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DRAFT REGULATORY GUIDE

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(Proposed Revision 3 to Regulatory Guide 1.82)

WATER SOURCES FOR LONG-TERM RECIRCULATION COOLING FOLLOWING A LOSS-OF-COOLANT ACCIDENT

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 systems be provided to perform specific functions, e.g., emergency core cooling, containment heat removal, and containment atmosphere clean up following a postulated design basis accident. These systems must be designed to permit appropriate periodic inspection and testing to ensure their integrity 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 functions to be performed.

This guide is being revised to describe methods acceptable to the NRC staff for implementing these requirements with respect to the sumps and suppression pools performing the functions of water sources for emergency core cooling, containment heat removal, or containment atmosphere clean up. The guide also provides guidelines for evaluating the adequacy of the availability of the sump and suppression pool for long-term recirculation cooling following a loss-of-coolant accident (LOCA). This guide applies to light-water-cooled reactors. Additional information is provided in NRC Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers By Debris in Boiling Water Reactors"; NRC Bulletin 95-02, "Unexpected Clogging of a Residual Heat Removal Pump Strainer While Operating in Suppression Pool

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This regulatory guide is being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. It has not received complete staff review or approval and does not represent an official NRC staff position.

Public comments are being solicited on this draft guide (including any implementation schedule) and its associated regulatory analysis or value/impact statement. Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Rules and Directives Branch, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001. Comments may be submitted electronically or downloaded through the NRC's interactive web site at <WWW.NRC.GOV> through Rulemaking. Copies of comments received may be examined at the NRC Public Document Room, 11555 Rockville Pike, Rockville, MD. Comments will be most helpful if received by **April 30, 2003.**

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Cooling Mode"; NRC Bulletin 93-02, "Debris Plugging of Emergency Core Cooling Suction Strainers"; Supplement 1 to NRC Bulletin 93-02, "Debris Plugging of Emergency Core Cooling Suction Strainers"; Generic Letter 85-22, "Potential for Loss of Post LOCA Recirculation Capability Due to Insulation Debris Blockage"; and Generic Letter 97-04, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps."

This regulatory guide is being revised to enhance the debris blockage evaluation guidance for pressurized water reactors. Research after the issuance of Revision 2 indicated that the previous guidance was not comprehensive enough to adequately evaluate a pressurized water reactor (PWR) plant's susceptibility to the detrimental effects caused by debris accumulation on debris interceptors (e.g., trash racks and sump screens). The sections pertaining to PWRs have been changed, and minor changes have been made to the sections on boiling water reactors (BWRs) to make them consistent with current staff positions as described in the Safety Evaluation on the Boiling Water Reactor Owners Group's response to NRC Bulletin 96-03 (1998).

This regulatory guide is also being revised to include guidance previously provided in Regulatory Guide 1.1, "Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps." The provisions of Regulatory Guide 1.1 have been updated to reflect the results of the NRC's review of responses to Generic Letter 97-04, "Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps," dated October 7, 1997.

Regulatory guides are issued to describe and make available to the public such information as methods acceptable to the NRC staff for implementing specific parts of the NRC's regulations, techniques used by the staff in evaluating specific problems or postulated accidents, and guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with regulatory guides is not required. Regulatory guides are issued in draft form for public comment to involve the public in developing the regulatory positions. Draft regulatory guides have not received complete staff review; they therefore do not represent official NRC staff positions.

The information collections contained in this draft regulatory guide are covered by the requirements of 10 CFR Part 50, which were approved by the Office of Management and Budget (OMB), approval number 3150-3011. The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

B. DISCUSSION

GENERAL

The primary safety concerns regarding long-term recirculation cooling following a LOCA are (1) LOCA-generated and pre-LOCA debris materials transported to the debris interceptors (i.e., trash racks, debris screens, suction strainers) resulting in adverse blockage effects, (2) post-LOCA hydraulic effects, particularly air ingestion, and (3) the combined effects of items (1) and (2) on long-term recirculation pumping operability (i.e., effect on net positive suction head (NPSH) available at the pump inlet).

