH1100 – Ablation of Surrounding Material by Release of Molten Liquids via Penetration Failure Pathways
Required

This record provides the parameters to be used for the calculation of ablation of the debris surrounding the bottom head penetrations in the bottom debris layer and the vessel wall (BH Package Reference Manual, Section 5). These parameters are employed only after flow of the molten liquids through the penetration locations has been initiated. If it is desired that penetration failures not be considered in the calculation, then NPIPES(1) through NPIPES(3) should each be set to 0 and all liquids will be retained within the lower plenum until bottom head creep rupture is predicted. The following six fields must be provided:

(1) NPIPES(1) - Number of bottom head penetrations passing through the central control volume of the debris bed bottom layer.

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

(2) NPIPES(2) - Number of bottom head penetrations passing through the second control volume of the debris bed bottom layer.
(type = integer, default = none, units = none)

(3) NPIPES(3) - Number of bottom head penetrations passing through the outermost (third) control volume of the debris bed bottom layer. If penetration failures are to be considered in the calculation, then NPIPES (1) through NPIPES (3) should sum to the total number of penetrations for the reactor under consideration.
(type = integer, default = none, units = none)

(4) DPIPES - Penetration inner diameter
(type = real, default = none, units = m)

(5) HPIPES - Heat transfer coefficient between molten material flowing through the penetration locations in the bottom debris layer (or the vessel wall) and the surrounding medium.
(type = real, default = none, units =$W/m^2 \bullet K$)

(6) TABLAT - Ablation temperature of material in the bottom debris layer.
(type = real, default = none, units = K)

The reader should note that the term "penetration" is used generically for both BWRs and PWRs, and that DPIPES is used as the initial characteristic diameter for penetration locations through which molten debris ablates layer 1 material, ablates the bottom head wall, and enters the containment. For scrammed BWR applications, it is recommended that only the instrument guide tube penetration be identified, since the control rod guide tube passageways would remain almost completely blocked by the internal control blade index tubes. Thus, for BWR applications, the sum of the NPIPES variables above should correspond to the total number of instrument guide tubes passing through the lower head wall.

2.5 Identification of the CVH Control Volumes that Interface with the BH Package

BH1200 – Control Volume Network and BH-CVH Volume-Height Consistency
Required

This record identifies the CVH volumes representing the downcomer (jet pump) region of the reactor vessel and the drywell heat sinks. In addition, the user is encouraged to check that the BH and CVH downcomer volume-height tables are consistent. The following four fields must be provided.

(1) ICVJP - CVH control volume representing the downcomer region.
(type = integer, default = none, units = none)

(2) ICVDWS - Control volume representing the containment CVH volume receiving heat transferred from the exterior surface of the reactor vessel bottom head wall above the point where the reactor vessel support skirt attaches to the vessel wall (HSKIRT, BH0600). ICVDWS may be the same as ICVCAV entered on card CORLHDII or it may be different depending on the containment nodalization employed by the user. CVH volume ICVCAV receives heat transfer from the exterior surface of the vessel wall from nodes at and below HSKIRT. For containment flooding situations, heat transfer from the exterior wall surface is either to the pool or to the atmosphere of the associated CVH volume depending on the location of the swollen liquid level along the exterior surface.
(type = integer, default = none, units = none)

(3) ICVHBH - Flag to remind the analyst that lower plenum and downcomer annulus volume-height data need to be consistent. Unless the user sets ICVHBH=1 or the databases are consistent, the code will abort.
(type = integer, default = 0, units = none)

(4) IBHLP - Control volume representing the lower plenum.
(type = integer, default = 0, units = none)

Note that when ICVHBH=1, no code abort will occur during MELGEN. However, by setting ICVHBH to 1, the analyst is reminded to check that the volume-height input for the CV and BH lower plenum and downcomer annulus are consistent. The number of pairs in both packages need not be the same; consistency here means that, if the height in the CV and BH input are equal for a given data pair, then the volume magnitude must be equal in both packages.

2.6 BH Package Print Edit Intervals

BH1300 – Print Edit Intervals and Maximum Debris Relocation Rate
Required

This record identifies the time interval between lower plenum debris bed printed output edits produced by BH package subroutine BHHED2. Information is printed to the normal MELCOR output but with a frequency specified by the DTPNTB variable. Also, the maximum rate of debris relocation into the lower plenum debris bed is specified.

The following two fields must be provided.

(1) DTPNTB - Time interval between BH package print edits.
(type = real, default = none, units = s)

(2) DBDRPR - Maximum rate (kg/s) in which debris will be added to the BH package debris bed from the core region. If the COR package attempts to relocate debris into the lower plenum faster than this rate, the excess mass, energy, and fission product inventories will be stored in a mass and energy "accumulator" and will be added to the debris bed over a series of timesteps at a rate equal to DBDRPR until the excess disappears. When material is added to the accumulator, it is equilibrated with the material currently being held. This input variable is intended to give the user a means of distributing over several cycles the large instantaneous debris relocations typically calculated by the COR package when core plate failure occurs. It has a direct impact on the magnitude of steam production and pressurization occurring as a result of any falling debris/water pool interactions described in Section 7 of the BH Package Reference Manual.
(type = real, default = none, recommended value = 2000.0, units = kg/s)

2.7 Failed Core Boundary to Vessel Wall Radiation Model Input

BH1400 – Number of Vessel Wall Heat Structures Involved in Radiation Model
Required for BWRs, ignored for PWRs

This input record identifies the number of structures modeled by the HS package that are to be used as radiation heat sinks for and adjacent to the failed core boundary model. Typically, these are vessel wall heat structures.

The failed core boundary model is described in Section 9.2.4 of the BH Package Reference Manual (see input record BH181KK).

NVWALL - Number of HS package structures adjacent to the core boundary.
($0 <$ NVWALL ≤ 99)
(type = integer, default = none, units = none)

BH142JJ – Vessel Wall Heat Structures
01 ≤ JJ ≤ 99, card counter
Required for BWRs, ignored for PWRs

(1) IHSBH(J) - NVWALL HS package structure numbers required and stored in IHSBH(J) where (NSHDLP+2)* ≤ J ≤ (NSHDLP+1+ NVWALL) with 00000 ≤ IHSBH(J) ≤ 99999. NSHDLP is the number of sections of the failed core boundary that radiate to the vessel wall (see Record BH1800). The multiplicity of heat structure IHSBH(J) must be unity as entered on input record HSCCCCC003 in HS package input. An arbitrary number of entries allowed per input record JJ with 01 ≤ JJ ≤ 99.
(type = integer, default = none, units = none)

Note: The vessel wall heat structures must be entered sequentially as one traverses from the bottom of the vessel wall adjacent to the downcomer to the top of the vessel wall. Also the left-hand side control volume number (IBVL) as entered on the HSCCCCC400 input record for vessel wall heat structures must also be ICVJP as entered on BH1200.

2.8 BH Package Right (Outside) Boundary Surface Data for Reactor Vessel Bottom Head

BH15CC – Right (Outside) Boundary Surface Data for Reactor Vessel Bottom Head Nodalization
01 ≤ CC ≤ 18, CC is lower head node number (node 1 is the lowermost wall node while node 18 is the uppermost wall node).
Required

The following fields must be provided.

(1) IBCBH - Boundary condition type. IBCBH must be one of the following integers specifying the type of boundary condition that is applied at the exterior boundary surface of wall node CC.
= 1 A convective boundary condition is applied with the heat transfer coefficients calculated by the HS package.
= 4XXX A convective boundary condition is applied with the heat transfer coefficients given as a function of time by Tabular Function XXX. The units of quantities obtained from Tabular Function XXX are assumed to be $W/m^2 \cdot K$.

* The first NSHDLP + 1 entries of IHSBH are dummies and are not used.

= 5XXX A convective boundary condition is applied with the heat transfer coefficients given as a function of the surface temperature by Tabular Function XXX. The units of quantities obtained from Tabular Function XXX are assumed to be $W/m^2 \cdot K$.

