DEBRIS GENERATION METHODOLOGY GUIDANCE

This document provides guidance on the methods to be used to determine the amount of debris generated by a postulated break in piping inside containment and the associated transport characteristics of that debris.

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1) GENERAL CONSIDERATIONS

This section provides guidance on evaluating debris generation to be used in assessing post-accident containment sump performance through:

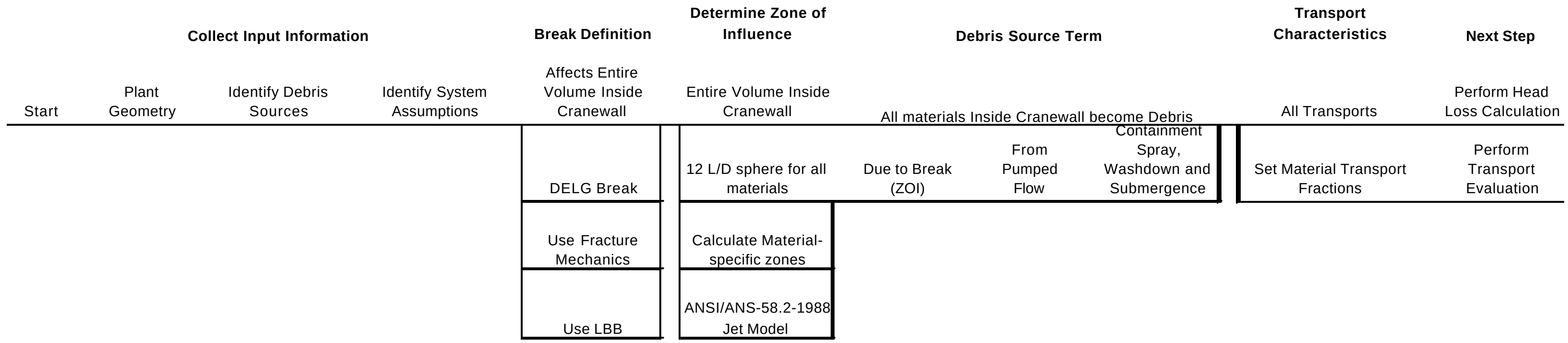
- The identification of an appropriate piping breach,
- Identification of an appropriate resulting Zone of Influence (ZOI) in which materials (insulation, protective coatings, other materials) are reduced to debris, and,
- Additional debris generation due to action of containment spray and submergence

The debris generation evaluated here is then used as input to an evaluation of the transport characteristics of that debris and its subsequent transport to the containment sump

A logic diagram, highlighting options that may be taken in performing the debris generation evaluation, is given in Figure 1-1. The diagram highlights the major steps in evaluating debris generation. Note under the title, "Break Definition," one may also insert Medium and Small LOCA's.

The process for collecting inputs for evaluating the break size, debris generation and resulting transport characteristics of the debris is presented graphically in the flowchart of Figure 1-2. Details describing the specific steps are described in the following sections.

Figure 1-2: Logic Diagram for Debris Generation Analysis



This figure presents a logic diagram of the steps needed to evaluate debris generation. To use this figure, start at the left-hand side of the figure and move to the right. Each junction represents an option in the evaluation methodology. For example, at the break definition, four (4) options are offered.

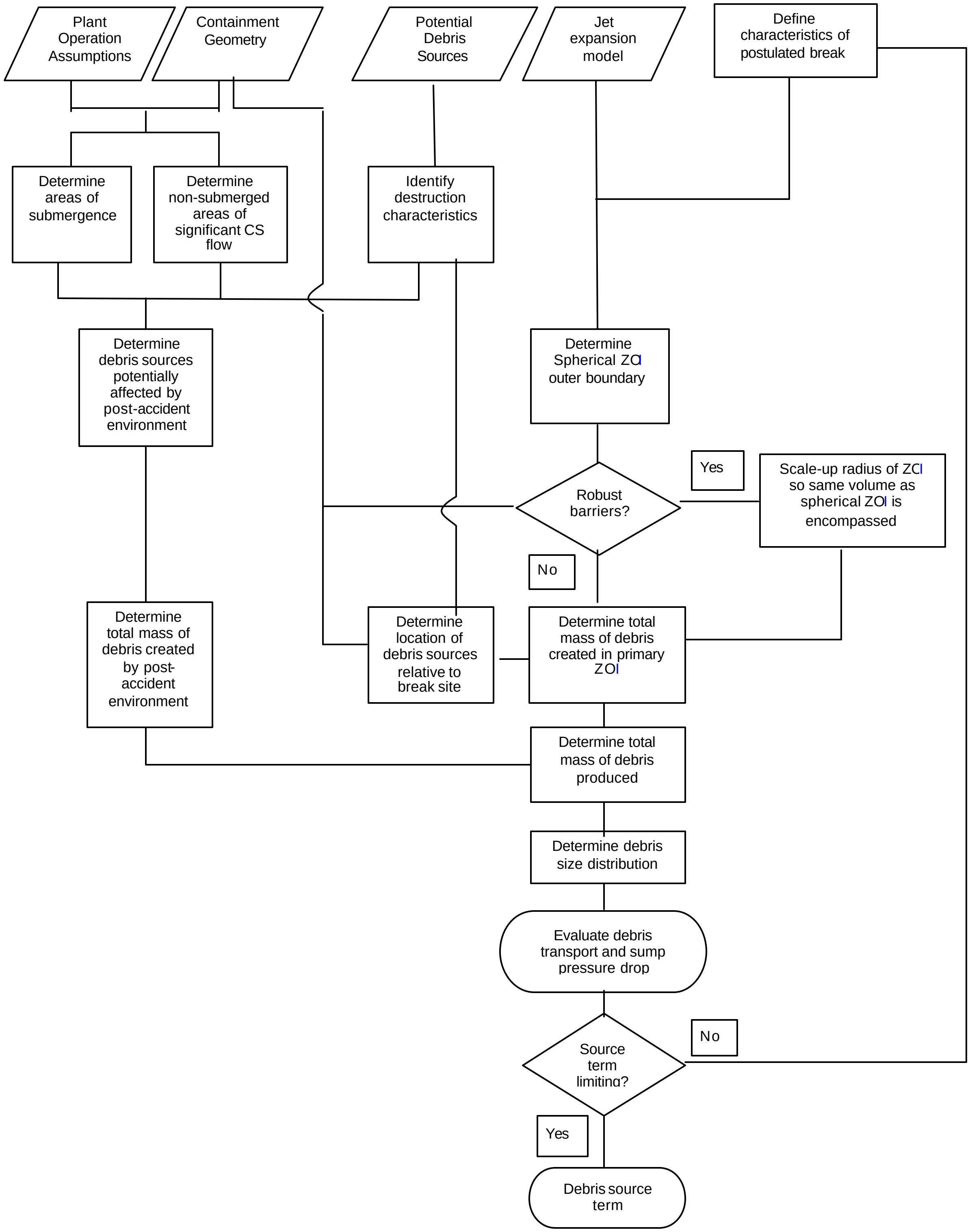
1. The first option takes the entire volume of the containment to be affected by the postulated break. This option removes the break size from consideration and provides for all insulation, non-DBA qualified coatings and other non-DBA qualified materials inside containment to be considered as a debris source. This option provides for the evaluation of an extremely conservative the region that would be affected by the energy release from the postulated break.