Debris resulting from a LOCA, together with debris that exists before a LOCA, could block the emergency core cooling (ECC) debris interceptors and result in degradation or loss of NPSH margin. Such debris can be divided into the following categories: (1) debris that is generated by the LOCA and is transported by blowdown forces (e.g., insulation, paint), (2) debris that is generated or transported by washdown, and (3) other debris that existed before a LOCA (e.g., corrosion material, sludge in a BWR suppression pool) and that may become suspended in the containment sump or suppression pool. Debris can be further subdivided into (1) debris that has a high density and could sink but is still subject to fluid transport if local recirculation flow velocities are high enough, (2) debris that has an effective specific gravity of 1.0 and tends to be suspended or sink slowly but will nonetheless be transported by very low velocities or local fluid turbulence phenomena, and (3) debris that will float indefinitely by virtue of low density and will be transported to and possibly through the debris interceptors. Debris generation, early debris transport, long-term debris transport, and attendant blockage of debris interceptors must be evaluated to ensure that the ability of the emergency core cooling system (ECCS) to provide long-term post-LOCA core cooling is not jeopardized. All potential debris sources should be evaluated, including but not limited to, the fire barrier material, insulation materials (e.g., fibrous, ceramic, and metallic), filters, corrosion material, and paints or coatings. Relevant information for such evaluations is provided in the Regulatory Position and in Appendix A to this guide. Additional information relative to the above concerns may be found in Revision 1 of NUREG-0897, NUREG/CR-2758, NUREG/CR-2759, NUREG/CR-2760, NUREG/CR-2761, NUREG/CR-2772, NUREG/CR-2791, NUREG/CR-2792, NUREG/CR-2982, NUREG/CR-3170, NUREG/CR-3394, NUREG/CR-3616, NUREG/CR-6224, NUREG/CR-6369, NUREG/CR-6762, NUREG/CR-6772, NUREG/CR-6773, NRC Information Notice 94-57, NRC Information Notice 95-06, NRC Information Notice 95-47, Regulatory Guide 1.1, Safety Evaluation on NRC Bulletin 96-03, NEDO-32686, and Generic Letter 97-04. A current knowledge base describing results of research on the BWR suction-strainer and PWR sump screen blockage is provided in NUREG/CR-6808.

This regulatory guide provides separate guidance for PWR and BWR plants based on the design features of currently operating reactors. Advanced PWR or BWR designs may employ design features which this regulatory guide only associates with the opposite reactor design (e.g., an advanced PWR design which employs an in-containment refueling water storage tank that is similar to the suppression pool of a current BWR design, or an advanced BWR design which employs a large dry containment that is similar to a current PWR design). Therefore, for advanced PWR and BWR designs, the guidance provided in both the PWR and BWR sections of this regulatory guide should be considered that is appropriate and consistent with the plant's design features.

PRESSURIZED WATER REACTORS

In PWRs, the containment emergency sumps provide for the collection of reactor coolant and chemically reactive spray solutions following a LOCA; thus, the sumps serve as water sources to support 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 ECCS and the containment spray systems (CSS) are referred to in this guide as ECC sumps. Features and relationships of the ECC sumps pertinent to this guide are shown in Figure 1. In operating PWRs, the ECC sump designs may vary from this figure (e.g., in some plants sump screens may be located below the floor level). A more comprehensive description of various ECC sump designs is included in NUREG/CR-6762.

The design of PWR sumps and their outlets includes consideration of the avoidance of air ingestion and other undesirable hydraulic effects (e.g., circulatory flow patterns, outlets 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 to this guide are followed. Revision 1 of NUREG-0897, NUREG/CR-2758, NUREG/CR-2761, and NUREG/CR-2792 provide additional technical information relevant to sump ECC hydraulic performance and design guidelines.

In order for a centrifugal pump to perform its safety function there must be adequate margin between the available net positive suction head (NPSH) and the required NPSH. Failure to provide and maintain adequate NPSH margin for the emergency core cooling system pumps could result in cavitation and their subsequent failure to deliver the amount of water assumed in design basis LOCA calculations. Failure to provide and maintain adequate NPSH for the containment heat removal pumps could result in pressurization of the containment above the design pressure and an increase in the offsite and control room radiological doses.

The available NPSH is a function of the static head of water above the pump suction, the pressure of the atmosphere above the sump water surface, and the temperature of the pumped water at the suction of the pump.