= 6XXX A convective boundary condition is applied with the heat transfer coefficients specified by Control Function XXX. The units of quantities obtained from Control Function XXX are assumed to be $W/m^2 \cdot K$.

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

For details of the input required for tabular functions, see the Tabular Function Package Users' Guide. If control functions are used to specify boundary conditions with IBCBH = 6XXX, their values must be initialized through their respective CFXXX01 cards. For details on control function input, see the Control Function Package Users' Guide.

(2) IFLOBH - Indicator for type of flow over right (outside) boundary surface of node CC. This value is used to determine the type of convective heat transfer correlation to be used in evaluating the heat transfer coefficient on this surface.
0 = internal flow
1 = external flow
No other values are permitted for this field.
(type = integer, default = none)

(3) FCRITR (POOL) Critical pool fraction for pool. This is the minimum value of the pool fraction such that heat transfer to the pool is from the entire node surface calculated for the right (outside) boundary surface of node CC. It must be between 0.0 and 1.0, inclusive. (See note.)
(type = real, default = none, units = none)

(4) FCRITR (ATM) - Critical pool fraction for atmosphere. This is the maximum value of the pool fraction such that heat transfer to the atmosphere from the entire node surface is calculated for the right (outside) boundary surface of node CC. It must be between 0.0 and 1.0, inclusive. (See note.)
(type = real, default = none, units = none)

Note: Although allowance has been made to read in separate "critical" pool fractions for each of the bottom head wall nodes (consistent with HS package format), MELGEN input processing will terminate execution if these two variables are not identical.

2.9 HS Package to BH Package Modeling Transfer

BH1600 – Number of Affected HS Package Structures
Required

This record specifies the number of heat structures to be deactivated upon initiation of the BH package. This information is required in order to eliminate duplicate modeling of the bottom head wall by both the HS and BH packages subsequent to initiation of the BH package.

IHSOFF - Number of heat structures to be deactivated;
(1 ≤ IHSOFF ≤ 99);
(type = integer, default = none, units = none)

BH16LL – Deactivated Heat Structure Numbers
1 ≤ LL ≤ IHSOFF
Required if IHSOFF (Card BH1600) is greater than zero

(1) IHSOFN(LL) - Heat structure number as identified in the HS package input (00000 ≤ IHSOFN ≤ 99999); this heat structure is deactivated once the BH package is initiated; IHSOFF structure numbers must be input and are stored in IHSOFN(LL) where 01 ≤ LL ≤ IHSOFF.
(type = integer, default = none, units = none)

Note: As described on input record BH0700, BH package modeling of the bottom head wall terminates at max (DRXID/2, HBSB+ 0.076m). Thus, the user should set up bottom head/reactor vessel wall heat structures in the HS package input such that one of the structures terminates at that elevation and then specify that wall heat structures at and below that elevation be deactivated via the BH16LL input.

The user should note that upon BH package initiation, the surface area available for settling of aerosols from the lower plenum atmosphere will be reduced consistent with deactivation of the structures identified by the IHSOFN array. If no other lower plenum HS package structures remain active, then the RN package will produce an abort. This abort can be avoided by entering the RNSETXXX input record with the IVOLF and IVOLT entries both identifying the lower plenum CVH volume. This measure effectively resuspends any aerosol settling from the atmosphere.

2.10 BH/HS Package Structure

BH1700 – HS Package/BH Package Interface Structure Indices

Required.

(1) IHSBOT - User number for heat structure that is turned off by card series BH16LL and which is also represented as node NWALL by the BH package vessel wall model. The portion of the reactor vessel bottom head represented by IHSBOT and NWALL begins at an elevation HBSB (input record BH0100) and continues to the elevation defined by max (DRXID/2, HBSB + 0.076) above vessel zero.

(00000 ≤ IHSBOT ≤ 99999)

(2) IHSTOP - User number of heat structure with which BH package upper wall node NWALL exchanges heat by conduction. Its geometry type (IGEOM) must be cylindrical as entered on input record HSCCCCC0000. In order that this heat structure may receive the conduction energy, the control function option of specifying internal heat sources for this structure must be specified on Record HSCCCCC300. The associated control function number must have "BH-COND-POW" as its argument (see input record CFnnnkk). This structure continues to receive heat by conduction until the BH package calculates that the bottom head experiences gross failure by either creep rupture or complete wall ablation.

(00000 ≤ IHSTOP ≤ 99999)

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

Although not required, it is recommended that the inner surfaces of HS structures IHSBOT and IHSTOP be identified to receive radiative heat transfer from the hot outer surfaces of core boundary structures surrounding the core (the core boundary structures are typically identified by COR package input variable IHSA on record CORZjj02). Radiative heat transfer from the boundary structures to the vessel wall structures can be calculated by the HS package surface-to-surface radiation model (see HS input record HSRDCCCCC0).

If the inner surface of IHSBOT is active in the radiation model, then subsequent to its deactivation at BH initiation, the inner surface temperature of structure IHSBOT is replaced by that of BH wall node NWALL. The net radiative heat transfer to wall node NWALL is communicated to the BH package for inclusion in the energy balance for NWALL. If IHSBOT is not considered in the HS radiation model, then a warning message is issued to the BH package user during MELGEN input processing and no radiative heat transfer will be calculated to wall node NWALL.

The user should be aware that the thermal response of heat structures (such as those modeling the reactor vessel wall adjacent to the water pool of the downcomer annulus) are strongly influenced by the critical pool fractions entered on input records HSCCCCC400 and HSCCCCC600. It is recommended that if the vessel wall axial noding is coarse, then CPFPL and CPFAL should be less than 10% in order that proper pool cooling of reactor vessel wall can be calculated.

2.11 BH Package Lower Plenum Debris to Overlying Surface Model Input

The BH18 record series identifies input required to evaluate the heat transfers associated with radiation from the surfaces of the lower plenum debris bed to selected overlying structures prior to core boundary failure. For BWRs, it defines the temperature at which the core boundary is assumed to fail and the HS package structures to be deactivated upon boundary failure (see Section 9 of the BH Reference Manual). Figure 2.1 identifies the five debris bed surfaces (I to V) and a typical nodalization of the lower plenum overlying surfaces (1 to 8). Dimensions listed are for a large (251 in., 3.188 m ID) BWR reactor vessel such as Grand Gulf.

Surface 1 is the exposed wall above the debris, 2 is the baffle plate, 3 and 4 are the lower core boundary, and 5 to 8 are the rings of core plate. There are a total of 1 + NSHDLP + NRAD total overlying surfaces with NSHDLP and NRAD specified via input for the BH and COR packages, respectively. NRAD is specified via input record COR00000. The following input is required for the BH package to support use of this model.

Also presented is a short summary of the execution sequence followed when initiating the failed core boundary model of the BH package.

BH1800 – Global Input Data for the Lower Plenum Debris Bed to Overlying Surface Model

Required

This input record determines the number of BWR downcomer baffle plate and lower core shroud heat structures below the core plate that participate in the model. For the PWR, no baffle plate exists, and so this record identifies only the number of lower core boundary structures active in the model.

