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Division 1
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PROPOSED REVISION 1 TO REGULATORY GUIDE 1.82

WATER SOURCES
[SUMPS] FOR [EMERGENCY-CORE-COOLING AND-CONTAINMENT-SPRAY-SYSTEMS] LONG TERM RECIRCULATION COOLING FOLLOWING A LOSS OF COOLANT ACCIDENT[1]

A. INTRODUCTION

General Design Criteria 35, "Emergency Core Cooling," 36, "Inspection of Emergency Core Cooling System," 37, "Testing of Emergency Core Cooling System," 38, "Containment Heat Removal," 39, "Inspection of Containment Heat Removal System," and 40, "Testing of Containment Heat Removal System," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," require that [a] systems be provided to [remove-the-heat-released-to-the-containment] perform specific functions; e.g., emergency core cooling, containment heat removal and containment atmosphere clean up following a postulated design basis accident [(DBA)-and-that-this-system]. These systems must be designed to permit appropriate periodic inspection and testing to ensure [its] their integrity, [capability,] and operability. General Design Criterion 1, "Quality Standards and Records," of Appendix A to 10 CFR Part 50 requires that structures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. This guide describes a method acceptable to the NRC staff for implementing these requirements with respect to the sumps/pools performing the functions of water source for the emergency core cooling, containment heat removal, or containment atmosphere clean up [and containment-spray-systems]. This guide applies to light-water-cooled reactors.

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[1]Comparative text based on "For Comment" version published May 1983. Proposed deletions from it are shown in bracket with overstrike ([-]) and additions to it are shown underscored (____). Tables and figures are not shown "comparative". "Active" revision was published June 1974 .

* Page dates are: 05/06/85 4, 9, 20, 22-30; 05/10/85 21; 05/31/85 2, 3, 6, 16-18; 06/04/85 5, 7, 8, 10, 14, 19; 07/23/85 12, 13, 15, 31; 07/24/85 1, 11, 32.

Any guidance in this document related to information collection activities has been cleared under OMB Clearance No. 3150-0011.

B. DISCUSSION

[~~Sumps or pump intakes serve the emergency core cooling system (ECCS) and the containment spray system (CSS) by providing for the collection of reactor coolant and chemically reactive spray solution and allowing its recirculation for additional cooling and fission product removal.~~

~~Placement of the ECCS sumps at the lowest level practical ensures maximum utilization of available recirculation coolant. However, there may be places within containment where coolant could accumulate during the containment spray period; providing these areas with drains or flow paths to the sump location will minimize coolant holdup. This guide does not address the design of such drain paths. However, since debris generated by a loss of coolant accident (LOCA) can migrate to the sump via these pathways, these drains are best terminated in a manner that will prevent debris from being transported to and accumulating on the ECCS sump. Appendix A addresses concerns related to debris transport and the effects of attendant sump screen blockage.~~

~~Small drainage sumps that are used to collect and monitor normal leakage flow for leakage detection systems within containment are separate from the ECCS sump and are at a lower elevation that the ECCS sump to minimize inadvertent spillover into the ECCS sump due to minor leaks or spills within the containment. The floor adjacent to the ECCS sump would normally slope downward, away from the ECCS sump toward the drainage collection sumps. This downward slope away from the ECCS sump will minimize the collection of debris against the sump screens~~].

B.1 Pressurized Water Reactors

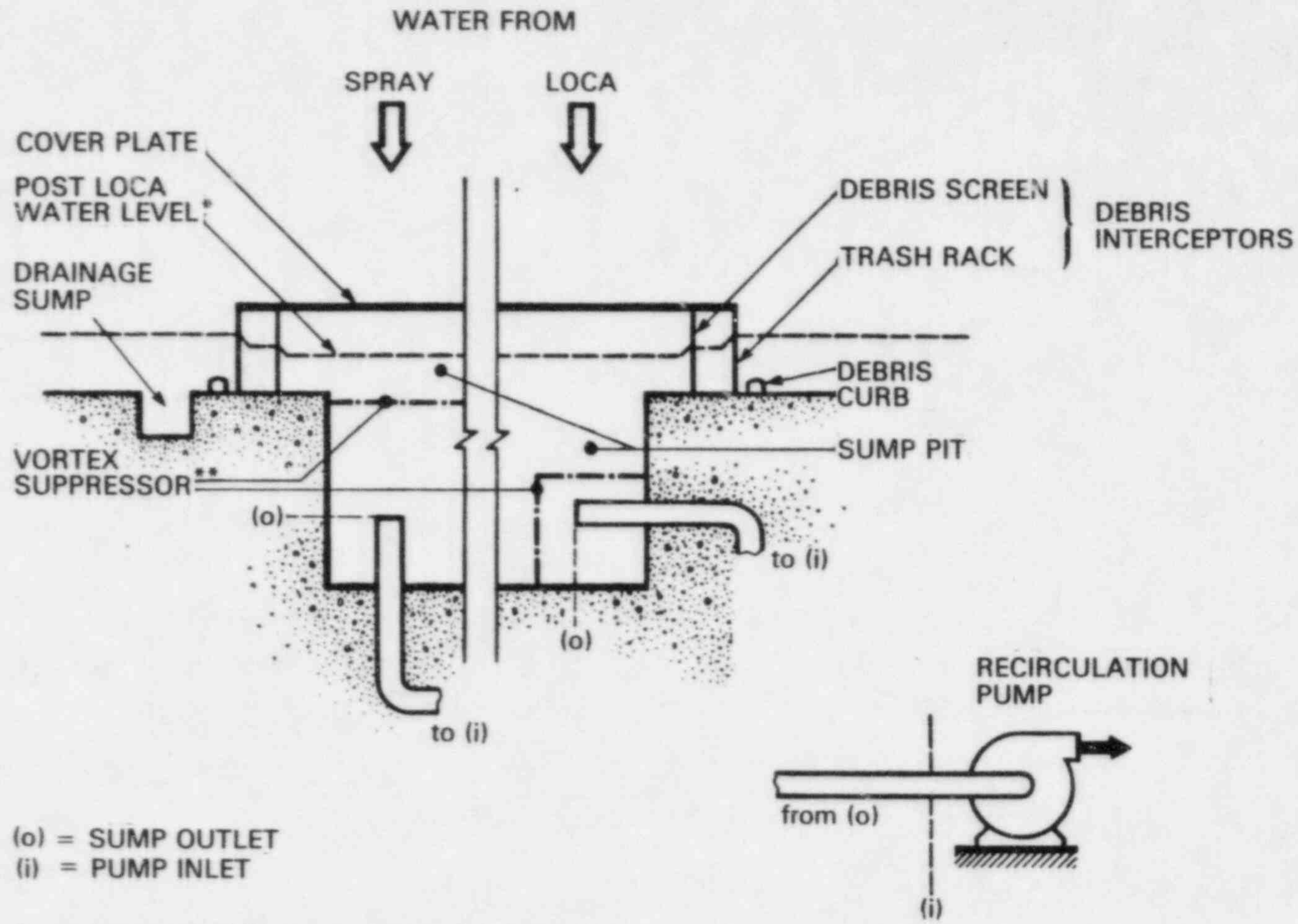
In pressurized water reactors (PWRs), the containment emergency sumps provide for the collection of reactor coolant and chemically reactive spray solutions following a loss-of-coolant accident (LOCA); thus the sumps serve as water sources to effect long term recirculation for the functions of residual heat removal, emergency core cooling and containment atmosphere cleanup. These water sources, the related pump inlets and the piping between the sources and inlets are important safety components. The sumps servicing the emergency

core cooling systems (ECCS) and the containment spray systems (CSS) are hereinafter referred to in this guide as ECC sumps. Features and relation ships of the ECC sumps pertinent to this guide are shown in Figure 1.

The primary areas of safety concern regarding ECC sumps and pumps inlets are: (a) post LOCA hydraulic effects, particularly air ingestion, (b) blockage of debris interceptors resulting from LOCA destruction of insulation and its transport, and (c) the combined effects of items (a) and (b) relative to recirculation pumping operability (i.e., impact on net positive suction head (NPSH) available at the pump inlet).

Debris resulting from a LOCA has the potential to block ECC sump debris interceptors (i.e., trash racks, debris screens) and sump outlets resulting [result] in a degradation of, or loss of [net-positive-suction-head-(]NPSH[)] margin. [The-LOCA-generated] Such debris can be divided into the following categories: (1) debris that is generated early in the LOCA period and is transported by blowdown forces (i.e., jet forces from the break), (2) debris that has a high density and will sink, but is still subject to fluid transport if local recirculation flow velocities are high enough, (3) debris that has an effective specific gravity near 1.0 and will float or sink slowly but will nonetheless be transported by very low velocities, and (4) debris that will float indefinitely by virtue of low density [or-composition] and will be transported to and possibly thru the [sump] debris screen. Thus, debris generation [due-to-the-LOCA], early transport due to blowdown loads, long-term transport, and attendant [screen] blockage [effects] of debris interceptors must be analyzed to determine head loss effects. Appendix A provides relevant information [guidelines] for such evaluations; References 1 through [5] 12 provide additional information relevant to the above concerns.

The design of sumps and their outlets includes consideration of the avoidance of air ingestion and other undesirable hydraulic effects (e.g., circulatory flow patterns, outlet designs leading to high head losses). The location and size of the sump outlets within ECC sumps is important in order to minimize air ingestion since ingestion is a function of submergence level and velocity in the outlet piping. It has been experimentally determined for PWRs that air ingestion can be minimized, or eliminated, if the sump hydraulic design considerations provided in Appendix A are followed. References 1, 3, 6, 7, and 8 provide additional technical information relevant to sump ECC hydraulic performance and design guidelines.