Predicted performance of the emergency core cooling and the containment heat removal pumps should be independent of the calculated increases in containment pressure caused by postulated LOCAs in order to ensure reliable operation under a variety of possible accident conditions. For example, if proper operation of the emergency core cooling system or the containment heat removal system depends on containment pressure above a specified minimum amount, then operation of these systems at a containment pressure less than this amount (resulting, for example, from impaired containment integrity or operation of the containment heat removal systems at too high a rate) could significantly affect the ability of this system to accomplish its safety functions. However, for some operating reactors, some credit for containment accident pressure may be necessary. This should be minimized to the extent possible.

The American National Standard for Centrifugal Pumps for Nomenclature, Definitions, Application and Operation, ANSI/HI 1.1-1.5- 1994 specifies a method of accounting for the decrease in required NPSH with an increase in temperature of the pumped fluid. This method is subject to restrictions specified in the standard dealing with experience with the specific pump, the amount of air dissolved in the fluid and the transient nature of the pressure and temperature of the pumped fluid. The staff considers it prudent to not take credit for the reduction in required NPSH due to the temperature of the pumped fluid because of the uncertainty in these factors.

Although it is possible to perform static NPSH calculations, transient calculations provide more information, ensure that the most conservative conditions are chosen, and ensure a consistent result.

Placement of the ECC sumps at the lowest level practical ensures maximum use of available recirculation coolant. Areas within the containment in which coolant could accumulate during the containment spray period are provided, as necessary, with drains or flow paths to the sumps to prevent coolant holdup. It is also a concern that these drains or flow paths may themselves be blocked either totally or partially, diverting water away from the active sump region. This guide does not address the design of such drains or flow paths. Because 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 are located at an elevation lower than the ECC sumps to minimize inadvertent spillover into the ECC sumps from 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 trash rack and debris screens. Debris blockage of the sump screen may also be mitigated by placement of an active device or system that will take some action to prevent debris, which could block restrictions or damage components in the systems served by the ECC pumps, from entering the ECC pump suction lines, remove debris from the sump screen and flow stream upstream of the ECC pumps, or mitigate any detrimental effects of debris accumulation. Examples of active mitigation systems are listed in Appendix B.

It is necessary to protect sump outlets with sump screens and trash racks 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. Considerations for selecting materials for the debris interceptors include long periods of inactivity, i.e., no submergence, and periods of operation involving partial or full submergence in a fluid that may contain chemically reactive materials. Isolation of the ECC sumps from high-energy pipe lines is an important consideration in protection against missiles, and it is necessary to shield the screens and racks adequately from impacts of ruptured high-energy piping and associated jet loads from the break. When the screen and rack structures are oriented vertically or nearly vertically, the adverse effects from large pieces of debris (e.g., partially torn insulation blankets or damaged reflective metallic insulation cassettes) collecting on them will be reduced. Consistent with the plant licensing basis single-failure criterion, redundant ECC sumps and sump outlets should be separated to the extent practical to reduce the possibility that a single event could render both sumps inoperative.

It is generally expected that the water surface will be above the top of the debris interceptor structure after completion of the safety injection, and before the ECC sumps become operational. However, the uncertainties about the extent of water coverage on the structure, the amount of floating debris that may accumulate, and the potential for early clogging do not favor the use of a horizontal top interceptor. Therefore, in the computation of available interceptor surface area, no credit may be taken for any horizontal interceptor surface unless plant evaluations that adequately account for inherent water source uncertainties demonstrate that the horizontal surface will be submerged at the time of recirculation. For certain sump designs, it is preferable that the top of the interceptor structure is a solid cover plate that will provide additional protection from LOCA-generated loads and is designed to provide for the venting of any trapped air. It is possible that ECC sumps in some plants may not be submerged completely under water at the time of recirculation, either because of unique sump designs or uncertainties in water level estimates. Such partially submerged sumps may be subject to failure criteria other than NPSH margin as discussed in NUREG/CR-6762. In the case of partially submerged sumps, credit should only be given to the portion of the sump screen that is expected to be submerged at the beginning of recirculation.

All debris that is transportable to the trash rack, the debris screen, and the outlets need to be analyzed for head loss effects. Debris that is small enough to pass through the trash rack and the debris screen needs to be analyzed for head loss effects together with the fibrous debris bed that may filter small particulates. Blockage of trash rack, sump screen, and sump outlet is a function of the types, combinations, sizes, shapes, and quantities of insulation debris that can be transported to these components. A vertical or nearly vertical inner debris screen located above the containment floor level would minimize the deposition or settling of debris on screen surfaces and thus help to ensure the greatest possible free flow through the fine inner debris screen. Similarly, locating the sump screens and trash racks above the containment floor level, preferably on a pedestal, minimizes the potential for debris buildup. NUREG/CR-6773 provides test results for transport of various types, sizes, and shapes of debris.