(1) NSHDLP - **for BWRs**

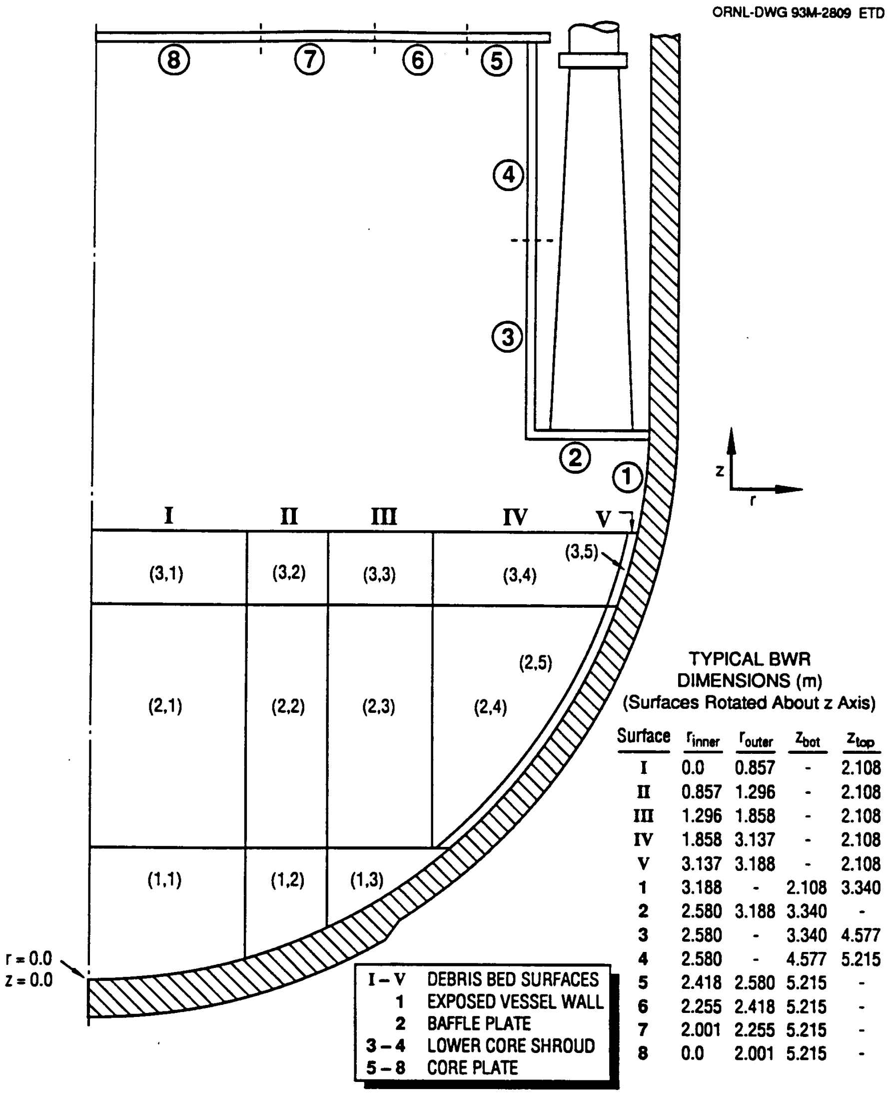
Number of HS package structures representing the baffle plate and lower core shroud

$2 \leq \text{NSHDLP} \leq 10$.

- **for PWRs**

Number of HS package structures representing the lower core boundary. The user input value of NSHDLP is increased by 1

internally to account for the non-existent baffle plate. See discussion for input record BH18JJ.
1 ≤NSHDLP ≤9.
(type = integer, default = none, units = none)



Surface	r_{inner}	r_{outer}	z_{bot}	z_{top}
I	0.0	0.857	-	2.108
II	0.857	1.296	-	2.108
III	1.296	1.858	-	2.108
IV	1.858	3.137	-	2.108
V	3.137	3.188	-	2.108
1	3.188	-	2.108	3.340
2	2.580	3.188	3.340	-
3	2.580	-	3.340	4.577
4	2.580	-	4.577	5.215
5	2.418	2.580	5.215	-
6	2.255	2.418	5.215	-
7	2.001	2.255	5.215	-
8	0.0	2.001	5.215	-

Figure 2.1 Typical Geometry of BWR Lower Plenum Debris Bed and Overlying Structures.

For BWRs

(2) TFAILS - Average temperature of structure ISHDLP(1) (or ISHDLP(2) for PWR) at which the entire core boundary is assumed to fail and

relocate onto the lower plenum debris bed (see input record BH18JJ.)
(type = real, default = none, units = K).

(3) NHSOF2 - Number of HS package structures representing the entire core boundary (e.g., for a BWR, NHSOF2 includes the baffle plate, the lower core shroud, and the upper core shroud). These structures are deactivated upon boundary failure with subsequent heatup and melting calculated by the BH package.

(As with the NSHDLP variable, the input value of NHSOF2 is automatically increased by 1 for PWR reactors to account for the non-existent baffle plate.) NSHDLP < NHSOF2.
(type = integer, default = none, units = none)

For PWRs No other values may be input.

BH18JJ – HS Package Heat Structures that Participate in the Debris-to-Structure Radiation Model Prior to Core Boundary Failure
$01 \leq JJ \leq 99$
Required

(1) ISHDLP(I) - $1 \leq I \leq NSHDLP$
For a BWR, the user-specified NSHDLP number of lower core shroud and baffle plate heat structures are stored in ISHDLP beginning at index 1 and ending at index NSHDLP. For a PWR, the user-specified number of lower core boundary heat structures NSHDLP are stored in ISHDLP beginning at index 2 and ending at index NSHDLP+1 with index 1 reserved for the non-existent baffle plate. (Also—as mentioned before—for PWRs, the internal value stored for NSHDLP is the user-input value plus 1. Thus in the remaining discussion, the quantity NSHDLP refers to the internally stored value of NSHDLP.) The sequence of structures entered is assumed to follow the counterclockwise numbering scheme indicated in Figure 2.1. Therefore, the correspondence of the structures identified in ISHDLP to the overlying surface indexing scheme employed in the debris to overlying surface radiation model is as follows:

Overlying Surface	ISHDLP Index
1 = exposed wall	-
2 = baffle plate	1 (dummy stored for PWR)
3 = lowermost core boundary segment	2
.	
.	
.	
NSHDLP + 1 = core boundary segment immediately below the core plate	NSHDLP

Input processing in the BH package enforces an HS package multiplicity of unity for the structures identified in ISHDLP. It also requires that the user identify the downcomer CVH volume ICVJP on input record BH1200 as the right-hand side or outer boundary control volume and that the left-hand side or inner boundary control volume be that associated with the lower plenum [ICVHC(1,1) entered on input record COR10101]. These checks are made to ensure proper heat structure orientation and multiplicity consistent with assumptions made within the model. If the checks are violated, then MELGEN processing terminates. (type = integer, default = none, units = none)

BH18JJKK – Debris Surface to Overlying Structure View Factors
01 ≤ JJ ≤ (1 + NSHDLP + NRAD)
01 ≤ KK ≤ 99 card counter
(Optional if NRAD = 4 and NSHDLP = 3; otherwise required)

(1) VIEW2 (LL,JJ) - The view factor from each of the five debris bed surfaces to each of the overlying structure surfaces must be input for the model. Therefore, a total of 5 * 1 + NSHDL + NRAD) view factors are required. Five entries are required for each overlying surface index JJ [1 ≤ JJ ≤ (1 + NSHDLP + NRAD)*. Sequential entries on each input record are stored as VIEW2 (LL, JJ) 1 ≤ LL ≤ 5, where LL corresponds to the debris surface index. An arbitrary number (≤5) of view factors are allowed on each record KK. **The sum of the view factors VIEW2 (LL, JJ) 1 ≤ JJ ≤ (1 + NSHDLP**

---

* For PWR applications, the value input on record BH1800 for NSHDLP is increased by 1 prior to processing view factor information. The additional surface index is required (along with appropriate view factors) to account for the open region below the downcomer.

+ NRAD) for each debris surface LL must lie within 2% of unity or MELGEN will abort.

It is recommended that the user employ methods such as those described in the BH Package Reference Manual to evaluate view factors to be used in the model. The view factors should be evaluated for the debris bed geometry that exists after layer three has formed and the debris bed is fully developed. The entire set of view factors is used in the radiation calculation. Prior to layer three setup, the only view factors used are from debris surfaces IV and V to overlying surfaces 1 and 2. This is because of the shielding between the debris of layer 2 and the core boundary (and core plate) provided by the mass of standing lower plenum structures. The view factors are assumed constant throughout the calculation (prior to core boundary failure) even through the debris bed geometry changes as a result of debris bed nodal merging, debris relocations from the failed reactor vessel, and debris relocations into the debris bed from the core region.