2. The second option is to take a complete severing of the pipe in question. This approach provides for the generation of a very conservative region of the containment that would be affected by the energy release from the postulated break, consistent with a double-ended rupture of piping.

3. The third option utilizes the flow area of a stable leakage flaw, with a multiplier, to define a break size for use in evaluating debris generation. This approach provides for a more realistic, but still conservative evaluation of the region of containment that would be affected by the energy release from the postulated break.

4. The fourth and final option is to use Leak Before Break (LBB) technology to define the flow through a stable leakage crack that is, in turn, used to evaluate debris generation. This approach provides for a realistic evaluation of the region of containment that would be affected by the energy release from the postulated break.

Figure 1-1: Flow Chart Describing Debris Generation Analysis



2) PLANT CONDITIONS

2.1) Containment Geometry

Use the results of the containment condition assessment performed using NEI-02-01 (Reference 1) to inventory the containment geometry information pertinent to the sump performance evaluation. In accomplishing this, it is recommended that the following tasks be performed:

2.1.1) Identify all robust barriers located inside containment. Robust barriers are defined as structures and equipment that are impervious to jet impingement and prevent further expansion of the break jet.

2.1.2) Record layout of high-energy piping.

2.1.3) Determine the major paths for containment spray flow and assess the areas covered by the containment sprays.

2.1.4) Determine the containment spray flow paths to the sump.

2.1.5) Determine areas where submergence will occur. It is recommended that this be accomplished by:

2.1.5.1) First determine the maximum possible sump depth.

2.1.5.2) All areas of the containment below that depth would then be considered submergence areas.

2.2) Debris Sources

Use containment walkdown results to inventory the potential debris sources inside containment.

2.2.1) Identify and document the types, quantities, and locations of insulation materials.

2.2.2) Identify and document the types, quantities, and locations of both DBA-qualified and non-DBA-qualified coatings (for pre-ANSI-101.2 plants, acceptable and non-acceptable coatings).

2.2.3) Determine the types, quantities, and locations of latent debris sources.

2.3) Plant System Operation Assumptions

The operation of plant systems will have an impact on the sump performance evaluation. The following may be used to define the plant system operations for the debris generation evaluation:

2.3.1) The following assumptions are recommended for use throughout the evaluation:

2.3.1.1) All containment spray trains are functional

2.3.1.2) Containment spray actuation occurs with Engineered Safeguards Features (ESF) pump start signals following a LOCA.

2.3.1.3) All ECCS trains are functional.

2.3.1.4) Loss of offsite power occurs coincident with event initiation (taken to be consistent with limiting single failure assumption for Design Basis Analysis calculations)

2.3.2) It is recommended that assumptions listed above be compared to documented vendor-specific and plant-specific accident sequences and environmental conditions. Where supported by plant-specific and vendor specific documentation, the plant-specific accident sequences and environmental conditions may be used.

2.3.3) It is suggested that NUREG/CR-6670 (Reference 2) be consulted for additional information that may be used to supplement and augment plant-specific and vendor-specific accident sequences and environmental conditions for debris generation.

3) BREAK CHARACTERISTICS AND LOCATIONS

3.1) Pipe Break Sizes

The debris generation for postulated large, medium and small piping breaks is to be considered. The debris generation for each of the breaks is calculated for each break size in an interative manner to determine the worst possible accident break size, location and accident sequence to evaluate a limiting source term for transport to the containment sump.

3.1.1) The timing of events in the postulated accident (such as spray washdown, transport, pool level, accident progression, and head loss) account for the break size used to for the purpose of debris generation.

3.1.2) Note that the pipe break size will determine the selection of the pipe break characteristics to be used to evaluate debris generation.

3.2) Pipe Break Characteristics

Table 3-1 identifies and gives a brief discussion of the recommended options a plant might choose with regard to identifying the characteristics of a postulated pipe break to be used to evaluate debris generation. The options provide results that range from extremely conservative to realistic. Note that the more realistic the pipe break characteristics selected by the plant, the greater the effort needed to support the use of that option. The plant may chose the pipe breach option it determines appropriate for its specific design and condition.

3.3) Pipe Runs to Consider

The break location with the limiting consequences for sump function will be used for the plant evaluation. Since debris generation and debris transport should be included in the identification of the limiting break location, the identification of that location will be an iterative process. As a minimum, breaks in the following lines should be considered:

3.3.1) Hot leg, cold leg, intermediate (crossover) leg and surge line.