* AS DETERMINED DURING SAFETY ANALYSIS

** CUBIC OR HORIZONTAL SUPPRESSOR MAY BE USED WITH EITHER SUMP OUTLET

PWR
FIGURE 1

Placement of the ECC sumps at the lowest level practical ensures maximum utilization of available recirculation coolant. However, since there may be places within containment where coolant could accumulate during the containment spray period, these areas can be provided with drains or flow paths to the sumps to prevent coolant holdup. This guide does not address the design of such drains or paths. However, since debris can migrate to the sump via these drains or paths they are best terminated in a manner that will prevent debris from being transported to and accumulating on or within the ECC sumps.

Containment drainage sumps are used to collect and monitor normal leakage flow for leakage detection systems within containments. They are separated from the ECC sumps and located at a lower elevation than the ECC sumps to minimize inadverdant spillover into the ECC sumps due to minor leaks or spills within containment. The floor adjacent to the ECC sumps would normally slope downward, away from the ECC sumps toward the drainage collection sumps. This downward slope, away from the ECC sumps will minimize the transport and collection of debris against the debris interceptors. High density debris may be swept along the floor by the flow toward the trash rack. A debris curb, upstream of and in close proximity to the rack, will decrease the amount of such debris reaching the rack.

It is necessary to protect sump outlets by debris interceptors [pump-intakes-by-screens-and-trash-racks-(coarse-outer-screens] of sufficient strength to withstand the vibratory motion of seismic events, to resist jet loads and impact loads that could be imposed by missiles that may be generated by the initial LOCA and to withstand the differential pressure loads imposed by the accumulation of debris [or-by-trash]. Considerations in material selection for the debris interceptors includes; long periods of inactivity, that is no submergence; and possibly periods of operation, that is partial or full submergence in a fluid that may contain chemically reactive materials. Isolation of the ECC[S] sumps from high-energy pipe lines is an important consideration in protection against missiles, and it is necessary to shield the screens and [trash] racks adequately from impacts of ruptured high-energy piping and associated jet loads from the break. When the screen and [trash] rack structures are oriented vertically [located-above-floor-level], the adverse effects from debris collecting on them [screen-structure] will be [at-a-minimum.--Separating-r] reduced. Redundant ECC[S] sumps [screens]

and sump outlets [pump-suction intakes] are separated to the extent practical [will-help] to reduce the possibility that an event causing [a-partially-clogged-screen-or-missile-damage-to-one-screen-would] the interceptors or outlets of one sump to either be damaged by missiles or partially clogged could adversely affect other pump circuits. [In-addition,-proper design-of-suction-intakes-will-avoid-flow-degradation-by-air-ingestion, swirl,-or-vertex-formation.]

[The-location-of-the-pump-suction-intakes-within-the-ECCS-sump-is-important-in-order-to-minimize-air-ingestion-that-is-a-function-of-submergence level-and-sump-outlet-velocity.--Other-factors-to-consider-are-vortex-formation-(which-can-lead-to-air-ingestion)-and-swirl-effects-at-the-suction-inlet. It-has-been-experimentally-determined-that-air-ingestion-can-be-minimized-or eliminated-if-the-hydraulic-design-guidelines-provided-in-Appendix-A-are followed.--References-1,-3,-6,-7,-8,-and-9-provide-additional-technical-information-relevant-to-sump-hydraulic-performance-and-design-guidelines.

As-noted-above,-the-design-of-pump-suction-intakes-includes-consideration for-avoiding-air-ingestion-or-other-undesirable-hydraulic-effects-(e.g., swirl,-suction-inlet-design-effects).--However,-for-small-amounts-of-air ingestion,-the-recirculation-pumps-can-still-be-considered-operable-provided sufficient-NPSH-margin-is-demonstrated.--Appendix-A-provides-guidance-for estimating-NPSH-margin-if-estimated-levels-of-air-ingestion-are-low-(i.e., ≤2%).--References-1-and-10-provide-additional-technical-findings-relevant-to pump-operation-and-NPSH-effects.]

It is expected that the water surface will be above the top of the debris interceptor [screen] structure after completion of the safety injection. However, the uncertainties about the extent of water coverage on the [screen] structure, the amount of floating debris that may accumulate, and the potential for early clogging do not favor the use of a horizontal top [screen] interceptor. Therefore, [because-of-this-uncertainty,] in computation of available interceptor surface area no credit [can] is to be taken [in-computing-the-available-surface area] for any [top] horizontal [sceen] interceptor surface, and the top of the interceptor [screen] structure [would] is preferably [be] a solid [deck] cover plate to provide additional protection from LOCA generated loads and designed to provide for the venting of any trapped air.

Debris which is small enough to pass through trash rack and which could clog or block the debris screens or outlets is to be analyzed for head loss

effects. Screen and sump outlet blockage will be a function of the types and quantities of insulation debris that can be transported to these components. A vertical inner debris screen would impede the deposition or settling of debris on screen surfaces and thus help to assure the greatest possible free-flow through the fine inner debris screen. Slowly settling debris that is small enough to pass through the trash rack openings could block the debris [inner] screens if the coolant flow velocity is too great to permit the bulk of the debris to sink to the floor level during transport. [A-vertically-mounted-inner-screen-would-minimize-settling-of-debris-on-the-screen-surface;-and-if-sufficient-unblocked-screen-area-is-provided-to-keep] If the coolant flow velocity [at] ahead of the screen is at or below approximately [6] 5 cm/sec (0.2 ft/sec), debris with a specific gravity of 1.05 or more will likely settle before reaching the screen surface and thus help to prevent undue clogging of the screen.

The size of openings in the [fine] screens is dependent on the physical restrictions [;-including-spray-nozzles;] that may exist in the systems that are supplied with coolant from the ECC[S] sump. The size of the mesh of the fine debris screen is determined based on consideration of a number of factors including the [The] size of openings in the containment spray nozzles, coolant channel openings in the core fuel assemblies, and pump design characteristics, for example seals, bearings, and impeller running clearances [will-need-to-be-considered-in-determining-the-size-of-the-fine-screen].

As noted above, degraded pumping can be caused by a number of factors, including plant design and layout. In particular, debris blockage effects or debris interceptor and sump outlet configurations, and post LOCA hydraulic conditions (e.g., air ingestion) must be considered in a combined manner. Small amounts of air ingestion, ≤2% i.e., will not lead to severe pumping degradation if the "required" NPSH from the pump manufacturer's curves is increased based on the calculated air ingestion. Thus the combined results of all post LOCA effects need to be used to estimate NPSH margin, as calculated for the pump inlet. Appendix A provides information for estimating NPSH margins in PWR sump designs, where estimated levels of air ingestion are low (≤2%). References 1 and 8 provide additional technical findings relevant to NPSH effects on pumps performing the functions of residual heat removal, emergency core cooling and containment atmosphere cleanup. When air ingestion is ≤ 2%, compensation for its effects may be achieved without redesign if the

"available" NPSH is greater than the "required" NPSH plus a margin based on the percent air ingestion. If air ingestion is not small, redesign of one or more of the recirculation loop components may be required to achieve satisfactory design.

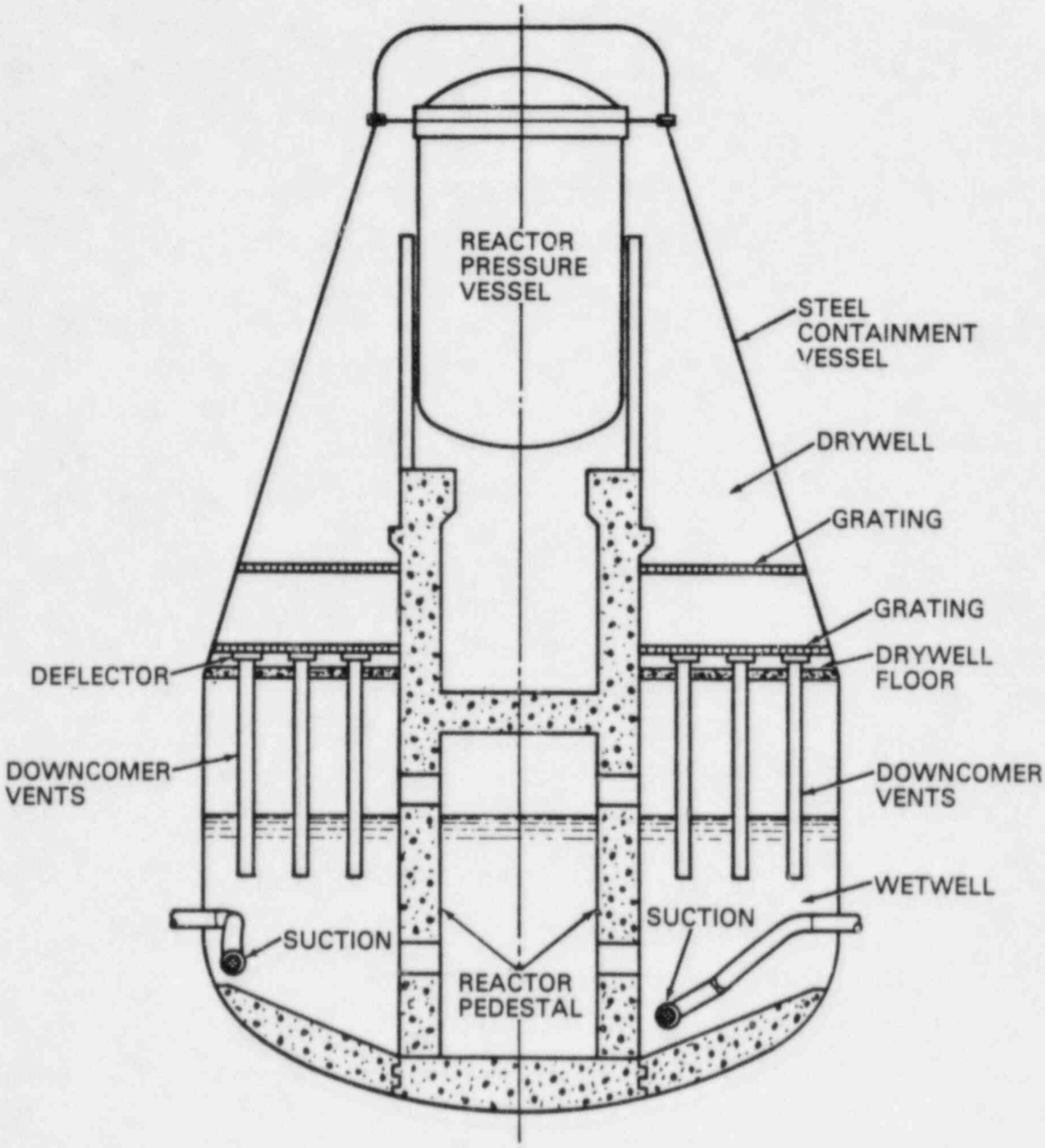
[Potential-blocking-of-the-fine-screen-would-reduce-the-free-flow-area through-the-screen;-and-it-is-essential-that-sufficient-flow-area-be-provided to-maintain-adequate-NPSH-margin.