View factors have been evaluated for the typical large BWR lower plenum/debris bed geometry shown in Figure 2.1 and reported in Table 2.2. If the user does not have access to a numerical integration scheme to determine the view factors for the nodalization of choice, it is recommended that the nodalization shown in Figure 2.1 be approximated and the view factors reported in Table 2.2 be employed. Default values for the view factors are taken from Table 2.2 for the geometry shown in Figure 2.1.
(type = real, default = Table 2.2, units = none)

Table 2.2 Typical View Factors for Debris Surface to Overlying Structures Radiation Model (see Figure 2.1), VIEW2(I,J), I = debris surface index, J = overlying structure index

	Debris Surface Index							
	I = 1	**I = 2**	**I = 3**	**I = 4**	**I = 5**			
J = 1	.135	.154	.191	.376	.564	J = 1	:	exposed wall
J = 2	.062	.080	.118	.220	.219	J = 2	:	JP baffle*
J = 3	.290	.285	.262	.121	.049	J = 3	:	core boundary structure 10014

* For PWR applications, this index represents the open area at the base of the downcomer.

	Debris Surface Index							
	I = 1	**I = 2**	**I = 3**	**I = 4**	**I = 5**			
J = 4	.110	.101	.086	.046	.024	J = 4	:	core boundary structure 10004
J = 5	.031	.031	.031	.022	.006	J = 5	:	COR ring 4
J = 6	.032	.032	.032	.022	.007	J = 6	:	COR ring 3
J = 7	.051	.051	.048	.036	.013	J = 7	:	COR ring 2
J=8	.283	.259	.225	.152	.098	J = 8	:	COR ring 1
Sum =	**.994**	**.993**	**.993**	**.995**	**.980**			

BH181KK – Deactivated HS Structures after Core Boundary Failure
01≤KK≤99 card counter
Required for BWRs, ignored for PWRs

NHSOF2 (see BH1800) identifies how many HS package structures representing the entire core boundary to be deactivated at the time of boundary failure. After the time of failure, modeling of the core boundary is performed by the BH package and is described in Section 9 of the BH Package Reference Manual.

(1) IHSOF2(I) - Heat structure number as identified in the HS package input (00000 ≤ IHSOF2(I) ≤ 99999) 1 ≤ I ≤NHSOF2. The structure numbers should be input sequentially (starting with the lowermost structure and progressing to the top of the core boundary) and their multiplicities must be unity. **Checks are made to ensure that the first NSHDLP structures of IHSOF2 are the same as ISHDLP identified on input record BH18JJ. The checks are made to enforce ordering consistent with assumptions made in the model. If the checks fail, MELGEN termination will occur.**
(type = integer, default = none, units = none)

It should be recognized that these steel core boundary structures may be considered for melting prior to failure. Melting may be calculated by special application of the HS degassing model employing the "SS" degassing material (see input record HSDGCCCCC0).

<u>Initiation Sequence for Failed Core Boundary Model</u>
For BWR applications, these data input for the BH18 card series are also used as input by the failed core boundary model. The sequence of steps identifying the core boundary segments used to initialize the failed core boundary model is listed as follows:

(1) Core boundary is assumed to collapse when the average temperature of structure ISHDLP(1) for the BWR meets or exceeds TFAILS.

(2) The structures identified by IHSOF2 are deactivated and the mass of the baffle plate structure ISHDLP(1) = IHSOF2(1) is immediately added to the lower plenum debris bed. Also, the remaining COR components at and above the core plate are relocated into the lower plenum at this time.

(3) The masses of structures ISHDLP(2)…ISHDLP(NSHDLP) are used to initialize the masses of core boundary segments (2…NSHDLP) of the failed core boundary model of BH. Segment 1 mass remains zero corresponding with non-existence or degradation of the baffle plate mass.

(4) The masses of deactivated structures IHSOF2(NSHDLP+1) to IHSOF2(NHSOF2) are combined and used to initialize the uppermost structure of the failed core boundary model. The index of this uppermost structure is NSHDLP+1.

2.12 BH Package Lower Plenum Vessel Penetration Break Size

BH1900 – BH Lower Plenum Penetration Break Size–Control Function
Required

(1) IABCFN - Control function number specifying area of failed penetration (m^2).
(type = integer, default = none, units = none)

This card has been altered from previous code versions. It heretofore included input for two control function identification numbers (ICFRLP(1) and ICFRLP(2)), which were used to specify the flow rate and temperature for water injected directly into the BH package. This water was independent of, and unrecognized by the CVH package. These options have been removed as part of the effort to make the bottom head package consistent with all other packages with regard to ownership of CVH materials and the exchange of these materials between packages.

It is recommended that the control function that specifies the penetration break area be structured so that the break area has a value no more than about 0.0005 m^2 when water is being or has been injected into the lower plenum. This is to recognize the partial plugging of the penetration pathways that would occur due to freezing of some of the flowing metals.

2.13 Fission Product Release

BHRN10K – BH-to-RN Class Mappings for Fission Product Releases
Optional

ICLSBH(I) - RN class index identified to receive volatilized material from BH package pure species I, where $1 \leq I \leq 20$ and I is identified on BH02JJ. **The RN class indices must be entered in order from low to high species numbers corresponding to the BH package materials.** Other input required for the fission product release modeling is taken from the RN package release modeling selected by the user for materials of the COR package. These include the release model flag ICRLSE on the RNFP000 input record where the CORSOR or CORSOR-M release models may be chosen with or without the surface area-to-volume ratio option.

The CORSOR-Booth model is not currently available for BH fission product release calculations. If CORSOR-Booth is chosen for COR package fission product modeling, the CORSOR-M model with the surface area-to-volume option is employed for BH Package releases. Because of the uncertainty in determining the surface area-to-volume ratio for a two-phase mixture of solid/molten debris, this parameter is simply set to 6/D, where D is the diameter of debris particles used throughout the BH package and is input via COR package input record CORIJJ04.

However, because this parameter is important to the release modeling, the user may vary the calculated release rates by use of RN package sensitivity coefficient 7104, where the surface area-to-volume ratio base may be changed from the default value of 422.5 m^{-1}.

If the user does not input the BHRN10K record, the default BH-to-RN class mappings are shown in Table 2.3.
(type = integer, default = below, units = none)

Table 2.3 Default BH Material to RN Class Mappings

BH Species		RN Class	BH Species		RN Class
1	Zr	8	11	ZrO_2	8
2	Fe	7	12	FeO	7
3	Cr	7	13	Fe_2O_3	7

BH Species		RN Class	BH Species		RN Class
4	Ni	7	14	Fe_3O_4	7
5	–	0	15	Cr_2O_3	7
6	Ag	12	16	NiO	7
7	CdIn	12	17	B_2O_3	13
8	–	0	18	UO_2	10
9	–	0	19	–	0
10	B_4C	13	20	–	0

2.14 MELCOR Input

The input records that may be specified on MELCOR restart are listed in Table 2.4. The variables for each record are separated into three categories: first, those permissible to change on MELCOR restart at any point in the calculation; second, those permissible to change only prior to the initiation of the BH package; and third, those that may not be changed after MELGEN processing.

All required entries on an input record must be included. For input records in which the variables are not all in the same category, the input for the variables that may not be changed at the time of the restart must be the same as that used by MELCOR during the previous execution. As an example, the input record BH1800 may be included on MELCOR restarts, but only the input variable TFAILS is permitted to change. This allows the user to vary the core boundary failure temperature prior to failure. If BH1800 is entered in MELCOR input, then NSHDLP and NHSOF2 entries must also be provided and must be the same as entered in MELGEN. Otherwise MELCOR restarts will be aborted.

As stated earlier the view factors for the debris surface to structures, input record BH18JJKK, are assumed constant throughout the calculations (prior to core boundary failure) even though the debris bed geometry changes, unless changed by user input. However, when a debris bed surface node is covered by water, the radiation to the overlying structures is ignored—in essence the debris bed node surface view factor is zeroed.