3.3.2) Piping attached to the reactor coolant system. Examples include, but are not limited to:

- Charging Lines
- RHR lines

3.3.3) Some plant designs require plants to eventually recirculate coolant from the sump for pipe ruptures other than LOCA's. Two such events are:

- Main feedwater breaks
- Steam line breaks

If this is true for the plant under consideration, then these lines must also be considered for debris generation.

3.4) Selection of Break Locations

For Options 2, 3 and 4 identified under Section 3.2, Pipe Break Characteristics, the volume of debris generated is evaluated by assuming a pipe break at 3-foot intervals along the run of the pipe. At each 3-foot interval, the volume of debris generated by the fluid released by the postulated break from the materials in the Zone Of Influence is calculated.

3.5) Other Considerations

3.5.1) Look for and evaluate breaks with the most direct flow path to the containment sump. Confirmation of the direct flow path between the break location and the containment sump from may be accomplished by using containment layout drawings.

3.5.2) Locations of large breaks that generate two or more different types of debris. These locations are determined by considering the location of materials (insulation, coatings, etc,) inside containment relative to the break location and Zone of Influence. The location of materials inside containment should have been identified during the application of NEI-02-01,

3.5.3) Medium and large breaks with the largest potential particulate debris to insulation ratio by weight.

3.5.4) Locations for which postulated breaks generate an amount of fibrous debris that, after transport to the sump screen, creates a minimum uniform thin bed (1/8-inch layer of fiber) to filter particulate debris.

3.6) Evaluate the probability of failure and the predicted mode of failure for each of the possible break locations. If the probability of rupture for a given location is extremely low, or a small failure is expected to occur instead of a full double-ended break, the dynamic effects associated with a rupture at that break site may be excluded from consideration.

Exclusions may only be made when piping system design analyses reviewed and approved by the NRC demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping.

Based on the probability and mode of failure for each possible break location, determine the Zone of Influence (ZOI) for each break site using the guidance presented in Section 4.

Table 3-1: Pipe Break Characteristics

Option	Pipe Break Characteristics	Pipe Break Size	Discussion
1	Assume that the postulated break affects the entire volume inside crane wall (This is not a break characteristic, but rather a consequence of the break.)	Debris generation is evaluated independent of pipe break size since the full containment volume inside the crane wall is affected by the break.	This approach: • Takes the entire volume of the containment to be affected by the postulated break. • Removes break size from consideration. • Provides for all debris sources inside containment to be considered in the total volume of debris generated. • Provides for the evaluation of an extremely conservative the region that would be affected by the energy release from the postulated break.
2	Complete severing of the pipe	Break area is equal to the total cross sectional area of both sides of the pipe. However, the break area is reduced if flow is terminated from one side of the break	This approach provides for the generation of a very conservative region of the containment that would be affected by the energy release from the postulated break, consistent with a double-ended rupture of piping. This approach would use a ZOI of either: • A sphere of 12 times the diameter of the broken pipe (constant ZOI), or,' • Material specific ZOI's, dependent upon the destruction pressure of materials inside containment.
3	Fracture Mechanics-Based Break	The following generic break flow areas are used for primary coolant piping: B&W : 83 in^2 CE : 40 in^2 Westinghouse :	This approach takes advantage of the inherent toughness of PWR piping design. Fracture Mechanics methods are applied to identify a stable leakage flaw flow area, and an associated multiplier on that flow area is applied to define a break size for use in evaluating debris generation. Break sizes calculated with this approach

		40 in^2 Flow areas from plant-specific fracture mechanics analyses, multiplied by 10^3, may also be used for surge line and other piping, if such analyses have been performed for the plant.	are typically less than the break size resulting from a complete severing of the pipe. Fracture mechanics approaches have typically been applied to piping that has been qualified as LBB pipe and may be applied, if desired, to additional non-LBB piping at the discretion of the plant owner. This approach provides for a more realistic, but still conservative evaluation of the region of that would be affected by the energy release from the postulated break. A hemispherical ZOI is used for this approach.
4	Leak Before Break (LBB) Methods	Twice the flow area of a stable through-wall flaw that yields a 10-gpm leak is used.	LBB methods require the use of fracture mechanics methods to define a through-wall crack that yields 10-gpm leak. LBB methods require that a crack twice the length of the 10gpm leak be shown to be stable (won't instantaneously grow). Twice the length yields twice the flow area of the 10 gpm through wall flaw. The flow area is, in turn, used to evaluate the flow rate through the flaw which, in turn, is used to evaluate debris generation. This approach provides for a realistic evaluation of the region of containment that would be affected by the energy release from the postulated break.
5	RCP Seal LOCA	Total flow is limited by the maximum seal leakage for the RCP pump being considered.	Consider the geometry of the discharge of the leakage flow path when evaluating debris generation associated with the postulated RCP seal LOCA. Specifically, consider the orientation of the leakage flow relative to its release into containment.

4) ZOI DEFINITION

4.1) ZOI Geometry

The Zone of Influence (ZOI) is the volume about the break in which the fluid escaping from the break has sufficient energy to generate debris from insulation, coatings, etc. The following table identifies and gives a brief discussion of the recommended options a plant might choose with regard to identifying a ZOI to be used to evaluate debris generation. The options identified provide for the evaluation of ZOI's that range from a physical representation of a jet to a conservative approximation that the entire volume within the crane wall becomes a potential source of debris. Note that the use of directionally dependent ZOI's will require a greater effort to support their use. The plant should chose the ZOI option it determines appropriate for its specific design and condition.

4.2) Robust barriers (structures that prevent further expansion of the break jet in a given direction) will be included in the evaluation.

4.2.1) If a break jet encounters a robust barrier, the ZOI created will have a spherical boundary with the exception of the volume beyond the robust barrier.

4.2.2) The radius of the spherical boundary will be redefined such that the volume encompassed by the ZOI is equal to that encompassed by the spherical ZOI that would be created if the robust barrier were not present.

4.2.3) Pure reflection of break jets will not be included in the evaluation. The use of a spherical ZOI is intended to bound any jet reflection effects.