The size of openings in the screens is dependent on the physical restrictions that may exist in the systems that are supplied with coolant from the ECC sump. The size of the mesh of the fine debris screen is determined by considering a number of factors, including the size of the openings in the containment spray nozzles, coolant channel openings in the core fuel assemblies, the presence of fuel assembly inlet debris screens, the minimum dimension within the flow-path (e.g., high pressure safety injection (HPSI) throttle valves), and such pump design characteristics as seals, bearings, and impeller running clearances.

As noted above, degraded pumping can be caused by a number of factors, including plant design and layout. In particular, debris blockage effects on 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, i.e., 2% or less, 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 it is important to use the combined results of all post-LOCA effects to estimate NPSH margin as calculated for the pump inlet. Appendix A to this guide provides information for estimating NPSH margins in PWR sump designs where estimated levels of air ingestion are low (2% or less). Revision 1 of NUREG-0837 and NUREG/CR-2792 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% or less, 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 percentage of 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.

To ensure the operability and structural integrity of the trash racks and screens, access openings are necessary to permit inspection of the ECC sump structures and outlets. Inservice inspection of racks, screens, vortex suppressors, and sump outlets, including visual examination for evidence of structural degradation or corrosion, should be performed on a regular basis at every refueling period downtime. Inspection of the ECC sump components late in the refueling period will ensure the absence of construction trash in the ECC sump area.

BOILING WATER REACTORS

In BWRs, the suppression pool, in conjunction with the primary containment, downcomers, and vents, serves as the water source for effecting long-term recirculation cooling. This source, the related pump suction inlets, and the piping between them are important safety components. Features and relationships of the suppression pool pertinent to this guide are shown in Figure 2. Concerns with the performance of the suppression pool hydraulics and ECC pump suction strainers include consideration of air ingestion effects, blockage of suction strainers (by debris), and the combined effects of these items on the operability of the ECC pumps (e.g., the impact on NPSH available at the pump inlets). Revision 1 of NUREG-0897 and NUREG/CR-2772 provide data on the performance and air ingestion characteristics of BWR suction strainer configurations.

In order for a centrifugal pump to perform its safety function there must be adequate margin between the available and the required net positive suction head (NPSH). Failure to provide and maintain adequate NPSH of the emergency core cooling system pumps could result in cavitation and their subsequent failure to deliver the amount of water assumed in design basis LOCA calculations. For those BWRs that credit containment spray systems in the safety analyses, failure to provide and maintain adequate NPSH of the containment heat removal pumps could result in overpressurization of the containment and an increase in the offsite and control room radiological dose.

Since the safety of a nuclear power plant depends on the expected performance of the centrifugal pumps in the emergency core cooling system and the containment heat removal system, it is important to maintain adequate margin between the available and required NPSH under all potential conditions.

The available NPSH is a function of the static head of water above the pump suction, the pressure of the atmosphere above the water level, and the temperature of the pumped fluid at the suction of the pump.

Predicted performance of the emergency core cooling and the containment heat removal pumps should be independent of the calculated increases in containment pressure caused by postulated LOCAs in order to ensure reliable operation under a variety of possible accident conditions. For example, if proper operation of the emergency core cooling system or the containment heat removal system depends on containment pressure above a specified minimum amount, then operation of these systems at a containment pressure less than this amount (resulting, for example, from impaired containment integrity or operation of the containment heat removal systems at too high a rate) could significantly affect the ability of this system to accomplish its safety functions. However, for some operating reactors, credit for containment accident pressure may be necessary. This should be minimized to the extent possible.

The American National Standard for Centrifugal Pumps for Nomenclature, Definitions, Application and Operation, ANSI/HI 1.1-1.5- 1994 specifies a method of accounting for the decrease in required NPSH with an increase in temperature of the pumped fluid. This method is subject to restrictions specified in the standard dealing with experience with the specific pump, the amount of air dissolved in the fluid and the transient nature of the pressure and temperature of the pumped fluid. The staff has considered it prudent to not take credit for the reduction in required NPSH due to the temperature of the pumped fluid because of the uncertainty in these factors.