A-significant-consideration-is-the-potential-for-degraded-pump-performance that-could-be-caused-by-a-number-of-factors;-including-the-loss-of-NPSH-margin. If-the-NPSH-available-to-a-pump-is-not-sufficient;-degraded-pump-performance will-significantly-reduce-the-capability-of-the-system-to-accomplish-its safety-function.--The-pressure-drop-across-partially-(or-completely-blocked screens-will-reduce-available-NPSH-margin-and-can-be-calculated-based-on-the debris-blockage-evaluation-methods-outlined-in-Appendix-A.]

To ensure the [readiness] operability and structural integrity of the racks and screens, access openings are necessary to permit inspection of the [inside] ECC sump structures and outlets [pump-suction-inlet-openings]. Inservice inspection [for-trash] of racks, screens, vortex suppressors, and sump outlets [pump-suction-inlet-openings], including visual examination for evidence of structural degradation or corrosion can be performed on a regular basis at every refueling period downtime. Inspection of the ECC[S] sump components is to be made late in the refueling period [would-help] to ensure the absence of construction [debris] trash in the ECC[S] sump area.

B.2 Boiling Water Reactors

In boiling water reactors (BWR) the suppression pool; in conjunction with the drywell, downcomers and vents; serves as the water source for effecting long-term recirculation cooling and for fission product removal. This source, the related pump inlets, and the piping between them are important safety components. These components are hereinafter referred to in this guide as the suppression pool. Features and relationships of the "suppression pool" pertinent to this guide are shown in figure 2. As with the ECC sumps in PWRs, there are similar concerns with the performance of the suppression pool and pump inlets namely, (a) post-LOCA hydraulic effects, particularly air ingestion, (b) blockage of debris interceptors resulting



BWR
FIGURE 2

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from LOCA destruction of insulation and its transport (including suppression pool bulk velocity effects), and (c) the combined effects of items (a) and (b) relative to recirculation pump operability (e.g., the impact on NPSH available at the pump inlet). References 1 and 7 provide data on the performance and air ingestion characteristics of BWR configurations.

As in the case of PWRs, it is desirable to include consideration of the use of debris interceptors in BWR designs to protect the pump inlets. However, the location of the debris interceptors need not be restricted to the pool itself. Debris interceptors or equivalent plant structures in the drywell in the vicinity of the downcomers or vents could serve effectively in reducing debris transport to the pump inlets.

Similarly, the smallest the opening in the debris interceptors is dependent on the physical restrictions that may exist in the systems served by the suppression pool. For example, spray nozzle clearances, coolant channel openings in the core fuel assemblies, and pump design characteristics; for example seals, bearings and impeller running clearances will need to be considered in the design.

C. REGULATORY POSITION

C.1 Pressurized Water Reactors

Reactor building sumps that are designed to be a source of water for the performance of the functions of emergency core cooling, [system (ECCS) or the] containment [spray system (CSS)] heat removal or containment atmosphere clean up following a loss-of-coolant accident (LOCA) should meet the following criteria:

a[1]. A minimum of two sumps should be provided, each with sufficient capacity to service one of the redundant halves of the ECCS and CSS [systems].

b[2]. To the extent practical, the redundant sumps should be physically separated by structural barriers from each other and from high-energy piping systems to preclude damage to the sump components (e.g., racks, screens and sump outlets [suction pipes]) by whipping pipes or high-velocity jets of water or steam.

c[3]. The sumps should be located on the lowest floor elevation in the containment exclusive of the reactor vessel cavity. The sump [intake]

outlets should be protected by at least two vertical[ly-mounted screens] debris interceptors: [(1)] (i) a fine inner debris screen and (ii) [(2)] a[n] coarse outer trash rack to prevent large debris from reaching the debris [fine-inner] screen. [The-sump-screens-should-not-be-depressed-below-the floor-elevation.] A curb should be provided [around-the-periphery] upstream of the trash racks [screens] to prevent high-density debris [(i.e.,-fine particulates)] from being swept along the floor into the sump.

d[4]. The floor in the vicinity of the ECC[S] sump should slope gradually downward away from the sump.

e[5]. All drains from the upper regions of the reactor building should terminate in such a manner that direct streams of water, which may contain entrained debris, will not impinge on the debris interceptors [filter-assemblies].

f[6]. The strength of the trash racks should be adequate to protect the [inner] debris screens from missiles and other large debris [generated-by-the LOCA]. Each interceptor should be capable of withstanding the loads imposed by missiles, by the accumulation of debris and by head differentials due to blockage.

g.[7. The-design-coolant-velocity-at-the-fine-inner-screen-should-be approximately-6-cm/sec-(0.2-ft/sec).] The available [screen] interceptor surface area used in determining the design coolant velocity should be calculated to conservatively account for [sump-screen] blockage that [might] may result [from-debris-generation-and-transport]. Only the vertical [sump screens] interceptor area that is below the design basis water level should be considered in determining available surface area. Fibrous type insulation debris should be considered as uniformly distributed over the available debris screen area. Blockage should be calculated based on levels of destruction estimated (See also Ref. 1 and 12).

h[8]. Evaluation[s] or confirmation of [(1)] (i) sump hydraulic performance (e.g., geometric effects and air ingestion), (ii) [(2)-LOCA-generated] debris effects (e.g., debris transport, [and-screen] interceptor blockage and head loss), and [(3)] (iii) the combined impact on [pump] NPSH [margin] available at the pump inlet should be performed to ensure that long-term recirculation cooling can be accomplished. [Sump-hydraulic-effects-and-debris blockage-considerations-that-could-have-an-adverse-impact-on-NPSH-margin-should be-considered-in-the-evaluation-of-the-ECCS-pump-performance] Such evaluation should arrive at a determination of NPSH margin, as calculated at the pump

inlet. An assessment of recirculation pump seal and bearing assembly design susceptibility to failure due to particulate ingestion and particulate abrasive effects should be made to protect against degradation of long term recirculation pumping capacity.

i[9]. The top of the [deck] debris interceptor structures should be a solid cover plate that is designed to be fully submerged after a LOCA and completion of the ECC injection. It [The-solid-deck] should be designed to ensure the venting of [any] air otherwise trapped underneath.

j[10]. The [trash-rack-and-screens] debris interceptors should be designed to withstand the vibratory motion of seismic events without loss of structural integrity.

k[11]. The size of openings in the [fine] debris screens should be based on the minimum restriction found in systems served by the pumps performing the recirculation function. The minimum restriction should take into account the requirements of the systems served.

l.[12.- Pump-intake-locations-within-the-sump] Sump outlets should be [carefully-considered] designed to prevent degradation of pump performance by [the-effects-of-such-conditions-as] air ingestion and other adverse hydraulic effects (e.g., circulatory flow patterns [sump-induced-swirl], high intake-head losses).

m[13]. Materials for [trash-racks-and-screens] debris interceptors should be selected to avoid degradation during periods of inactivity and operation and should have a low sensitivity to such adverse effects as stress-assisted corrosion that may be induced by the chemically reactive spray during LOCA conditions.

n[14]. The [trash-rack-and-screen] debris interceptor structures should include access openings to facilitate inspection of these structures, any vortex suppressors and the [pump-suction-intake] sump outlets.

o[15]. Inservice inspection requirements for ECC[S] sump components (e.g. debris interceptors [trash-racks,-screens], any vortex suppressors, and [pump-suction-inlets] sump outlets) should include:

i[a]. Inspection [of-ECCS-sump-components] during every refueling period downtime, and

ii[b]. A visual examination [of-the-components] for evidence of structural distress or corrosion.