Upon core boundary failure in BWR applications, the debris bed to the overlying structures' view factors are automatically adjusted. The view factors corresponding to the core plate radial sections for each debris bed node surface are lumped together to form the new view factor from the debris bed node surface to the entire length of the core shroud previously above the core plate. Second, the view factors from the interior debris bed node (I-III) surfaces to the exposed vessel wall are zeroed. Likewise the view factors corresponding to the lowermost portion of the core shroud are correspondingly enhanced. Finally, since the baffle plate has failed and relocated into the debris bed and because the entire core shroud has moved downward to rest upon the bed surface, the view factors from the debris bed node surfaces to the lowermost portion of the core shroud are again enhanced by the baffle view factors, which are then zeroed. A complete description of the way in which the view factors are adjusted is given Section 9.2.4.1 of the BH Package Reference Manual. Thus, if a user decides to change the view factors after core boundary failure, then the new view factors should be determined in accordance with the preceding geometric adjustments and not for the geometry shown in Figure 2.1.

The user should be aware that in addition to changing the control function identification number on input record BH1900 the value of the previously identified control functions may be modified via MELCOR restarts (see allowable MELCOR input for Control Function package).

Table 2.4 Adjustment of BH Package Input Variables on MELCOR Restarts

Card Number Identifier	Variable Name	Condition Under Which Variables May Be Changed on MELCOR Restarts			Notes
		Anytime	Prior to BH Initiation	Never	
BH0000	BHTITL	X			
BH0100					
	HBSB		X		
	NA		X		
	NPS		X		
	IEUTEC	X			
BH02JJ					
	AMTMEL		X		
	AMMLWT		X		
	AMLAMF		X		
BH03LL					
	HH		X		
	VCORE		X		
	VSHRD		X		
BH04LL					
	HPS		X		
	VPS		X		
BH0500					
	PORBOX	X			1,9
	PORBM	X			1,9
	DTHEAD	X			2,10
	H1MAX		X		
	HD1D2		X		
	DPART	X			

Card Number Identifier	Variable Name	Condition Under Which Variables May Be Changed on MELCOR Restarts			Notes
		Anytime	Prior to BH Initiation	Never	
BH0600					
	HSKIRT		X		
	THKCRS		X		
	THKHD1		X		
	THKHD2		X		
	THK6	X			3
	THK60	X			3
BH0700					
	IMWDEB	X			4
	SFCRDB	X			5,10
	SFCRSS	X			
	FZRMX1	X			4
	FSSMX1	X			4
	DRXID		X		
	TFAIL2	X			
	HCYL		X		
	RCYL		X		
	XOZRMX	X			
	XOSSMX	X			
BH08LL					
	TMLIEU	X			
	IEUKEY	X			
	FRCKEY	X			
	EKYMIN	X			
BH09LLK	Eutectic Constituents (IEU)	X			
BH10LLK	Constituent Mole Fractions (XRNKEY)	X			
BH1100					
	NPIPES(1)	X			6
	NPIPES(2)	X			6
	NPIPES(3)	X			6
	DPIPES		X		
	HPIPES	X			7
	TABLAT	X			8

Card Number Identifier	Variable Name	Condition Under Which Variables May Be Changed on MELCOR Restarts			Notes
		Anytime	Prior to BH Initiation	Never	
BH1200					11
	ICVJP			X	
	ICVDWS			X	
BH1300					
	DTPNTB	X			
	DBDRPR	X			
BH13NN					
	BHTIME	X			
	DTPNTB	X			
BH1400					11
	NVWALL			X	
BH142JJ					11
	IHSBH(J)			X	
BH15CC					
	IBCBH	X			
	IFLOBH	X			
	FCRITR(POOL)	X			
	FCRITR(ATM)	X			
BH1600					11
	IHSOFF			X	
BH16LL					11
	IHSOFN(LL)			X	
BH1700					11
	IHSBOT			X	
	IHSTOP			X	
BH1800					12
	NSHDLP			X	
	TFAILS	X			
	NHSOF2			X	
BH18JJ					11
	ISHDLP(I)			X	
BH18JJKK					
	VIEW2(LL,JJ)	X			
BH181KK					11
	IHSOF2(I)			X	
BH1900					
	IABCFN	X			

Card Number Identifier	Variable Name	Condition Under Which Variables May Be Changed on MELCOR Restarts			Notes
		Anytime	Prior to BH Initiation	Never	
BHRN10K	ICLSBH(I)	X			

Table Notes

(1) Changing these porosities after BH package initiation will affect the volume occupied by:

(a) debris that subsequently enters the lower plenum from the core region, and

(b) any bed control volume that is reconfigured due to liquid formation within and drainage from the control volume. It should be recognized that debris control volume geometries are not automatically reinitialized to be consistent with changed values of PORBOX and PORBM. (When the free volume fraction exceeds 1.25*PORBOX, tumbling of the remaining solids into a new configuration is modeled, and the current values of PORBOX and PORBM are used to set the new free volume.)

(2) Should be maintained at values greater than the maximum timestep length.

(3) The predicted bottom head penetration weld creep rupture failure time is never allowed to increase once set. Therefore, increasing the values of THK6 and THK60 after the BH package is initiated may not delay penetration weld creep rupture.

(4) For IMWDEB equal to 2 or 3, code logic will internally set IMWDEB equal to 0 (and write a message that "lower plenum Zr oxidation stopped") whenever the ratio of zirconium reacted to the initial zirconium mass exceeds FZRMX1.

(5) Each timestep, the oxidation rate determined by the reaction kinetics equations is multiplied by the factor 1.0/SFCRDB.

(6) If zero at the time the BH package is initiated, then must remain zero throughout the calculation. But if NPIPES(j) has a value NPI when BH is initiated, then it may be shifted from NPI to zero (to simulate plugging of penetrations) and back again on subsequent restarts.

(7) If set to zero, will terminate ablation both within the layer 1 debris and in the wall.

(8) If set to a value greater than the temperature TLLIQ of the flowing liquids, will terminate ablation of the lower layer solid debris. Within subroutine BHDBMX, the temperature of the ablating surface is set to:

MAX [TABLAT,1/3*TLLIQ+2/3*TMLPO(1,jj)],

where TMLPO(1,jj) is the average temperature of the debris control volume jj in layer 1. Thus adjustments to TABLAT for values less than TMLPO(1,jj) will have no effect.

(9) Values must be less than 1.0.

(10) Entries with value zero will cause divide-by-zero and code aborts.

(11) Input record is ignored during MELCOR input processing.

(12) Only the first value of this card may be input for PWR applications. In addition, this value must be identical to that entered in MELGEN.

2.15 Sensitivity Coefficients

This section lists the BH sensitivity coefficients that are accessible to the user, along with a brief description and gives their default values, units, and EQUIVALENCE variable names. All BH package sensitivity coefficients are in the 5000 to 5199 range.

5001 – Control Rod Poison (Ag-In-Cd) Composition Fractions

The control rod poison Ag-In-Cd for PWR applications is defined in the COR package as a single species. When passed to the BH package, this material is partitioned into Ag and InCd. Sensitivity coefficient 5001 defines the mass fractions of Ag and InCd in the poison.

C5001(1)- mass fraction of Ag
(default = 0.8, units = none, equiv = PWRXMF(1))

C5001(2)- mass fraction of In-Cd
(default = 0.2, units = none, equiv = PWRXMF(2))

5010 – INACTIVATED

Formerly the maximum water transfer rate from the CVH lower plenum pool into the BH debris/water interaction model. Because the BH package no longer has ownership of CVH materials, this sensitivity coefficient is no longer required and has been removed.
C5010 - Removed.

5020 – BH/FDI-CAV - Initial Debris Holdup Mass.

Due to numerical problems encountered in the CAV package arising from the existence of small quantities of debris on the containment floor, logic has been implemented to delay the initial debris ejection into either the FDI or CAV package from BH. As implemented, no initial debris transfer will be allowed until the integrated mass of debris leaving the failed reactor vessel has reached the value specified by this sensitivity coefficient. When this threshold has been exceeded, all of the ejected debris is transferred into either CAV or FDI. After this point, no holdup occurs, and debris is transferred into FDI or CAV as it leaves the vessel.

If the user encounters abnormal MELCOR terminations shortly after BH package penetration failure occurs, it is recommended that the value of this sensitivity coefficient be increased to 5000.0 kg.