4.2.4) Likewise, the effects of pipe whip and traveling jets are bounded by the spherical ZOI.

4.3) Thermal Hydraulic Conditions

4.3.1) LOCA Definitions

The following break sizes are defined for the purposes of performing this evaluation:

Large LOCA - > 6-inches

Medium LOCA - from 2-inches to 6-inches

Small LOCA - < 2-inches

Plant-specific definitions of the various categories may supercede these definitions.

4.3.2) For the postulated break location, determine the following information:

4.3.2.1) System fluid conditions (pressure and temperature of the RCS coolant).

4.3.2.2) Size of break, based on the size of the pipe and results of piping analyses. See Attachment A for breach size as determined through the application of Fracture Mechanics.

4.3.2.3) Locations and geometry of equipment and structures surrounding the break site.

4.3.2.4) Destruction pressures of materials surrounding the break site that are potential contributors to the debris source term.

4.3.3) Define the jet impingement pressure(s) of interest, based on the destruction pressures of materials surrounding the break site. Three methods recommended for defining the jet impingement are:

4.3.3.1) Using a sphere having a radius of 12 times the break size, assume that all debris sources become debris.

4.3.3.2) Identify the types of potential debris in the area of containment surrounding the break site. Determine which potential debris source has the lowest destruction pressure. Use this destruction pressure to as the jet impingement pressure of interest.

4.3.3.3) Identify the types of potential debris in the area of containment surrounding the break site. Consider multiple jet impingement pressures, with each equal to the destruction pressure of one of the potential debris sources being considered.

4.3.4) If using destruction pressures to evaluate debris generation:

4.3.4.1) Use the break size and geometry, the system fluid conditions, and the containment thermodynamic state as initial conditions to calculate the jet expansion and equivalent static impingement force as described in Chapter 7 of ANSI/ANS-58.2-1988 (Reference 3).

4.3.4.2) Using the volume of the expanded jet calculated from the preceding step, calculate the diameter of an equivalent sphere that would have the same volume as that jet. This spherical volume is the ZOI.

4.3.4.3) Consider both transient and steady state break flow in calculating the volume of the ZOI.

4.3.5) Determine where the outer boundary of the sphere or hemisphere would exist inside containment.

4.3.6) Evaluate the effects of robust barriers (defined as structures and equipment that are impervious to jet impingement and prevent further expansion of the break jet):

4.3.6.1) Use the locations and geometry of equipment and structures surrounding the break site to determine if robust barriers are present.

4.3.6.2) Calculate the portion of the spherical ZOI that would be intercepted by the robust barriers.

4.3.6.2.1) If a break jet encounters a robust barrier, the ZOI created will have a spherical boundary with the exception of the volume beyond the robust barrier.

4.3.6.2.2) Debris generation in any part of the ideal spherical ZOI that would be located beyond the robust barriers is not considered.

4.3.6.3) The overall volume of the ZOI is not reduced. Re-calculate the radius of the spherical boundary such that the volume encompassed by the ZOI is equal to that encompassed by the spherical ZOI that would be created if the robust barrier were not present.

Note that increasing the radius of the outer boundary of the ZOI could cause additional robust barriers to be encountered. Thus, multiple re-calculations of the outer boundary of the ZOI may be necessary.

4.3.7) If multiple jet impingement pressures are being considered, repeat the process of determining the outer boundary of the ZOI for each pressure of interest.

Table 4-1: ZOI Geometry

Option	ZOI Geometry	Discussion
1	Entire volume within crane wall	This assumes that a postulated pipe break generated debris from all insulation and coatings within the crane wall. This approach provides for the postulated generation of a maximum volume of debris.
2	Sphere having a diameter of 12 times the cross sectional diameter of the severed pipe	This geometry is used with a complete severing of the pipe being evaluated. A constant sphere of 12 times the diameter of the pipe provides for a maximum ZOI volume, which, in turn, maximizes the debris from robust and non-robust insulation types.
3	Spheres of various diameters, depending upon the destruction pressure of the material being considered as a debris source	This geometry is used with a complete severing of the pipe being evaluated. Accounting for the destruction pressure of materials being considered can reduce the volume of debris generated from robust materials.
4	Hemispherical shape having a diameter of 12 times the hole size.	This geometry is used with a postulated hole in piping taken from the stable leakage flaw flow area calculated using fracture mechanics methods. This takes the postulated hole to be circular. A constant hemisphere of 12 times the diameter of the hole size calculated using fracture mechanics methods provides for a maximum ZOI volume, which, in turn, maximizes the debris from robust and non-robust insulation types.
4	Hemispheres of various diameters, depending upon the destruction pressure of the material being considered as a debris source	This geometry is used with a postulated hole in piping taken from the stable leakage flaw flow area calculated using fracture mechanics methods. This takes the postulated hole to be circular. Accounting for the destruction pressure of materials being considered can reduce the volume of debris generated from robust materials. The use of a hemispherical ZOI suggests that debris generation is dependent upon the break orientation.

		The break orientation may affect the volume of debris generated and should be considered in calculating the volume of debris resulting from the break.
5	ANSI/ANS-58.2-1988 Jet Model	This geometry is used with a postulated hole in piping taken from the stable leakage flaw flow area calculated using fracture mechanics methods. This takes the postulated hole to be circular. This model predicts geometry of a jet and its associated static pressure as the jet expands. The use of the model gives a direction to the destruction caused by the jet. Thus, orientation of the break becomes important, as only those items in the path of the expanding jet are considered "targets" for debris generation. The directional effects of the jet become important when the fracture mechanics approach described in Section of the is particularly the case in the event of the requires the direction of the escaping coolant to be

5) DEBRIS QUANTITY CALCULATION

For the purposes of this document, the following terms are defined:

Encapsulated Insulation: Encapsulated insulation is insulation covered on all surfaces by metal sheets. Examples of encapsulated insulation include RMI and calcium silicate cassettes.