C.2 Boiling Water Reactors

The suppression pool, which is the source of water for the performance of functions of emergency core cooling, containment heat removal and containment atmosphere cleanup following a loss-of-coolant accident (LOCA) in combination with the vents and downcomers between drywell and wetwell, should contain the following features:

a. The inlet of pumps performing the above functions should be protected by two debris interceptors:

i. a fine downstream debris screen; and

ii. a coarse upstream trash rack to prevent large debris from reaching the debris screen.

It should be noted that certain design features of BWRs may perform the equivalent function of trash racks and debris screens. Design features such as deflectors and suction strainers may be considered equivalent to trash racks and debris screens. Hereafter "trash rack" or "debris screen" includes equivalent plant features.

b. If it is demonstrated that significant amounts of debris will not be generated within the wetwell then the trash rack may be located in the drywell or the downcomer system between the drywell and wetwell.

c. All drains from the upper regions of the reactor building should terminate in such a manner that direct streams of water, which may contain entrained debris, will not impinge on the debris interceptors.

d. The strength of the trash rack should be adequate to protect the debris screen from missiles and other large debris. Each interceptor should be capable of withstanding the loads imposed by missiles, by debris and by head differentials due to blockage.

e. Bulk suppression pool velocity due to recirculation operation should be considered for both debris transport and coolant velocity computations.

f. The available interceptor area used in determining the design coolant velocity should conservatively account for blockage that may result. Fibrous type debris should be assumed to be uniformly distributed over the available

debris screen surface. Blockage should be calculated based on levels of destruction estimated. (See also Ref. 1 and 12.)

g. Evaluation or confirmation of (i) suppression pool hydraulic performance (e.g., geometric effects and air ingestion), (ii) debris effects (e.g., debris transport, interceptor blockage and head loss, and particulates clogging of pump seals), and (iii) the combined impact on NPSH available at the pump inlet should be performed to ensure that long-term recirculation cooling can be accomplished. An assessment of recirculation pump seal and bearing assembly design susceptibility to failure due to particulate ingestion and particulate abrasive effects should be made to protect against degradation of long term recirculation pumping capacity.

h. The debris interceptors should be designed to withstand the vibratory motion of seismic events without loss of structural integrity.

i. The size of openings in the screens should be based on the minimum restriction found in systems served by the suppression pool. The minimum restriction should take into account the operability of the systems served.

j. The pool outlets to the recirculation pumps should be designed to prevent degradation of pump performance through air ingestion and other adverse hydraulic effects (e.g., circulatory flow patterns, high intake-head losses).

k. Material for debris interceptors should be selected to avoid degradation during periods of inactivity and normal operations, and should be compatible with the characteristics of the spray during LOCA events.

l. Inservice inspection requirements should include:

(i) inspection during every refueling period downtime;

(ii) a visual examination for evidence of structural distress or corrosion and

(iii) an inspection, for evidence of debris or trash, of (I) the wetwell air spaces and (II) the dry well floor region including the vents, downcomers and deflectors.

ii[b]. A visual examination [of-the-components] for evidence of structural distress or corrosion.

C.2 Boiling Water Reactors

The suppression pool, which is the source of water for the performance of functions of emergency core cooling, containment heat removal and containment atmosphere cleanup following a loss-of-coolant accident (LOCA) in combination with the vents and downcomers between drywell and wetwell, should contain the following features:

a. The inlet of pumps performing the above functions should be protected by two debris interceptors:

i. a fine downstream debris screen; and

ii. a coarse upstream trash rack to prevent large debris from reaching the debris screen.

It should be noted that certain design features of BWRs may perform the equivalent function of trash racks and debris screens. Design features such as deflectors and suction strainers may be considered equivalent to trash racks and debris screens. Hereafter "trash rack" or "debris screen" includes equivalent plant features.

b. If it is demonstrated that significant amounts of debris will not be generated within the wetwell then the trash rack may be located in the drywell or the downcomer system between the drywell and wetwell.

c. All drains from the upper regions of the reactor building should terminate in such a manner that direct streams of water, which may contain entrained debris, will not impinge on the debris interceptors.

d. The strength of the trash rack should be adequate to protect the debris screen from missiles and other large debris. Each interceptor should be capable of withstanding the loads imposed by missiles, by debris and by head differentials due to blockage.

e. Bulk suppression pool velocity due to recirculation operation should be considered for both debris transport and coolant velocity computations.

f. The available interceptor area used in determining the design coolant velocity should conservatively account for blockage that may result. Fibrous type debris should be assumed to be uniformly distributed over the available

debris screen surface. Blockage should be calculated based on levels of destruction estimated. (See also Ref. 1 and 12.)

g. Evaluation or confirmation of (i) suppression pool hydraulic performance (e.g., geometric effects and air ingestion), (ii) debris effects (e.g., debris transport, interceptor blockage and head loss, and particulates clogging of pump seals), and (iii) the combined impact on NPSH available at the pump inlet should be performed to ensure that long-term recirculation cooling can be accomplished. An assessment of recirculation pump seal and bearing assembly design susceptibility to failure due to particulate ingestion and particulate abrasive effects should be made to protect against degradation of long term recirculation pumping capacity.

h. The debris interceptors should be designed to withstand the vibratory motion of seismic events without loss of structural integrity.

i. The size of openings in the screens should be based on the minimum restriction found in systems served by the suppression pool. The minimum restriction should take into account the operability of the systems served.

j. The pool outlets to the recirculation pumps should be designed to prevent degradation of pump performance through air ingestion and other adverse hydraulic effects (e.g., circulatory flow patterns, high intake-head losses).

k. Material for debris interceptors should be selected to avoid degradation during periods of inactivity and normal operations, and should be compatible with the characteristics of the spray during LOCA events.

l. Inservice inspection requirements should include:

(i) inspection during every refueling period downtime;

(ii) a visual examination for evidence of structural distress or corrosion and

(iii) an inspection, for evidence of debris or trash, of (I) the wetwell air spaces and (II) the dry well floor region including the vents, downcomers and deflectors.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants regarding the NRC staff's plans for using this regulatory guide. This regulatory guide has been developed from an extensive experimental and analytical data base. The applicant/licensee is free to select alternate calculation methods which are founded on substantiating experiments and/or limiting analytical considerations. [This-proposed-revision-to-the-regulatory guide-has-been-published-to--encourage-public-participation-in-its-development.] Except in those cases in which the applicant/licensee proposes an alternative method for complying with the specified portions of the Commission's regulations, the methods described in this [the-revised-active] guide [reflecting-public-comments] will be used by the NRC staff in its evaluation of all:

1) standard reference system preliminary design applications or final design applications that are docketed after[2];

2) licenses to manufacture that are docketed after[2];

3) construction permit applications that are docketed after[2];

4) operating license applications that are docketed after[2]

[the-design-and-construction-of-sumps-for-emergency-core-cooling-and-containment-spray-systems.--In-addition,-the-NRC-staff-intends-to-use-this-guide to-evaluate-the-design-and-construction-of-sumps-in-plants-for-which-an operating-license-has-been-issued,-the-implementation-date-will-be-specified in-the-active-guide].

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[2] Six (6) months after issuance of the Regulatory Guide

APPENDIX A

GUIDELINES FOR REVIEW OF SUMP DESIGN AND WATER SOURCES FOR EMERGENCY CORE COOLING

[ECCS-SUMPS]

1. General

The ECC[S] sump performance should be evaluated under possible post LOCA conditions to determine design adequacy for providing long-term recirculation. Technical evaluations can be subdivided into (1) Sump Hydraulic Performance, (2) [effects-of] LOCA-Induced Debris Effects, and (3) Pump Performance Under Adverse Conditions. Specific considerations within these categories, and the combining thereof, are shown in Figure A-1. Determination that adequate NPSH margin exists at the pump inlet under all postulated post-LOCA conditions is the final requirement.

2. Sump Hydraulic Performance

Sump hydraulic performance (with respect to air ingestion potential) can be evaluated on the basis of submergence level (or water depth above the sump [suction] outlets) and required pumping capacity (or [sump-suction outlet] pump inlet velocity). The water depth above pipe centerline (s) and [suction] inlet pipe velocity (U) parameters can be expressed nondimensionally as the Froude number:

$$\text{Froude number} = U/\sqrt{gs}$$

where g is the acceleration due to gravity [gravitational-constant]. Extensive experimental results have shown that the hydraulic performance of ECC[S] sumps (particularly air ingestion potential) is a strong function of Froude number. Other nondimensional parameters (e.g., Reynolds number and Weber number) are of secondary importance.

Sump hydraulic performance can be divided into three performance categories:

a. Zero air ingestion, [thus-avoiding-pump-cavitation;] which requires no vortex suppressors or increase of the "required" NPSH above that from the pump manufacturer's curves.

b. Air ingestion ≤2%, a conservative level [at-which] where degradation of pumping capability is not expected based on an increase of the "required" NPSH (see Figure A-2),

c. Use of vortex suppressors to reduce air ingestion effects to [a negligible-level] zero.