C5020 - Initial debris holdup mass
(default = 0.0, units = kg, equiv = AMLOSI)

3. Plot Variables and Control Function Arguments

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

bh-cpu	/p/	Total CPU usage required in executing the BH package. (units = s)
bh-gas-ener.n	/p/	Cumulative gas enthalpy released or extracted by the BH package during gas release. n = 1 for the lower plenum atmosphere. n = 2 for the containment atmosphere. (units = J)
bh-gsms-lh.n	/p/	Cumulative gas mass extracted from the lower plenum atmosphere by the BH package for n = 1 to nmmat gases; the gas indices are identified in the printed output for the BH package. (units = kg)
bh-gsms-dw.n	/p/	Cumulative gas mass exhausted into the containment atmosphere by the BH package for n = 1 to nmmat gases; the gas indices are identified in the printed output for the BH package. (units = kg)

bh-rad-ener	/p/	Cumulative energy added to the lower plenum atmosphere by the BH package. Before failure and collapse of the lower plenum structures, this variable may be negative. This is due to the large thermal mass and surface area of these cold structures at the time of lower plenum dryout and, thus, their cooling effect on the lower plenum atmosphere. After they fail and collapse into the lower plenum debris bed, the lower plenum atmosphere rapidly heats due to radiative exchange from the surface of the debris bed and this variable becomes positive. (units = J)
bh-jp-ener	/p/	Cumulative energy added to the water pool in the downcomer by the BH package. (units = J)
bh-cav-ener	/p/	Cumulative energy added to the reactor cavity CVH volume (ICVCAV) atmosphere since the initiation of the BH package. (units = J)
bh-dwl-ener	/p/	Cumulative energy added to the containment CVH volume (ICVDWS) atmosphere immediately above the reactor vessel skirt since the initiation of the BH package. (units = J)
bh-pour-temp	/p/	Temperature of debris pouring from the reactor vessel bottom head over a system cycle. (units = K)
bh-species-rate.index*	/p/	Rate of species' mass ejection as calculated by the BH package; if no ejection is calculated, then 0.0 is plotted. (units = kg/s)
bh-oxides-rate	/p/	Rate of oxide mass ejection from the lower plenum as calculated by BH; represents the sum of species flows for species 10 to 18. (units = kg/s)
bh-metals-rate	/p/	Rate of metal mass ejection from the lower plenum as calculated by BH; represents the sum of species flows for species 1 to 9. (units = kg/s)

For plot variables "bh-species-rate.index" and "bh-species-cumul.index", the following table must be used to identify the pure species index to be used in the plotting input. (Blank species' names are for future use.)

bh-total-rate	/p/	Total rate of debris ejection from the lower plenum as calculated by BH summed over species 1 to 18. (units = kg/s)
bh-ex-ves-dk-pow	/p/	Not currently available. (units = W)
bh-species-cumul.index*	/p/	Cumulative mass of debris species ejected from the reactor vessel. (units = kg)
bh-oxides-cumul	/p/	Cumulative mass of oxidic debris ejected from the reactor vessel summed over species 10 to 18. (units = kg)
bh-metals-cumul	/p/	Cumulative mass of metallic debris ejected from the reactor vessel summed over species 1 to 9. (units = kg)
bh-debris-cumul	/p/	Cumulative debris mass ejected from the reactor vessel summed over species 1 to 18. (units = kg)
bh-wall-power-nn	/p/	Instantaneous heat transfer rate for BH package bottom head node nn external surface ($01 \leq nn \leq 18$). (units = W)
bh-fflag	/c/	Flag switching from 0.0 to 1.0 to indicate gross failure of the bottom head wall by either creep rupture or ablation. This control function is useful in controlling a "valve" in a CVH/FL flow path. If such a flow path between the lower plenum and containment CVH volumes is not specified, then there is no gas or water pool flow from the lower plenum to the containment after gross failure of the bottom head wall.
bh-cond-pow	/c/	Conduction power calculated from node NWALL of the BH package wall model to IHSTOP of the HS (see input record BH1700). (units = W)

For plot variables "bh-species-rate.index" and "bh-species-cumul.index", the following table must be used to identify the pure species index to be used in the plotting input. (Blank species' names are for future use.)

bh-shroud-mass.i /p/ mass of core boundary structures represented by the BH after failure of the core boundary structure.
(units = kg); $1 \le I \le (NSHDLP+1)$ where I is the structure index having the following meaning:

I	Identifier
1	baffle plate for BWR; blank for PWR
2	lowermost core boundary segment
.	.
.	.
.	.
.	
NSHDLP	core boundary segment immediately below the core plate location
NSHDLP+1	entire core boundary portion above the core plate

bh-shroud-temp.i /p/ Temperature of core boundary structures represented by the BH package after failure of the core boundary; $1 \le I \le (NSHDLP+1)$; see plot variable 22 for definition of I.
(units = K)

bh-shroud-tmlt /p/ Total mass of core boundary that has melted and relocated into the core or the lower plenum regions after dryout of the downcomer annulus.
(units = kg)

bh-lp-water-mass /p/ Lower plenum water mass present in the BH package model of debris/water pool interactions.
(units = kg)

bh-lp-water-temp /p/ Temperature of the lower plenum water pool mass present in the BH package model of debris/water pool interactions.
(units = K)

bh-accum-mass /p/ Instantaneous mass of all debris that has left the core region but that has not yet entered the BH package lower plenum debris bed.
(units = kg)

bh-fprls-rate.n /p/ Instantaneous elemental radioactive class release (e.g., fission products) rate of RN package class n summed over

		all control volumes of the BH debris bed; does not include nonradioactive released masses associated with class n; see RN Package Users' Guide for RN class definitions. (units = kg/s)
bh-fprls-cum.n	/p/	Cumulative elemental radioactive (e.g., fission product) class release of RN package class n summed over all control volumes of the BH debris bed; does not include nonradioactive released masses associated with class n; see RN Package Users' Guide for RN class definitions. (units = kg)
bh-energy-err	/p/	BH package energy error; see Section 11.4.4 of the BH Package Reference Manual. (units = J)
bh-rel-engy-err	/p/	BH package relative energy error; see Section 11.4.4 of the BH Package Reference Manual.

Index	Species Name	Index	Species Name
01	Zr	10	B_4C
02	Fe	11	ZrO_2
03	Cr	12	FeO
04	Ni	13	Fe_2O_3
05	blank	14	Fe_3O_4
06	Ag	15	Cr_2O_3
07	CdIn	16	NiO
08	blank	17	B_2O_3
09	blank	18	UO_2