Although it is possible to perform static NPSH calculations, transient calculations provide more information and ensure that the most conservative conditions have been used.

It is desirable to consider the use of debris interceptors (i.e., suction strainers) in BWR designs to protect the pump inlets and NPSH margins. The debris interceptor can be a passive suction strainer or an active suction strainer or active strainer system. A passive suction strainer is a device that prevents debris, which may block restrictions in the systems served by the ECC pumps or damage components, from entering the ECC pump suction line by accumulating debris on a porous surface. An example of a passive suction strainer is a truncated-cone-shaped, perforated plate strainer. An active suction strainer or an active strainer system is a device or system that will take some action to prevent debris, which may block restrictions in the systems served by the ECC pumps or damage components, from entering the ECC pump suction lines, remove debris from the flow stream upstream of the ECC pumps, or mitigate any detrimental effects of debris accumulation. Examples of active mitigation systems are listed in Appendix B.

Suppression pool debris transport analysis should include the effects of LOCA progression because LOCAs of different sizes will affect the duration of LOCA-related hydrodynamic phenomena (e.g., condensation oscillation, chugging). The LOCA-related hydrodynamic phenomena and long-term recirculation hydrodynamic conditions will affect the transport of debris in the suppression pool.

Debris that is transported to the suppression pool during a LOCA, or that is present in the suppression pool prior to a LOCA (NRC Information Notices 94-57, 95-06, and 95-47) could block or damage the suction strainers and needs to be analyzed for head loss effects. This head loss analysis should include filtering of particulate debris by the accumulated debris bed. The head loss characteristics of a debris bed will be a function of the types and quantities of the debris, suction strainer approach velocities, and LOCA-related hydrodynamic phenomena in the suppression pool.

C.   REGULATORY POSITION

1. PRESSURIZED WATER REACTORS

1.1 Features Needed To Minimize the Potential for Loss of NPSH

The ECC sumps, which are the source of water for such functions as emergency core cooling and containment heat removal following a LOCA, should contain an appropriate combination of the following features and actions to ensure the availability of the ECC sumps for long-term cooling. The adequacy of the combinations of the features and actions taken should be evaluated using the criteria and assumptions in Regulatory Position 1.3.

1.1.1 ECC Sumps, Debris Interceptors, and Debris Screens

1.1.1.1 A minimum of two sumps should be provided, each with sufficient capacity to service one of the redundant trains of the ECCS and CSS.

1.1.1.2 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 components of both sumps (e.g., trash racks, sump screens, and sump outlets) by whipping pipes or high-velocity jets of water or steam.

1.1.1.3 The sumps should be located on the lowest floor elevation in the containment exclusive of the reactor vessel cavity. The sump outlets should be protected by at least two vertical or nearly vertical debris interceptors: (1) a fine inner debris screen and (2) a coarse outer trash rack to prevent large debris from reaching the debris screen. A curb should be provided upstream of the trash racks to prevent high-density debris from being swept along the floor into the sump.

1.1.1.4 The floor in the vicinity of the ECC sump should slope gradually downward away from the sump to reduce the fraction of debris that might reach the sump screen.

1.1.1.5 All drains from the upper regions of the containment should terminate in such a manner that direct streams of water, which may contain entrained debris, will not directly impinge on the debris interceptors or discharge in the close proximity of the sump. The drains and other narrow pathways that connect compartments with potential break locations to the ECC sump should be designed to ensure that they would not become blocked by the debris; this is to ensure that water required for an adequate NPSH margin could not be held up or diverted from the sump.

1.1.1.6 The strength of the trash racks should be adequate to protect the debris screens from missiles and other large debris. Trash racks and sump screens should be capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under design-basis flow conditions.

1.1.1.7 The top of the 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 should be designed to ensure the venting of air trapped underneath the cover.

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

1.1.1.9 Materials for debris interceptors and sump screens should be selected to avoid degradation during periods of both 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.

1.1.1.10 The debris interceptor structures should include access openings to facilitate inspection of these structures, any vortex suppressors, and the sump outlets.

1.1.1.11 A sump screen design (i.e., size and shape) should be chosen that will avoid the loss of NPSH from debris blockage during the period that the ECCS is required to operate in order to maintain long-term cooling or maximize the time before loss of NPSH caused by debris blockage when used with an active mitigation system (see Regulatory Position 2.1.5).