For PWRs zero air ingestion can be [ensured] assured by use of the design [criteria] guidance set forth in Table A-1. Determination of those designs having air ingestion levels ≤2% [or-less] can be obtained using correlation given in Table A-2 and the attendant sump geometric envelope[,-placement,]. Geometric and screen guidelines for PWRs are contained in Tables A-3.1, A-3.2, A-4, and A-5. Table A-6 presents design guidelines for vortex suppressors [ion-devices] that have shown the capability to reduce air ingestion to zero. These guidelines (Tables A-1 through A-6) were developed from extensive full-scale sump hydraulic tests and provide a [concise] rapid means of assessing sump hydraulic performance. If the PWR sump design deviates significantly from the design boundaries noted, then similar performance data should be obtained for verification of adequate sump hydraulic performance.

For BWRs, full scale tests of pool outlet designs for recirculation pump have shown that air ingestion is zero for Froude numbers of less than 0.8 with a mininum submergence of 6 feet, and operation up to a Froude number of 1.0 with the same minimum submergence may be possible before air ingestion levels of 2% may occur (see also References 1 and 7).

3. [Effects-of] LOCA-Induced Debris Effects

Assessment of LOCA debris generation and determination of possible debris interceptor [sump-screen] blockage is complex. The evaluation of this safety question is dependent on the types and quantities of insulation employed, the location of such insulation materials within containment and with respect to the sump location, the estimation of quantities of debris generated by a pipe break, and the migration of such debris to the [sump screen] interceptors. Thus [estimates-of-sump-screen] blockage estimates are specific to the insulation material, [and] the plant design and require consideration of such effects as are outlined in Table A-7.

Since break jet forces are the dominant debris generator, the predicted jet envelope will determine the quantities and types of insulation debris.

Figure A-3 provides a three region model which has been developed from analytical and experimental considerations, as identified in reference 1. The destructive results of the break jet forces will be considerably different for different types of insulation and must be individually addressed. The insulation type, how and whether it is encapsulated, and how it is fastened to the insulated surfaces, all have significant influence on the maximum volume of insulation debris generated. Region I represents a total destruc tion zone; Region II a region where high levels of damage are possible depending on insulation types, whether encapsulation is employed, methods of attachment, etc.; Region III a region where dislodgement of insulation in whole, or as-fabricated, segments is likely occur. A more detailed discussion of these considerations is provided in Reference 1. Use of the outer boundary of Region II for estimating maximum volumes of total insulation destruction is considered a conservative bounding condition.

[Since-evaluation-of-debris-effects-is-dependent-on-the-material-type and-also-on-recirculation-flow-velocities;-a-series-of-limiting-evaluations can-be-performed;-these-are-outlined-in-Tables-A-8-and-A-9.--Table-A-8-provides a-concise-means-of-evaluating-the-potential-for-debris-transport-at-various flow-velocities-for-three-major-types-of-insulation.--Table-A-9-provides-a rapid-means-of-assessing-the-transport-of-fibrous-insulation-debris-and-quantifying-the-volume-of-such-debris-that-could-result-in-loss-of-50%-of-the-NPSH requirement.--Loose-fibrous-debris-will-be-transported-by-velocities-as-low as-0.2-ft/sec-(6-cm/sec).]

If-Table-A-8-or-Table-A-9-does-not-readily-identify-negligible-or-conservatively-low-levels-of-sump-screen-blockage;-the-considerations-outlined in-Table-A-7-must-be-evaluated-on-a-plant-specific-basis.--Figure-A-2-is provided-for-additional-guidance-in-estimating-such-debris-blockage-effects; and-results-obtained-from-such-an-evaluation-would-be-used-to-estimate-the impact-on-NPSH-margin.] References 1, [2,-4,] 9, 10, 11 and [5] 12 provide more detailed information relevant to assessment of debris [effects] generation and transport.

4. Pump Performance Under Adverse Conditions

The pump industry historically has determined net positive suction head requirements for pumps on the basis of a percentage degradation in [performance] pumping capacity . The percentage has [at-times] been at times arbitrary,

but [is] generally in the range of 1% to [1-] 3%. A 2% limit on allowed air ingestion is recommended since higher levels have been shown to initiate degradation of pumping capacity.

The 2[volume]percent-volume limit on sump air ingestion and the NPSH requirements act independently. However, air ingestion levels less than 2% can also affect NPSH requirements [conditions.--Figure-A-3-is-therefore provided-as-a-guide-for-evaluating-conditions-at-the-pump-inlet;-commencing at-the-sump.] If air ingestion is indicated, correct the NPSH requirement from the pump curves [should-be-corrected] by the relationship:

$$\text{NPSH}_{\text{required [(air/liquid)]}(\alpha_p < 2\%)} = \text{NPSH}_{\text{required(liquid)}} \times \beta$$

where $\beta = 1 + 0.50\alpha_p$, and α_p is the air ingestion rate (in percent by volume) at the pump inlet flange.

5. Combined Effects

As shown in Figure A-1, three-interdependent effects (i.e., sump hydraulic performance, [LOCA] debris effects, and pump operation under adverse conditions) require evaluation for determining long-term recirculation capability. Figure A-[4] 2 provides a logic diagram for combining these considerations to evaluate the ECC[S] sump design and expected performance. The same logic applies to BWR design evaluations of suppression pools and the outlets to recirculation pumps.

Table A-1

Hydraulic Design Guidelines* for Zero Air Ingestion

Item	Horizontal Outlets	Vertical Outlets
Minimum submergence, s (ft) (m)	9 2.7	9 2.7
Maximum Froude Number, Fr	0.25	0.25
Maximum Pipe Velocity, U (ft/s) (m/s)	4 1.2	4 1.2

*These guidelines were established using experimental results from references 3, 4 and 5 and are based on sumps having a right rectangular shape.

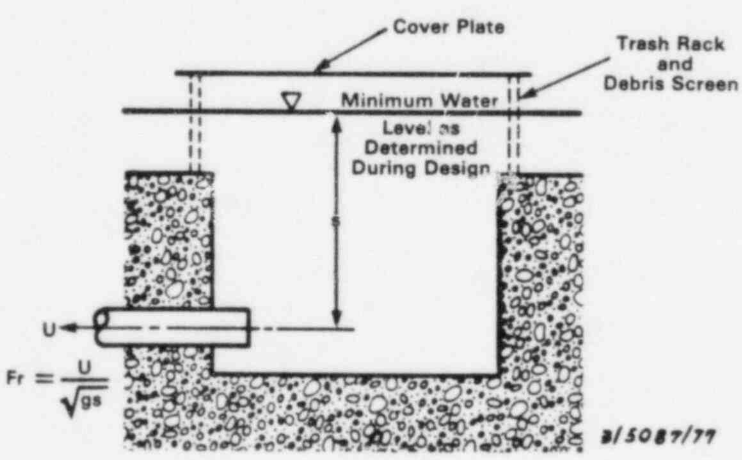


Table A-2

Hydraulic Design Guidelines for Air Ingestion $\leq 2\%$
Air ingestion α is empirically calculated as
$$\alpha = \alpha_o + (\alpha_1 \times Fr)$$
where α_o and α_1 are coefficients derived from test results as given in the table below.

Item	Horizontal Outlets		Vertical Outlets	
	Dual	Single	Dual	Single
Coefficient α_o	-2.47	-4.75	-4.75	-9.14
Coefficient α_1	9.38	18.04	18.69	35.95
Minimum Submergence, s (ft)	7.5	8.0	7.5	10
(m)	2.3	2.4	2.3	3.1
Maximum Froude Number, Fr	0.5	0.4	0.4	0.3
Maximum Pipe Velocity, U (ft/s)	7.0	6.5	6.0	5.5
(m/s)	2.1	2.0	1.8	1.7
Maximum Screen Face Velocity (blocked and minimum submergence) (ft/s)	3.0	3.0	3.0	3.0
(m/s)	0.9	0.9	0.9	0.9
Maximum Approach Flow Velocity (ft/s)	0.36	0.36	0.36	0.36
(m/s)	0.11	0.11	0.11	0.11
Maximum Sump Outlet Coefficient C_L	1.2	1.2	1.2	1.2

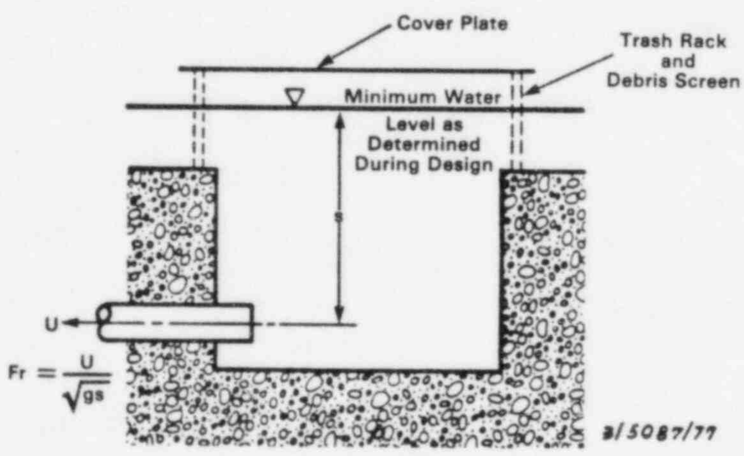


Table A-3.1

GEOMETRIC DESIGN ENVELOPE GUIDELINES FOR HORIZONTAL SUCTION OUTLETS**

	Size			Sump Outlet Position*						Screen	
Sump Outlet	Aspect Ratio	Min. Perimeter (ft)	(m)	e_y/d	$(B - e_y)/d$	c/d	b/d	f/d	e_x/d	Min. Area (ft^2)	(m^2)
Dual	1 to 5	36	11					≥4		75	7
				≥1	≥3	≥1.5	≥1		≥1.5		
Single	1 to 5	16	4.9					-		35	3.3

*Preferred location.
**Dimensions are always measured to pipe centerline.