Jacketed Insulation: Jacketed insulation is installed insulation material that is covered on the outer diameter by a wide variety of materials, typically metallic. Examples of jacketed material include fiberglass or calcium silicate wrapped with aluminum foil.

Wrapped Insulation: Wrapped insulation is insulation that is covered on the outside by a non-metallic wrapping. Typically, the wrapping is an epoxy impregnated fiberglass mesh that is either fastened to the insulation by tie wraps, or has been glued to the insulation.

5.1) ZOI

The following is a recommended process for calculating the amount of debris generated within the ZOI. The boundaries of the ZOI are calculated using one of the methods described in Section 4.

5.1.1) For each potential debris source of interest, calculate the amount of material that is located inside the ZOI. All material located in this area will contribute to the debris source term.

5.1.2) For breaks postulated in the vicinity of the pressure vessel, consider packing materials used in penetrations as a potential source of debris. Review the design and test packages for these materials to determine if they should be included as a debris source for break locations located near the pressure vessel.

5.1.3) Use the debris characteristics in Section 6 to assign a debris size distribution to each debris type.

5.1.4) Catalog the results for each debris type.

5.2) Post-Accident Environment

5.2.1) Containment Spray Washdown

Containment spray action has the potential to cause debris generation from some materials used inside containment. The recommended procedure to determine the quantity of debris generated by this mechanism is as follows:

5.2.1.1) Use containment walkdown data to identify the potential debris sources located throughout containment.

5.2.1.2) Catalog the type, location, and quantity of each potential debris source.

5.2.1.3) Evaluate the debris production from each of the potential sources. It is recommended that the following considerations be made when performing the evaluation:

5.2.1.3.1) RMI is not affected by washdown effects since it is not soluble or easily penetrable by water and therefore will not become a debris source from the action of containment sprays.

5.2.1.3.2) Calcium Silicate with metal encapsulation will not become a debris source from the action of containment sprays.

5.2.1.3.3) DBA-qualified coatings will not become a debris source from the action of containment sprays.

5.2.1.3.4) Non-DBA-qualified coatings will become debris sources. Section 6.4, Table 6.5 (later), and Appendix (later) contain detailed information regarding the failure of these materials.

5.2.1.3.5) Encapsulated insulation materials not within the ZOI are resistant to containment spray action and therefore are not a debris source.

5.2.1.3.6) Jacketed insulation that could be subjected to containment spray should be evaluated as a debris source.

If the jacketing is overlapped or butted end-to-end, deterioration of insulation due to containment sprays is mitigated: the configuration of the jacketing, however, should be confirmed by walkdown.

If the jacketing is not overlapped or butted end-to-end, debris generation due to erosion may occur.

It is recommended that the volume of insulation that will be treated as debris be calculated using four times the width of the gap between two adjacent jackets, and the thickness of the insulation at that location.

It is also recommended that the debris generated due to this method be treated as fines or individual fibers.

5.2.1.3.7) Unjacketed and / or unencapsulated insulation may be susceptible to damage as a result of containment sprays. These types of materials are typically used in fire barrier applications.

If this type of insulation is known to be subject to erosion, and the material is subjected to containment spray, then it is recommended that the entire volume of the material be treated as a debris source.

It is also recommended that the debris generated due to this method be treated as fines or individual fibers.

5.2.1.3.8) Various other types of materials in containment contribute to the debris source term. Section 6 contains detailed information regarding these materials.

5.2.2) Pumped Break Flow

This is not considered to be a credible debris generation mechanism as the jet resulting from RCS depressurization will cause significantly more damage to insulation and will result in the distribution of the resulting debris about the containment away from the postulated break location.

5.2.3) Submergence

Submergence has the potential to cause debris generation from some materials used inside containment. The recommended procedure to determine the quantity of debris generated by this mechanism is as follows:

5.2.3.1) Determine what areas inside containment will be submerged in the post-accident environment.

5.2.3.2) Submerged areas that are either isolated from the sump, or for which fluid in the area does not equal or exceed the transport threshold velocity of debris contained within that area, may be excluded from the evaluation. Debris generated in these areas is not transportable to the sump.

5.2.3.3) For areas that have transport paths to the containment floor or sump, the following procedure should be used:

5.2.3.3.1) Determine the maximum water height above the containment floor, based on the plant operation assumptions recommended above.

5.2.3.3.2) Assume all areas below the maximum water height are fully submerged (all surfaces are exposed to water – credit will not be taken for air pockets).

5.2.3.3.3) Determine other areas inside containment that will be submerged. Possible areas include cable trays and the refueling canal.

Note that it is possible that some areas will be continuously draining yet remain filled with water because of continuous water input from containment sprays.

5.2.3.4) Use condition assessment and containment walkdown data to identify the potential debris sources located in areas subject to submergence.

5.2.3.5) Catalog the type, location, and quantity of each potential debris source.

5.2.3.6) Evaluate the consequential debris production due to submergence from each of the potential types, particularly if the debris generated by fluid escaping from the break remains in the flow path to the containment sump. Base the debris production amount on the debris characteristics presented in Section 5. It is recommended that the following considerations be made when performing the evaluation:

5.2.3.6.1) RMI is not affected by submergence effects since it is not soluble or easily penetrable by water and therefore will not become a debris source from the action of containment sprays.

5.2.3.6.2) Encapsulated insulation materials are resistant to submergence effects and therefore are not a debris source.

5.2.3.6.3) Jacketed insulation that could be subjected to submergence should be evaluated as a debris source.

If the jacketing is overlapped or butted end-to-end, deterioration of insulation due to submergence is mitigated: the configuration of the jacketing, however, should be confirmed by walkdown.

If the jacketing is not overlapped or butted end-to-end, debris generation due to submergence and limited erosion may occur.

It is recommended that the volume of insulation that will be treated as debris be calculated using four times the width of the gap between two adjacent jackets, and the thickness of the insulation at that location.

It is also recommended that the debris generated due to this method be treated as fines or individual fibers.