4. Example Input

4.1 Example MELGEN Input

The following are sample MELGEN input records for the BH package.

```
*
*
*  ORNL BOTTOM HEAD INPUT
BH0000  'GRAND GULF SHORT TERM STATION BLACKOUT WITH ADS ACTUATION'
*
*         HBSB      NA    NPS  IEUTEC
```

```
BH0100    3.340     26    26     4
*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    1234.0   107.870   1.04796E5   *  ag
BH0207    1200.0   114.215   3.49550E4   *  cdin
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   *  FE304
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        *
*
*
*          HH        VCORE     VSHRD
*         (M)       (M**3)     (M**3)
BH0301   0.0        0.0         0.0
BH0302   .15113     1.68429E-1  0.0
BH0303   .27686     6.21753E-1  0.0
BH0304   .39726     1.32452E0   0.0
BH0305   .56134     2.66651E0   0.0
BH0306   .76454     4.87033E0   0.0
BH0307  1.02870     8.51884E0   0.0
BH0308  1.29540     1.33883E1   0.0
BH0309  1.83515     2.68349E1   0.0
BH0310  2.28600     4.02051E1   0.0
BH0311  2.70510     5.28351E1   0.0
BH0312  3.02514     6.21827E1   0.0
BH0313  3.0861      6.40303E1   0.0
BH0314  3.3401      7.17287E1   0.0         * bot of downcomer
BH0315  3.59918     7.73934E1   2.18771E0
BH0316  3.75158     8.06903E1   3.50982E0
BH0317  4.41198     9.27526E1   1.14633E1
BH0318  4.48056     9.42169E1   1.20776E1
BH0319  4.57200     9.61589E1   1.29060E1
BH0320  4.75234     1.00110E2   1.44221E1
BH0321  4.85394     1.02490E2   1.51216E1
BH0322  5.08000     1.07740E2   1.67233E1
BH0323  5.21462     1.10416E2   1.75386E1
BH0324  5.26796     1.11414E2   1.79240E1
BH0325  5.36702     1.13392E2   1.86398E1
BH0326  5.49402     1.15998E2   1.95573E1 * BAF
*
*          HPS        VPS
*          (M)       (M**3)
```

```
BH0401   0.0       0.0
BH0402    .15113   7.94850E-2
BH0403    .27686   2.00115E-1
BH0404    .39726   3.47646E-1
BH0405    .56134   6.18128E-1
BH0406    .76454   1.09838E0
BH0407   1.02870   1.99424E0
BH0408   1.29540   2.81399E0
BH0409   1.83515   3.77871E0
BH0410   2.28600   4.58458E0
BH0411   2.70510   5.33370E0
BH0412   3.02514   6.20283E0
BH0413   3.08610   6.30123E0
BH0414   3.34010   6.71138E0
BH0415   3.59918   7.12976E0
BH0416   3.75158   7.37583E0
BH0417   4.41198   8.44221E0
BH0418   4.48056   8.55296E0
BH0419   4.57200   8.70061E0
BH0420   4.75234   8.99179E0
BH0421   4.85394   9.15588E0
BH0422   5.08000   9.52089E0
BH0423   5.21462   1.03269E1
BH0424   5.26796   1.03269E1
BH0425   5.36702   1.03269E1
BH0426   5.49402   1.03269E1
*
*     PORBOX  PORBM DTHEAD  H1MAX   HD1D2     DPART
BH0500  0.4     0.32  10.0   0.6096  2.04749   0.004
*
*      HSKIRT   THKCRS    THKHD1     THKHD2     THK6   THK60
BH0600 1.59106 0.050801  0.17356    0.18415   1672.0  1560.9
*
*--------+---------+---------+---------+---------+---------+---------+--
*      I   S   S   F   F
*      M   F   F   Z   S
*      W   C   C   R   S
*      D   R   R   M   M
*      E   D   S   X   X
*      B   B   S   1   1  DRXID  TFAIL2   HCYL     RCYL   XOZRMX  XOSSMX
BH0700 1 1.0 1.0 1.0 1.0 7.0104 1523.0  2.047494 3.187699 1.0E-6  1.0E-6
*
*       TMLIEU  IEUKEY  FRCKEY   EKYMIN
BH0801   1523.0   2      .65977    0.0
BH0802   1700.0   3      .19152    0.0
BH0803   1873.2  18      .02756    0.0
BH0804   2573.2  11      .86800    0.0
*
*     IEU(J,LL) 1.LE.J.LE.20, 1.LE.LL.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 =   AG    CDIN  -     -     B4C
*         11 12 13 14 15 =   ZRO2  FEO   FE2O3 FE3O4 CR2O3
*         16 17 18 19 20/=   NIO   B2O3  UO2   -     - /
*
*     IEU(J,LL)=0 MEANS THAT SPECIES J IS NOT IN EUTECTIC LL
*              =1 MEANS THAT SPECIES J IS IN EUTECTIC LL
*BH09LLK
```

```
*      LL=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  1  1  1  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
*
*BH10LLK
*      LL=EUTECTIC INDEX
*       J=PURE SPECIES INDEX
*       K=CARD COUNTER
*       XRNKEY(J,LL)  1.LE.J.LE.20, 1.LE.LL.LE.IEUTEC, 1.LE.K.LE.4
* EUTECTIC 1
BH10011  0.100  0.65977  0.17237  0.06786  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     .36712    0.44375   0.11593    0.04564   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       0.02756    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     .868      0.0       0.0        0.0       0.0
BH10044     0.0       0.0       .132       0.0       0.0
*
*         ---- NPIPES----  DPIPES    HPIPES      TABLAT
*         (1)   (2)   (3)   (M)       (W/M**2-K)   (K)
BH1100    10    26    22   .04572    1.0214E3    1755.4
*         CVH VOLUME         CVH VOLUME      VOLUME/HEIGHT     CVH VOLUME
*         REPRESENT.         REPRESENT.       CONSISTENCY      REPRESENT.
*          JET PUMP            D W S          CHECK FLAG      LOWER PLENUM
*
BH1200       105               201                1              120
```

```
*
*
*
*       user controlled
*       print frequency
*      for bottom head
*         DTPNTB(sec)      dbdrpr(kg/sec)
BH1300     300.0             2000.0
*         BHTIME (sec)        DTPNTB (sec)
BH1301     0.0                200.0
*
*
* failed core shroud to vessel wall thermal radiation model input
*       nvwall
BH1400    1
*
*   enter the vessel wall heat structure numbers
*   nvwall entries required
*   JJ is the card counter
*BH142JJ
BH14201   10502
*
**
*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: hsoff option in hsrun3
BH1600  4
BH1601  10001 * bottom head; axial seg 1
BH1602  10002 * bottom head; axial seg 2
BH1603  10003 * bottom head; axial seg 3
BH1604  10501 * bottom head; top bh package wall
*
* input HS wall structures interfaced with BH
*      IHSBOT  IHSTOP
BH1700  10501  10502
*
* input for the BH package lower plenum debris to overlying
* structure radiation model (BH18... series)
```

```
*     NSHDLP   TFAILS  NHSOF2
BH1800  3      850.0     14
*          ISHDLP(i) 1.le.i.le.nshdlp
BH1801  10013 10014 10004
*
*          IHSOF2(i) 1.le.i.le.nhsof2
BH18101  10013  10014  10004  10005  10206  10207
BH18102  10208  10209  10210  10211  10212  10213
BH18103  10301  10302
*
*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 abrk control functions
BH1900  193
*
CF19300  'BH BREAK AREA'    EQUALS  1    1.0  0.0
CF19301   0.0  * initialize
CF19310   0.0  0.01  TIME * area=0.01 m**2
*
*  RN classes associated with the NPURE BH package species
* (ICLSBH(I) 1.le.I.le.20)
BHRN101    8  7 7 7  0   12  12 0 0 13    8 7  7 7 7  7 13 10 0 0
*
*********************************************
* MELGEN input associated with BH        ****
*********************************************
*
* BH controlled flow path valve for flow from vessel
* after gross head failure
FL03200   'GROSS VES FAIL'   100  201  0.    -0.2254
FL03201   0.01   0.2254  0.0               * INITIALLY CLOSED
FL03202   0  0  0  0
FL03203   1.0     1.0
FL032S0   0.01   0.2254  0.1128
FL032V0   -1  132  132
*
CF13200   'GROSS VES FAIL'  EQUALS  1  1.0  0.0
```

```
CF13201   0.0 * initial value
CF13210   1.0  0.0   BH-FFLAG
*
CF13300   'HEAD FAIL MESS' L-GT 2  1.0  0.0
CF13301    .FALSE.  * initial value
CF13306   2 'BH PACKAGE : GROSS HEAD FAILURE OCCURS'
CF13310   1.0  0.0  BH-FFLAG
CF13320   0.0  0.5  TIME
*
* REACTOR VESSEL WALL AROUND DOWNCOMER (CORE)
HS10502000         5    2   -1    0 * no ss temp calc
HS10502001     'MAIN CYL CORE   '
HS10502002         3.5052      1.00 * start at DRXID/2=3.5052
HS10502003          1.0  *  MULTIPLICITY
HS10502100        -1          1        3.18754
HS10502102       3.231988      2
HS10502103       3.276436      3
HS10502104       3.320883      4
HS10502105       3.365331      5
HS10502200     -1
HS10502201     'CARBON STEEL            '       4
HS10502300       9013  -111   1.0  * use cf-013 to determine source (w)
*       power fractions for intervals
HS10502301       0.2449  1
HS10502302       0.2483  2
HS10502303       0.2517  3
HS10502304       0.2551  4
*
*  control function to determine internal power source for HS10502
CF01300   'CONDUCTION POWER'   EQUALS  1  1.0  0.0
CF01301    0.0  * initial value
CF01310    1.0  0.0  BH-COND-POW
* rest of HS10502 input data
HS10502400         1       105     'INT'      0.05      0.05
HS10502401     0.7000     'EQUIV BAND'      0.20
HS10502500        242.15         0.50        11.9248
HS10502600      5120       201     'EXT'      1.00      1.00
HS10502700        255.66         0.20        11.9248
HS10502800      -1
HS10502801       560.0       5
*
*CV100 settling flow through to itself for when the lower plenum
* heat structures are deactivated at BH initiation
* go away (area=1.0e-6 to allow MAEROS somewhere to settle aerosols)
RNSET017  100  100 0.0  1.0e-6
**********************************************************************
*  end of MELGEN input associated with BH
**********************************************************************
*
* terminator record
```