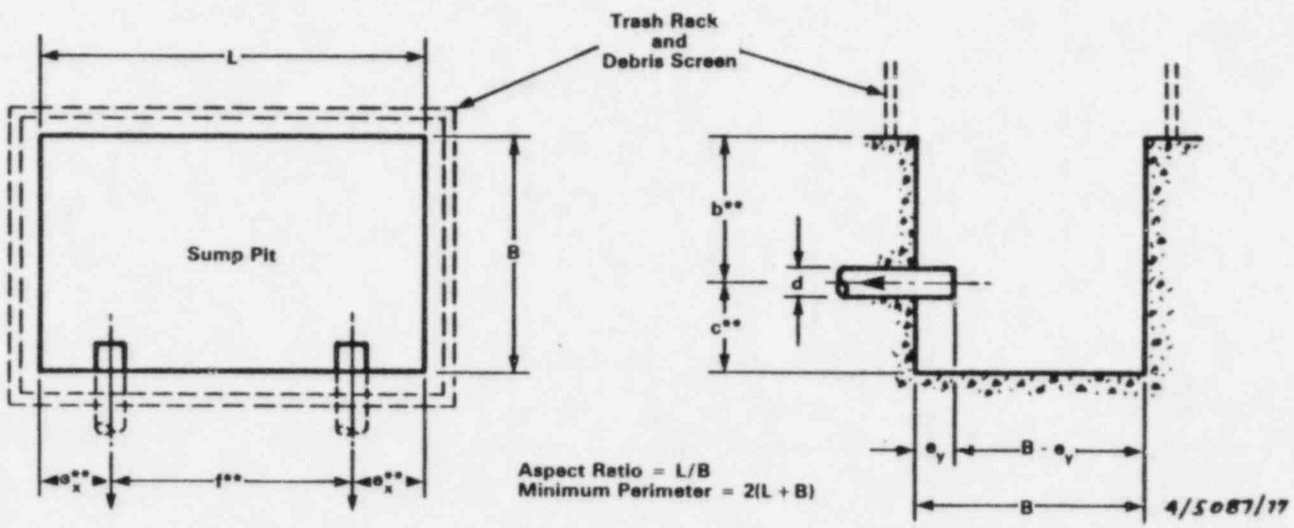


Table A-3.2

GEOMETRIC DESIGN ENVELOPE GUIDELINES FOR VERTICAL SUCTION OUTLETS**

Sump Outlet	Size: Aspect Ratio	Size: Min. Perimeter (ft)	Size: Min. Perimeter (m)	Sump Outlet Position*: e_y/d	$(B - e_y)/d$	c/d	b/d	f/d	e_x/d	Screen: Min. Area (ft^2)	Screen: Min. Area (m^2)
Dual	1 to 5	36	11			≥ 0		≥ 4		75	7
				≥ 1	≥ 1		≥ 1		≥ 1.5		
Single	1 to 5	16	4.9			≤ 1.5		-		35	3.3

*Preferred location.
**Dimensions are always measured to pipe centerline.

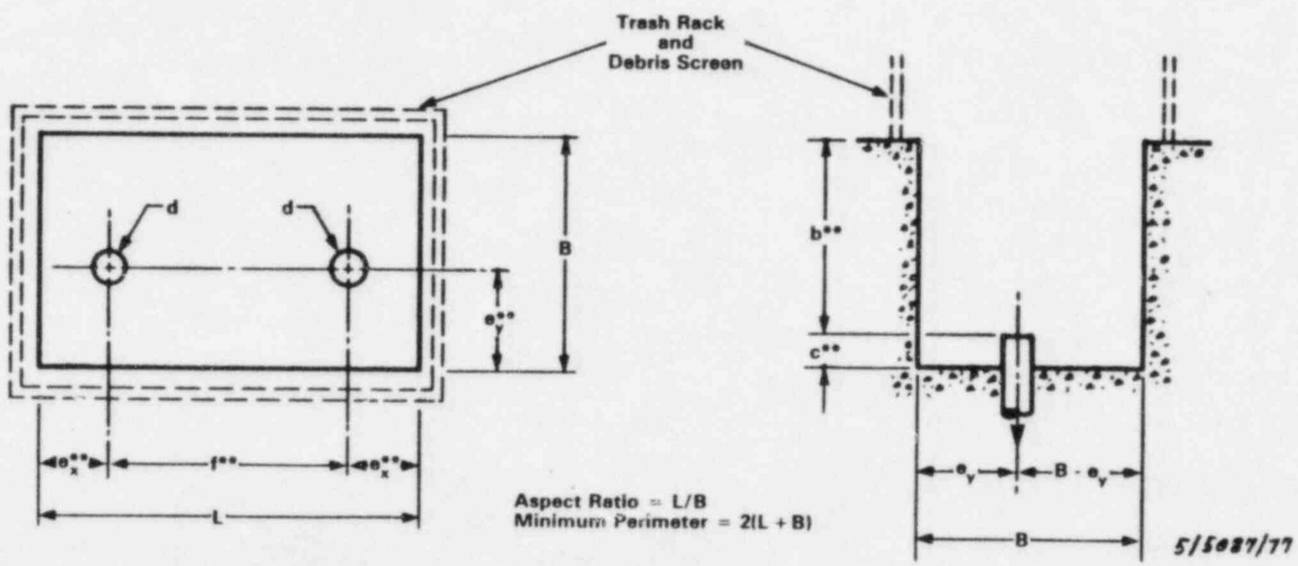


Table A-4

Additional Guidelines Related to Sump Size and Placement

1. The clearance between the trash rack and any wall or obstruction of length ℓ equal to or greater than the length of the adjacent screen/grate (B_s or L_s) should be at least 4 ft (1.2 m).

2. A solid wall or large obstruction may form the boundary of the sump on one side only, i.e., the sump must have three sides open to the approach flow.

3. These additional guidelines should be followed to ensure the validity of the data in Tables A-1, A-2, A-3.1, and A-3.2.

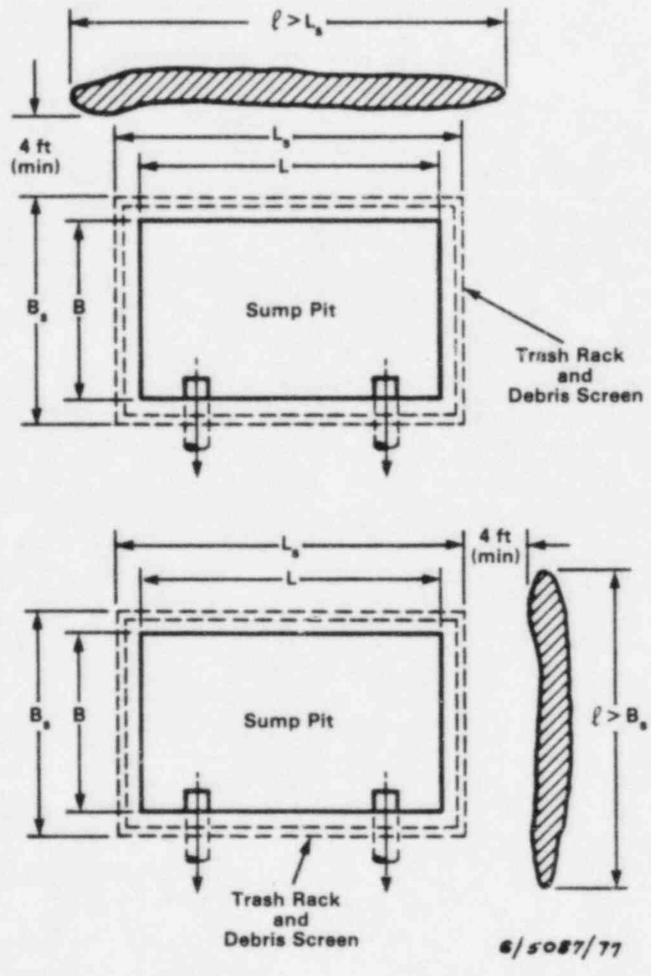
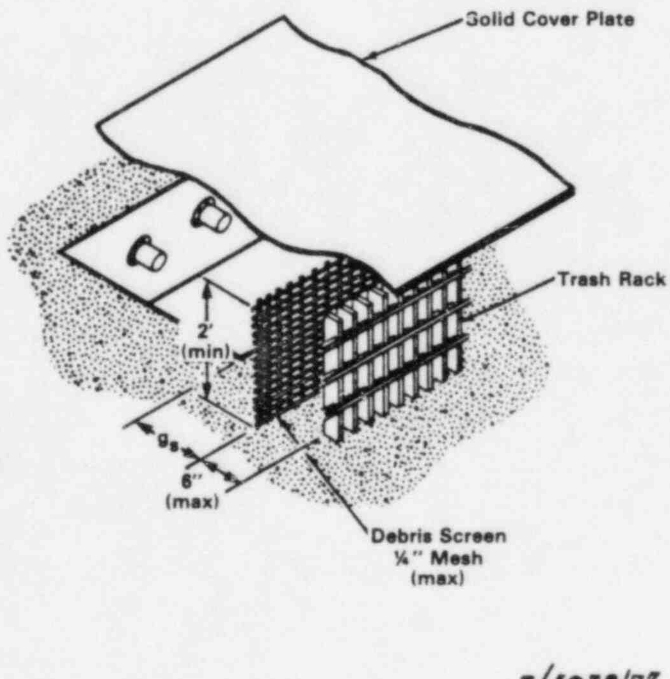


Table A-5

Design Guidelines* for Interceptors and Cover Plate

1. Screen area should be obtained from Table A-3.1 and A-3.2.
2. Minimum height of interceptors should be 2 feet (0.61 m).
3. Distance from sump side to screens, g_s, may be any reasonable value.
4. Screen mesh should be 1/4 inch (6.4 mm) or finer.
5. Trash racks should be vertically oriented 1- to 1-1/2-inch (25- to 38-mm) standard floor grate or equivalent.
6. The distance between the debris screens and trash racks should be 6 inches (15.2 cm) or less.
7. A solid cover plate should be mounted above the sump and should fully cover the trash rack. The cover plate should be designed to ensure the release of air trapped below the plate (a plate located below the minimum water level is preferable).