5.2.3.6.4) Unjacketed and / or unencapsulated insulation may be susceptible to damage as a result of submergence. These types of materials are typically used in fire barrier applications.

If this type of insulation is known to be subject to erosion, and the material is subjected to immersion, then it is recommended that the entire volume of the material be treated as a debris source.

It is also recommended that the debris generated due to this method be treated as fines or individual fibers.

5.2.3.6.5) DBA-qualified coatings tested in immersion will not become a debris source from either the action of containment sprays or post-accident submergence.

5.2.3.6.6) Non-DBA-qualified coatings, and DBA-qualified coatings not tested in immersion, are potential debris sources. Section 6.4 contains information regarding the failure of these materials.

5.2.3.6.7) Various other types of materials in containment contribute to the debris source term when submerged. Section 6 contains detailed information regarding these materials.

5.3) Total Debris Source Term

The total debris source term is determined by summing the volume of:

- The individual debris types produced in the ZOI,
- The individual debris types produced in the post-accident environment, and,
- The volume of latent containment debris evaluated for the plant.

The total debris source term is used in the remainder of the sump performance evaluation: debris transport to the containment sump, debris accumulation and head loss across the containment sump screen.

If the results of the evaluation using a particular debris source term do not represent the worst case with respect to debris generation, debris transport or debris accumulation and sump screen pressure drop, the postulated break should be changed and a new source term calculated.

6) DEBRIS CHARACTERISTICS

This section provides data to be used with the logic and procedures presented above to conservatively predict the characteristics of debris generated as a result of a LOCA.

6.1) Fibrous Insulation

Physical characteristics of fibrous materials (except Calcium Silicate, which is addressed in Section 6.2) are identified in Table 6-1. Not all generated fibrous debris will be assumed to be of a size that is transportable. The specifics of transportability will be discussed in the Debris Transport section.

Fire barrier materials are addressed separately in Section 5.6.

For some plant sites, it may be desirable to use a bounding, simplifying assumption for the debris size distribution. It would always be acceptable to conservatively assume that all debris is generated into fine particles. It is also acceptable to assume a more conservative (biased toward smaller pieces) distribution than that presented in the table above.

6.2) Cal-Sil Insulation

6.2.1) Calcium silicate insulation typically has a higher destruction pressure than most types of fibrous insulation.

6.2.1.1) NRC confirmatory analyses performed to support resolution of strainer issues for BWRs indicate a destruction pressure of 150 psi for calcium silicate insulation with an aluminum jacket.

6.2.1.2) However, calcium silicate destruction tests performed by Ontario Power Generation indicate that the destruction pressures can be less than 24 psid, depending on the orientation of the longitudinal cladding seams.

6.2.2) The destruction pressures for calcium silicate are given in Table 6-2.

6.2.3) If credit for orientation of cladding seams is to be taken:

6.2.3.1) Data from the licensee's walkdown program will be used to determine the orientation of seams relative to the postulated break. Probabilistic methods will not be used with regard to seam orientation.

6.2.3.2) Assumptions according to Table 6-2 are recommended to determine the destruction pressure of the cal-sil insulation. The values are based on the Ontario Power Generation jet impact tests.

6.2.3.3) The licensee should implement sufficient procedures and configuration controls to assure that future modifications or repairs to insulation will either not invalidate the debris generation evaluation, or will initiate a review of the debris generation evaluation to evaluate the effect of the modifications or repairs on the volume of debris generated.

6.2.4) The suggested method for determining calcium silicate debris generation is:

1. Identify seam orientation of jacketing for each pipe section located within the ZOI based on the lowest calcium silicate destruction pressure
2. Use the stagnation pressure vs. radius information to determine the impingement pressure on each pipe section. The pipe section shall be defined as the length of pipe that is covered by one piece of jacketing.
3. If $p_0 > p_{dest}$, assume all calcium silicate insulation on the pipe section in question fails.

6.2.5) As an alternative, a conservatively low destruction pressure can be assumed for all sections of pipe that are potentially located within the primary ZOI.

6.2.6) When calcium silicate insulation is damaged, a number of types of debris can be generated. The recommended debris size distribution is given in Table 6-2.

6.3) Reflective Metallic Insulation (RMI)

6.3.1) RMI debris is assumed generated within the ZOI. Typically, RMI is installed in pre-fabricated cassettes that conform to the piece of equipment being insulated. Break jet impingement can dislodge RMI and possibly destroy cassettes, creating smaller pieces of debris.

The following information will be used to evaluate the potential for debris generation from RMI cassettes:

6.3.1.1) Latch mechanism types and characteristics

6.3.1.2) Pressure at which destruction of the cassettes will occur

6.3.1.3) Differences in destruction pressure for different insulation brands and types

6.3.1.4) Modes of insulation detachment and destruction

6.3.1.5) Destruction of insulation adjacent to the break site

6.3.2) RMI destruction regimes are defined as:

6.3.2.1) Dislodged cassettes

6.3.2.2) Damaged cassettes (individual foils produced)

6.3.2.3) Complete destruction (shredded and crumpled foils). This occurs for RMI located on the section of piping where the break occurs and on sections of pipe and components located within 6 pipe diameters of the break site.

6.3.3) The destruction pressures for RMI are given in Table 6-3.

6.3.4) The recommended debris size distribution is given in Reference 4.

6.4) Coatings

6.4.1) DBA-qualified coatings outside the ZOI do not fail and do not contribute to the debris source term.

6.4.2) All coating materials (Q and non-Q) will be assumed to fail within the ZOI and will contribute to the debris source term. Representative physical characteristics of the failed coating materials within the ZOI are shown in Table 6.5 (later).

6.4.3) Non-DBA-qualified coatings, and DBA-qualified coatings not tested in immersion, outside the ZOI may disbond from the substrate and contribute to the debris source term. A conservative fraction of failed non-qualified coatings should be determined from existing empirical data with consideration of location, application methods, coating condition, etc. An EPRI/NUCC white paper "(later)" addresses this topic and is included in its entirety as Appendix A.