4.2 Example MELCOR Input

The following are sample MELCOR input records for the BH package.

```
*  ORNL MELCOR BOTTOM HEAD INPUT
BH0000  'Modified, GRAND GULF SHORT TERM STATION BLACKOUT WITH ADS ACTUATION'
```

```
*
* increase number of entries in the vcore/vshrd and vps input by one
*         HBSB      NA    NPS  IEUTEC
BH0100    3.340     27    27     4
*HBSB at bottom of downcomer
*
* reiterate the properties for UO2
*         AMTMEL    AMMLWT    AMLAMF
*           (K)               (J/KG)
BH0218    3010.9   270.070   2.74468E5   *  UO2
*
*
*         HH        VCORE     VSHRD
*        (M)       (M**3)     (M**3)
BH0326  5.49400    1.15996E2   1.95572E1 * BAF
BH0327  5.49402    1.15998E2   1.95573E1 * BAF
*
*         HPS        VPS
*         (M)       (M**3)
BH0426   5.49400   1.03269E1
BH0427   5.49402   1.03269E1
*
*  increase the debris porosity
*     PORBOX  PORBM  DTHEAD    H1MAX    HD1D2  DPART
BH0500  0.45   0.34    10.0   0.6096  2.04749  0.004
*
* increase the temperature of thk60
*      HSKIRT   THKCRS    THKHD1     THKHD2     THK6   THK60
BH0600 1.59106 0.050801  0.17356    0.18415   1672.0  1561.0
*
* increase the temperature of tfail2
*      I   S   S   F   F
*      M   F   F   Z   S
*      W   C   C   R   S
*      D   R   R   M   M
*      E   D   S   X   X
*      B   B   S   1   1  DRXID  TFAIL2   HCYL     RCYL   XOZRMX  XOSSMX
BH0700 1 1.0 1.0 1.0 1.0 7.0104 1524.0  2.047494 3.187699 1.0E-6  1.0E-6
*
* reiterate the fourth eutectic
*       TMLIEU  IEUKEY  FRCKEY   EKYMIN
BH0804   2573.2  11     .86800    0.0
*
*     IEU(J,LL) 1.LE.J.LE.20, 1.LE.LL.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 =   AG    CDIN  -     -     B4C
*         11 12 13 14 15 =   ZRO2  FEO   FE2O3 FE3O4 CR2O3
*         16 17 18 19 20/=   NIO   B2O3  UO2   -     - /
*
*     IEU(J,LL)=0 MEANS THAT SPECIES J IS NOT IN EUTECTIC LL
*              =1 MEANS THAT SPECIES J IS IN EUTECTIC LL
*BH09LLK
*      LL=EUTECTIC INDEX
*       J=PURE SPECIES INDEX
*       K=CARD COUNTER
* 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
*
*BH10LLK
*      LL=EUTECTIC INDEX
*       J=PURE SPECIES INDEX
*       K=CARD COUNTER
*       XRNKEY(J,LL)  1.LE.J.LE.20, 1.LE.LL.LE.IEUTEC, 1.LE.K.LE.4
* 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  .868    0.0    0.0     0.0    0.0
BH10044  0.0     0.0    .132    0.0    0.0
*
* zero the number of penetrations
*         ---- NPIPES----  DPIPES    HPIPES      TABLAT
*         (1)   (2)   (3)   (M)      (W/M**2-K)   (K)
BH1100      0     0     0   .04572    1.0214E3    1755.4
*
*       user controlled
*       print frequency
*      for bottom head
*         DTPNTB(sec)      dbdrpr(kg/sec)
BH1300     180.0             2000.0
*
*
**
*BH15CC heat transfer characteristics of bottom head
* external surface
*      ibcbh(jj) iflobh(jj)   fcrtr(pool,jj) fcrtr(atm,jj)
BH1509     1         1           0.45           0.45
BH1514     1         1           0.45           0.45
BH1517     1         1           0.45           0.45
BH1518     1         1           0.45           0.45
*
* reset tfails
* input for the BH package lower plenum debris to overlying
* structure radiation model (BH18... series)
*     NSHDLP   TFAILS  NHSOF2
BH1800  3      1700.0     14
*
*
* reiterate the view factors for the debris bed to COR ring 3
*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
BH180601  0.032  0.032  0.032  0.022  0.007  * JJ=06:COR ring 3
*
```

```
* bh lp abrk control functions
BH1900  193
*
*  RN classes associated with the NPURE BH package species
* (ICLSBH(I) 1.le.I.le.20)
BHRN101    8  7 7 7  0   12  12 0 0 13    8 7  7 7 7  7 13 10 0 0
*
******************************************************************
******************************************************************
CF01300 'CONDUCTION POWER' EQUALS   1   1.0   0.0 * use BH to HS
*                                          conduction power up wall
******************************************************************
*
* reset minimum initial liquid debris pour mass for BH
SC00231  5020  5000.0  1
* terminator record
.
```

5. BH Package Output: Other Package Output

In general, the BH package output is self-explanatory. Examples are provided in Section 6.0 of the Bottom Head (BH) Package Reference Manual, together with a detailed description of each item of the pictorial display and tabulated output.

For a MELGEN run and on the first cycle of a MELCOR restart, all of the input information to the BH package is printed, including much of the time-independent database. The temperature, masses, and energy exchange are written during succeeding edit cycles controlled by DTPNTB on BH1300 and BH13NN input records. In addition, the cumulative energy/enthalpy and gas mass exchanges between BH and CVH are included in the normal MELCOR print edits. Localized heat transfer coefficients and computed flow regime identifiers for the bottom head external surface are also included.

A summary of the various terms of the BH package energy balance is included. All three models (debris/wall, debris/pool, and post core boundary failure model) are summarized.

In addition to the discussion above concerning BH printed output, the user should be aware that during the period that BH is exercised, the COR package output does not contain information pertaining to axial segments below the level of the core plate. (All values below index NTLP are set to zero.) This is because COR package processing is bypassed for the lower plenum region and the user should consult the output from the BH package. Affected portions of the following COR package output include: component temperatures, component decay power, component masses, cell volumes, and component surface areas. In addition, the COR package output concerning the lower head penetrations and the lower head is also bypassed during this period.

Output concerning fission product distributions, the associated decay heats, and the release fraction information should be interpreted with special understanding. No fission product release calculations are performed by the COR package for debris in the lower plenum once the BH package has begun processing.

However, fission product releases from this debris are performed by the BH package. To facilitate the integration of the release information into the RN package from BH, the transfer arrays and the RN package processing logic developed for COR releases are utilized with no modification to accept BH-derived information. As a result, the RN package printed edits for inventory and release information do not distinguish between the COR package and the BH package. In particular, the printed RN inventories of elemental radioactive masses for each class appearing to reside in core cell 101 for the particulate debris component (6) are equivalent to the sum for each class over all of the control volumes of the BH package debris bed.

To clarify and identify fission product information of interest to the BH package, printouts of the current fission product class mass inventories in each debris bed control volume as well as the instantaneous and cumulative fission product class releases from the entire bed calculated by the BH package are summarized in the BH package section of MELCOR output.