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*See Ref 1.

Table A-6

Guidelines for Selected Vortex Suppressors*

1. Cubic arrangement of standard 1-1/2-inch (38-mm) deep or deeper floor grating (or its equivalent) with a characteristic length, ℓ_v, that is ≥ 3 pipe diameters and with the top of the cube submerged at least 6 inches (15.2 cm) below the minimum water level. Noncubic designs with $\ell_v \geq 3$ pipe diameters for the horizontal upper grate and satisfying the depth and distances to the minimum water level given for cubic designs are acceptable.

2. Standard 1-1/2-inch (38-mm) or deeper floor grating (or its equivalent) located horizontally over the entire sump and containment floor inside the screens and located below the lip of the sump pit.

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*Tests on these types of vortex suppressors at Alden Research Laboratory have demonstrated their capability to reduce air ingestion to zero even under the most adverse conditions simulated.

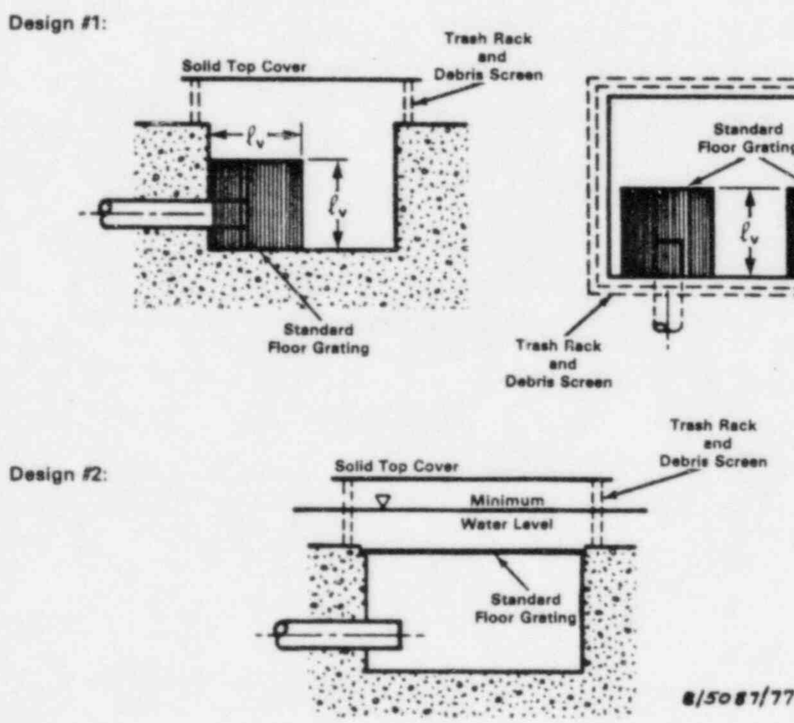

Table A-7

Debris Assessment

CONSIDERATION	EVALUATE
1. Debris generator (pipe breaks & location as identified in SRP Section 3.6.2)	• Major pipe breaks & location • Pipe whip & pipe impact • Break jet expansion envelope (This is the <u>major</u> debris generator)
2. Expanding jets	• Jet expansion envelope • Piping & plant components targeted (i.e., steam generators) • Jet forces on insulation • Insulation that can be destroyed or dislodged by blowdown jets • Survivability under jet loading.
3. Short-term debris transport by blowdown jet forces)	• Jet/equipment interaction • Jet/crane wall interaction • Sump location relative to expanding break jet
4. Long-term debris transport (transport to the sump during the recirculation phase)	• Containment layout & sump (or suction) locations • Debris physical characteristics • Recirculation velocity • Debris transport velocity
5. Screen or sump outlet blockage effects (impairment of flow and/or NPSH margin)	• Screen or outlet area • Water level under post-LOCA conditions • Recirculation flow requirements • Head loss across blocked screen or outlet
6. Downstream blockage (effects of debris deposition and recirculation)	• Core coolant channels • Spray nozzles • Pump clearances
Key elements for assessment of debris effects	• Estimated amount and type of debris that can reach sump • Predicted screen or outlet blockage • ΔP across blocked screens or outlets • NPSH required vs NPSH available