6.4.4) Non-DBA-qualified coatings that are potential debris sources include coatings on equipment permanently stored in containment or temporarily left in containment after an outage.

6.4.5) Representative physical characteristics of failed coating materials within the ZOI are shown on Table 6.5 (later) and will be used as input to the transport evaluation.

6.5) Tape and Stickers

6.5.1) All tape and stickers located in the ZOI will fail and contribute to the debris source term. This includes but is not limited to materials that are qualified for service in DBA conditions. Duct, electrical, masking, and grip tape are potential debris sources but other types of adhesive tape can be used inside containment. Equipment labels and tags secured by adhesives or other means are also potential sources of debris. All tape and stickers located in the ZOI will be assumed to be destroyed, creating small pieces and or fibers.

6.5.2) Tape and stickers should be incorporated in licensees' FME programs to minimize the amount present inside containment. A licensee's FME program will be considered when performing the plant-specific evaluation.

6.5.3) All non-qualified tape and stickers outside the ZOI are assumed to fail unless a technical justification to exclude them from the source term is available. Non-soluble tape, stickers, and tags secured by adhesives located outside the ZOI will be assumed to fail by peeling off the surface they are attached to. Soluble tape, stickers, and tags secured by adhesives or other means will be assumed to dissolve under the action of containment sprays or other sources of water.

6.5.4) The size distribution of the debris produced by tape and stickers will be evaluated on a case-specific basis. The properties of the materials in question will be used to determine a conservative debris size distribution (i.e., biased toward smaller, transportable forms). It is appropriate to assume that all debris created from tape and stickers is reduced into fine or small pieces or individual fibers.

6.5.5) It is noteworthy that for some plant-specific applications, the amount of debris produced by tape and stickers will be quite small compared to the contributions from other materials inside containment. In these cases, it may be possible to neglect the contribution of tape and stickers to the debris source term.

6.6) Fire Barrier Materials

6.6.1) Fire barrier material may be a source of debris inside containment.

6.6.1.1) This includes board material, blanket material, and foam material.

6.6.1.2) Fire barrier materials within the ZOI are to be evaluated as potential debris sources.

6.6.2) Fire barriers consist of many types of insulation and other materials.

6.6.3) Many of the materials are similar or identical to those used to insulate RCS piping and components.

6.6.3.1) These fire barrier materials may be treated in the same way as their counterparts used in other applications inside containment (i.e. the same destruction pressures can be used).

6.6.3.2) However, differences in attachment, encapsulation, and construction of the fire barrier materials compared to RCS insulation will be accounted for when determining the amount of debris generated from materials that are also used in other applications.

6.6.4) Fire barrier materials are typically unencapsulated. The destruction pressures for these non-encapsulated blanket materials will be lower than encapsulated RCS insulation of comparable composition.

6.6.5) For materials that are unique to fire barrier applications and do not have supporting test data, assume a destruction pressure equal to that of low-density fiberglass.

6.6.6) Available destruction information for fire barrier and other materials that might be found inside typical PWR containments are given in Table 6-4.

6.6.7) A ZOI for fire barrier materials can then be constructed.

6.6.7.1) This ZOI will be conservative since many fire barrier materials such as fibrous boards will have a higher destruction pressure than low-density fiberglass.

6.6.7.2) As an alternative, engineering judgment can be used to assign destruction pressures based on similarities in material properties between the fire barrier materials and materials for which destruction pressures are known.

6.6.8) There is little information is available regarding the destruction of board-type insulation. In most cases, the destruction pressure for the blanket-type insulation can be assumed to be the same as for low-density fiberglass piping insulation.

6.6.9) Specific Fire Barrier Materials.

6.6.9.1) Marinite board debris is generated within the ZOI.

6.6.9.1.1) According to NUREG/CR-6772, large amount of plastic deformation is necessary to break Marinite Board apart.

6.6.9.1.2) Therefore, Marinite board is assumed destroyed within the ZOI but left intact outside the ZOI.

6.6.9.1.3) All destroyed Marinite board will be assumed to be broken into large chunks.

6.6.9.2) Kaowool Blanket and Mineral Wool

6.6.9.2.1) These types of insulation will be destroyed in the ZOI.

6.6.9.2.2) Destruction data on these materials is needed.

6.6.9.3) RTV foam is assumed to be destroyed within the ZOI.

6.6.9.3.1) As with some other types of fire barrier, destruction information is needed for RTV / silicone foam insulation.

6.6.9.3.2) Foam was not considered in the BWROG URG.

6.7) Miscellaneous Debris Sources

This section discusses the generation of debris from sources inside containment other than RCS and fire barrier insulations. There are many miscellaneous debris sources inside containment. Some common sources are discussed in the following sections.

Due to the variations in containment design and size from unit to unit, many miscellaneous sources will be evaluated on a plant-specific basis. It is not appropriate for the licensees to use their FME programs to entirely eliminate sources of miscellaneous debris.

6.7.1) Dust and dirt.

Dust and dirt includes miscellaneous particulates that are present in the containment. Potential origins for this material include activities performed during outages and foreign particulates brought into containment during outages. Plant-specific walkdown results can be used to determine a conservative amount of dust and dirt to be included in the debris source term.

6.7.2) Concrete.

Concrete located sufficiently close to the break will produce particulate debris. It is appropriate for the licensee to assume all concrete debris will be in the form of fine particulates. The quantity of concrete debris produced will be evaluated on a break-specific and plant-specific basis.

Other miscellaneous debris sources that are to be evaluated on a plant-specific basis are listed below. For each potential debris type considered, debris generation resulting from jet impingement and washdown effects is to be considered.

6.7.3) Fabric equipment covers

6.7.4) Fire hoses

6.7.5) Ropes

6.7.6) Ventilation system filters

6.7.7) Cloth

6.7.8) Wire ties

6.7.9) Plastic sheeting

6.7.10) Rust from unpainted surfaces

6.7.11) Scaffolding

6.7.12) Auxiliary equipment left inside containment

6.7.13) Caulking, mastic, or filler materials

6.7.14) Fibrous material from lead blanket covering material

6.7.15) Radiation protection signage

6.7.16) Operations tags

7) REFERENCES

1.) NEI-02-01, Revision 1, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments", dated September 2002

2.) NUREG/CR-6670, GSI-191: Thermal-Hydraulic Response of PWR Reactor Coolant System and Containments to Selected Accident Sequences

3.) ANSI/ANS-58.2-1988, "Design Basis for Protection of Light Water Nuclear Power Plants Against the Effects of Postulated Pipe Rupture", dated October 6, 1988

4.) "Air Blast Destructive Testing of NUKON® Insulation Simulation of a Pipe Break LOCA," Performance Contracting Inc., dated October 1993

5.) SEA NO. 95-970-01-A:2, "Experimental Investigation of Head Loss and Sedimentation Characteristics of Reflective Metallic Insulation Debris," May 1996, NRC Accession Numbers 9608050121 and 9608050125

Table 6-1: Damage Characteristics of Common Fibrous Insulation Materials Inside PWR Containments

Material Category / Type	Destruction Pressure (psi)	Debris Size Distribution	Comments
1. Fiberglass - Generic a. Unjacketed b. Encapsulated c. Steel-jacketed		Assume same as NUKON.	Assume equal destruction pressure to that of NUKON. Account for encapsulation / jacketing configuration.
2. Fiberglass – NUKON a. Jacketed, with modified “Sure-Hold” bands, Camloc strikers and latches b. Jacketed, with standard bands c. Unjacketed	a. 190 psi b. 10 psi c. 10 psi	NUREG/CR-6224 characterizes NUKON fibers	See Reference 3 for additional information regarding destruction pressure.
3. Fiberglass – Temp-Mat a. Unjacketed, with stainless steel wire retainer b. Other configurations	a. 17 b. Conservatively use data from 3(a), above	Assume same as NUKON.	Use destruction pressure for NUKON. Account for encapsulation / jacketing configuration.
4. Fiberglass – Transco	NUREG/CR 6369 - the debris transport tests at CESI - used Transco blankets. Document has been requested.	Assume same as NUKON.	Assume equal destruction pressure to that of NUKON. Account for encapsulation / jacketing configuration.

5. Mineral Wool	NEA/CNSI/R (95) 11 has information on Mineral Wool. There is some concern of the applicability of this information. Consider using a bounding assumption.	Assume same as NUKON However, it is unclear if fiberglass and mineral wool exhibit similar destruction characteristics.	Using existing data with caution.
6. Miscellaneous Fibrous a. Asbestos b. Min-K – not fiber – this is a micorporous insulation NUREG/CR-6762 indicates it is fibrous c. Unibestos	a. Data needed. b. < 4 psi c. Data needed.	b. SEM of Min-K shows amorphous globs in fiber bed.	Some forms of Calcium Silicate use asbestos fibers as reinforcement. Calcium Silicate is still the insulation type subject to destruction. Therefore, for this insulation, the asbestos reinforcement should not be considered separately.

Table 6-2: Damage Characteristics of Calcium Silicate Insulation Inside PWR Containments

Material Description	Destruction Pressure (psi)	Debris Size Distribution	Comments
Metal-jacketed Aluminum cladding, stainless steel bands	51 (seam at 0°) >24 (seam at 45°) >64 (seam at 180°) NRC SER on the BWR URG suggests 20 psi as a generic value.	Debris Fines: 75% < 1 in.: 10% 1-3 in.: 10% > 3 in.: 5%	Debris destruction pressures determined in NUREG/CR-6762, Vol.3 are based on Ontario Power Generation tests. Debris distribution determined based on data from Ontario Power Generation tests. These data apply only to the type of calcium silicate tested. NEA/CNSI/R (95) 11 has a table on Newtherm – a European variant of Calcium Silicate. Considering the differences in strength between aluminum and stainless steel, it is suggested that the destruction pressure and debris size distribution evaluated for aluminum cladded calcium silicate may be conservatively applied to stainless steel cladded calcium silicate.

Table 6-3: Damage Characteristics of Common Reflective Metallic Insulation Inside PWR Containments

Material Description	Destruction Pressure (psi)	Debris Size Distribution	Comments
Stainless steel a. Transco b. Diamond Power MIRROR (with “Sure-Hold” bands, Camloc strikers and latches) c. Diamond Power MIRROR (with standard banding d. Darchem DARMET	a. 190 psi b. 150 psi c. 4 psi d. 190 psi	See Reference 4 for size distribution	

Table 6-4: Damage Characteristics of Common Fire Barrier and Other Insulation Inside PWR Containments

Material Description	Destruction Pressure (psi)	Debris Size Distribution	Comments
1. 3M Interam	Assume same destruction data as for NUKON (representative of low-density fiberglass).	Assume same destruction data as for NUKON (representative of low-density fiberglass).	Account for encapsulation / jacketing configuration.
2. Fiberglass blanket	Conservatively assume destruction data for fiberglass or Temp-Mat.	Conservatively assume destruction data for fiberglass or Temp-Mat.	Account for encapsulation / jacketing configuration.
3. Kaowool	Assume same destruction data as for NUKON (representative of low-density fiberglass).	Assume same destruction data as for NUKON (representative of low-density fiberglass).	Account for encapsulation / jacketing configuration.
4. Marinite board	Conservatively assume destruction data for fiberglass or Temp-Mat.	Conservatively assume destruction data for fiberglass or Temp-Mat.	Assumes conservatively low destruction pressure.
5. Silicone foam	Conservatively assume destruction data for fiberglass or Temp-Mat.	Assume debris, regardless of size, floats.	Assumes conservatively low destruction pressure.
6. Koolphen (closed cell phenolic)	4 psi (From the BWROG URG)	Limited Data Debris observed to float	NUREG/CR-6762 Volume 2 does not identify Koolphen as an insulation that is used in U.S. PWR containments.