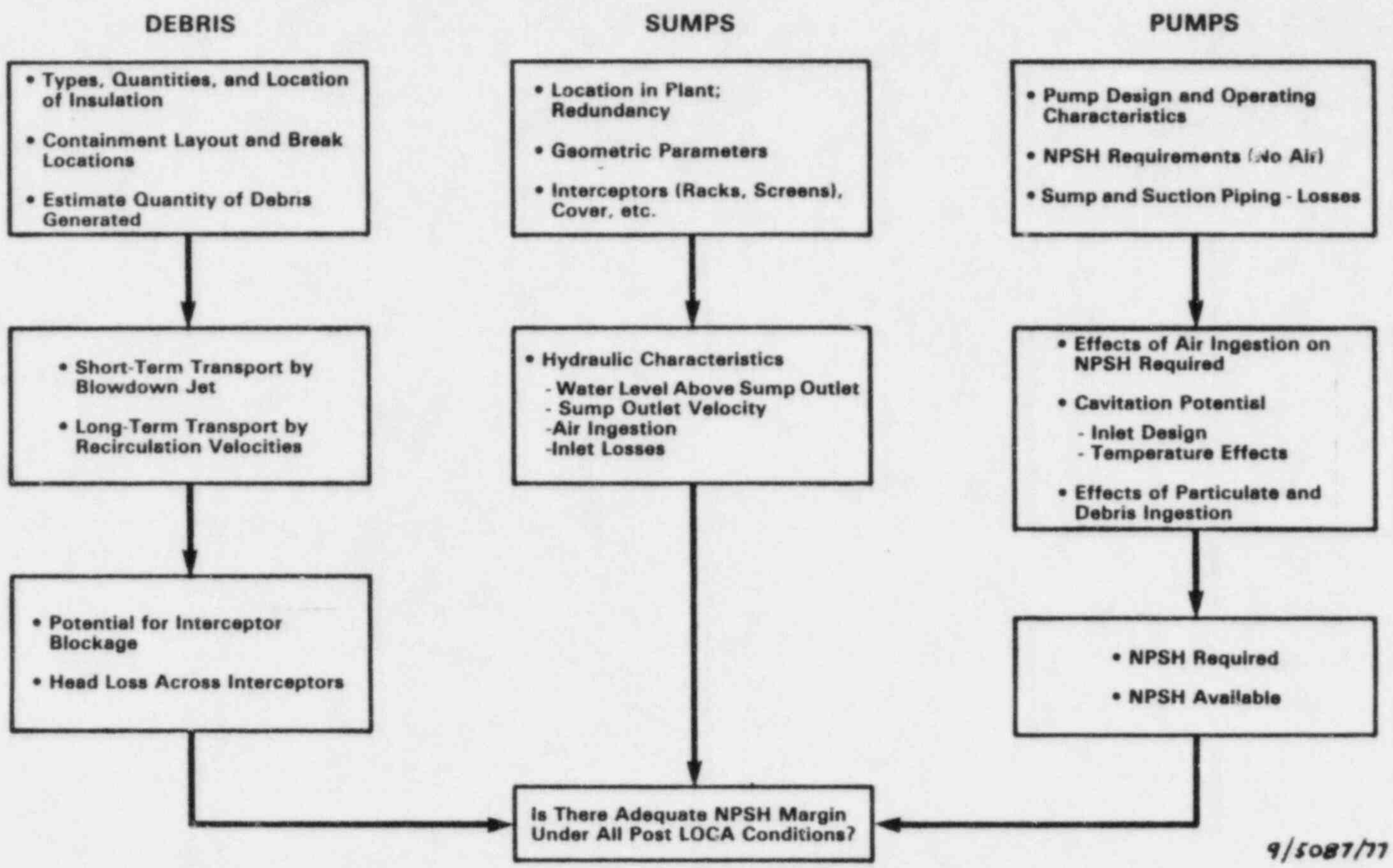

Figure A-1 Technical Consideration Relevant to ECC[S] Sump Performance

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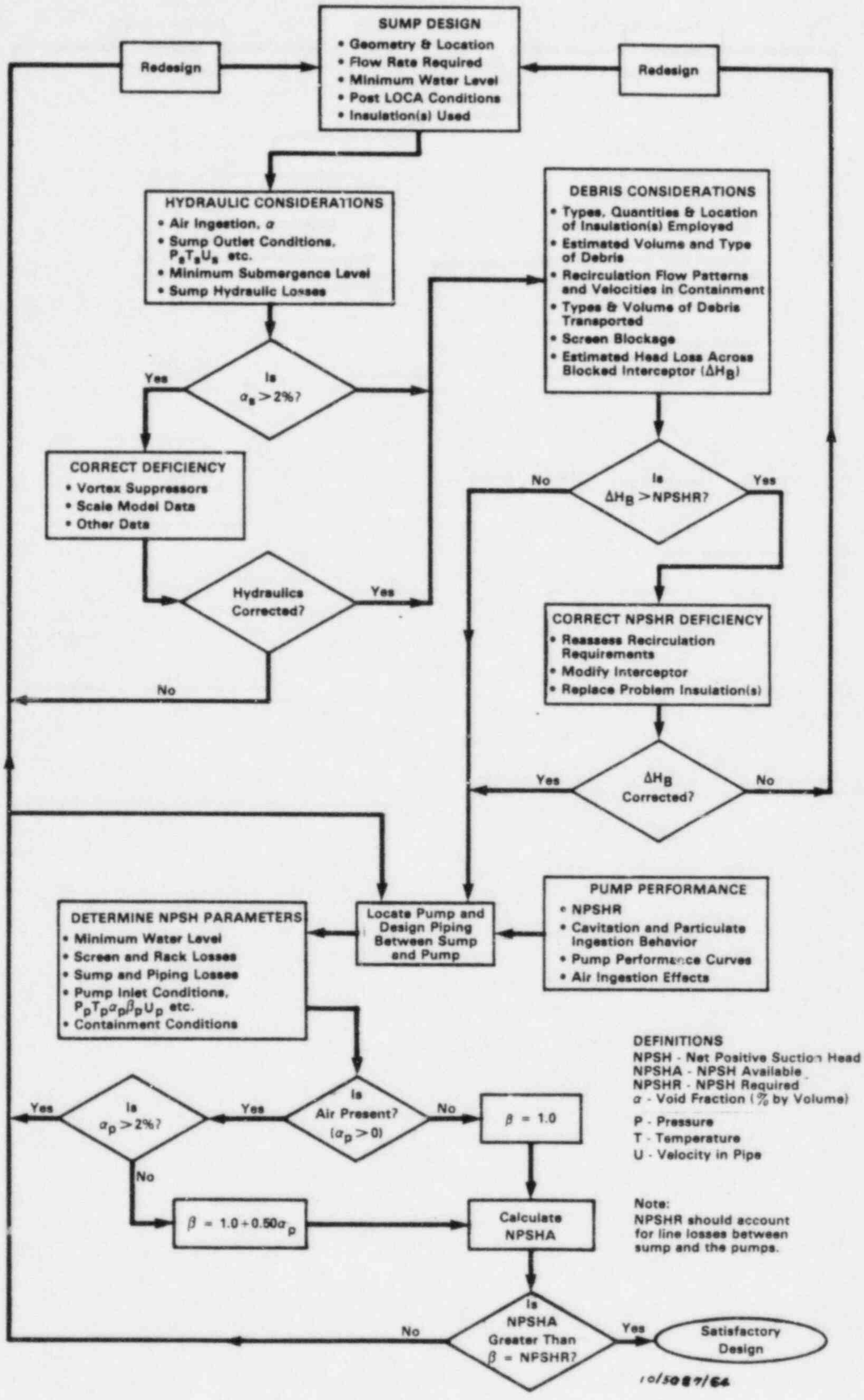

Figure A-2. Combined Technical Considerations for Sump Performance

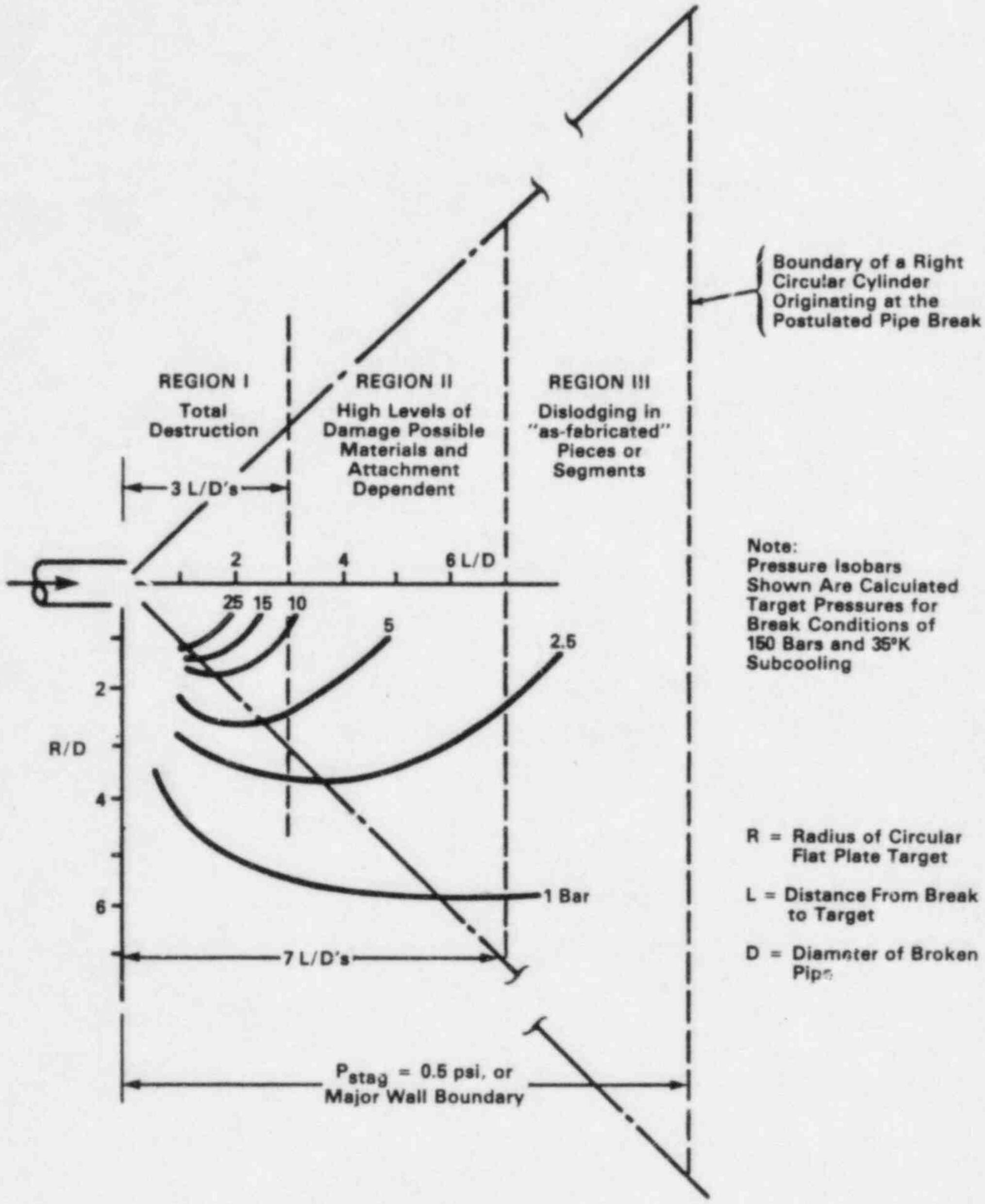

Figure A-3 Multiple Region Insulation Debris Model
(A discussion of the model is provided in Ref 1)

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1. U.S. Nuclear Regulatory Commission, "Containment Emergency Sump Performance (Technical Findings Related to Unresolved Safety Issue [USI] A-43)," NUREG-0897, [September 1982] Draft Revision 1B, June 5, 1985, awaiting publication

2. U.S. Nuclear Regulatory Commission, "Methodology for Evaluation of Insulation Debris Effects," NUREG/CR-2791 (SAND82-7067), September 1982.

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4[6.]. U.S. Nuclear Regulatory Commission, "A Parametric Study of Containment Emergency Sump Performance: Results of Vertical Outlet Sump Tests," NUREG/CR-2759 (SAND82-7062), [September] October 1982.

5.[7.] U.S. Nuclear Regulatory Commission, "Assessment of Scale Effects on Vortexing, Swirl and Inlet Losses in Large Scale Sump Models," NUREG/CR-2760 (SAND82-7063), June 1982.

6.[8.] U.S. Nuclear Regulatory Commission, "Results of Vortex Suppressor Tests, Single Outlet Sump Tests and Miscellaneous Sensitivity Tests," NUREG/CR-2761 (SAND82-7065), September 1982.

7.[9.] U.S. Nuclear Regulatory Commission, "Hydraulic Performance of Pump Suction Inlets for Emergency Core Cooling Systems in Boiling Water Reactors," NUREG/CR-2772 (SAND82-7064), June 1982.

8.[10.] U.S. Nuclear Regulatory Commission, "An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions," NUREG/CR-2792 (CREARE TM-825), September 1982.

9. [4.] U.S. Nuclear Regulatory Commission, "Buoyancy, Transport, and Head Loss of Fibrous Reactor Insulation," NUREG/CR-2982 (SAND82-7205), [November 1982] Revisions 1, July 1983.

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12. U.S. Nuclear Regulatory Commission, "Transport and Screen Blockage Characteristics of Reflective Metallic Insulation Materials," NUREG/CR-3616 (SAND 83-7471). January 1984.

NOTE: NUREG-series documents are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, D.C. 20013-7982. Information concerning placing orders can be obtained by calling 202-275-2060 or 2171. [NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, DC 20555.] Dates are publishing dates.