1.1.1.12 The diameter of the circular opening or the length of the diagonal that connects the opposite corners for rectangular openings in the sump screen should be smaller than the minimum restrictions found in systems served by the ECC sumps. The minimum restriction should take into account the operability of the systems served. For example, spray nozzle clearances, coolant channel openings in the core fuel assemblies, the presence of fuel assembly inlet debris screens, minimum dimension within the HPSI throttle valve flow-path, and such pump design characteristics as seals, bearings, and impeller running clearances will need to be considered in the design to ensure long-term pump operability.

1.1.1.13 The ECCS pumps should be assessed to determine their susceptibility to degradation from debris ingestion and abrasive effects, and actions should be taken to minimize the potential for degradation of long-term recirculation pumping capacity.

1.1.1.14 ECC pump suction inlets 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).

1.1.1.15 All drains from the upper regions of the containment building should terminate in such a manner that direct streams of water, which may contain entrained debris, will not discharge downstream of the sump screen.

1.1.2 Minimizing Debris

The debris (see Regulatory Position 1.3.2) that could accumulate on the sump screen should be minimized.

1.1.2.1 Cleanliness programs should be initiated to clean the containment on a regular basis, and plant procedures should be established for control and removal of foreign materials from the containment.

1.1.2.2 Procedures should be established for using alternative water sources to be activated when unacceptable head loss renders the sump inoperable. The valves needed to align the ECCS with an alternative water source should be periodically inspected and maintained.

1.1.3 Instrumentation

If relying on operator actions to mitigate the consequences of the accumulation of debris on the ECC sump screens, safety-related instrumentation that provides operators with an indication and audible warning of impending loss of NPSH for ECCS pumps should be available in the control room.

1.1.4 Active Sump Screen System

An active device or system (see examples in Appendix B) may be provided to prevent the accumulation of debris on a sump screen or to mitigate the consequences of accumulation of debris on a sump screen. An active system should be able to prevent debris that may block restrictions found in the systems served by the ECC pumps from entering the system. The operation of the active component or system should not adversely affect the operation of other ECC components or systems. Performance characteristics of an active sump screen system should be supported by appropriate test data that addresses head loss performance.

1.2 Evaluation of Alternative Water Sources

In order to demonstrate that a combination of the features and actions listed above are adequate to ensure long-term cooling and that the five criteria of 10 CFR 50.46(b) will be met following a LOCA, an evaluation using the criteria and assumptions in Regulatory Position 1.3 should be conducted. If a licensee is relying on operator actions to prevent the accumulation of debris on ECC sump screens or to mitigate the consequences of the accumulation of debris on the ECC sump screens, an evaluation should be performed to ensure that the operator has adequate indications, training, time, and system capabilities to perform the actions required. Procedures should be established for using alternative water sources to be activated when unacceptable head loss renders the sump inoperable. The valves needed to align the ECCS with an alternative water source should be periodically inspected and maintained.

1.3 Evaluation of Long-Term Recirculation Capability

The following techniques, assumptions, and criteria should be used in a deterministic, plant-specific evaluation to ensure that any implementation of a combination of the features and actions listed in Regulatory Position 1.1 are adequate to ensure a reliable water source for long-term recirculation following a LOCA. The assumptions and criteria listed below can also be used to develop test conditions for sump screens.

Evaluation and confirmation of (1) sump hydraulic performance (e.g., geometric effects and air ingestion), (2) debris effects (e.g., debris transport, interceptor blockage, and head loss), and (3) the combined impact on NPSH available at the pump inlet should be performed to ensure that long-term recirculation cooling can be accomplished following a LOCA. Such an evaluation should arrive at a determination of NPSH margin calculated at the pump inlet. An assessment should also be made of the susceptibility to debris blockage of the containment drainage flow paths to the recirculation sump; this is to protect against reduction in available NPSH if substantial amounts of water are held up or diverted away from the sump. An assessment should be made of the susceptibility of the flow restrictions in the ECCS and CSS recirculation flow paths downstream of the sump screens, and of the recirculation pump seal and bearing assembly design to failure from particulate ingestion and abrasive effects to protect against degradation of long-term recirculation pumping capacity.

1.3.1 Net Positive Suction Head of ECCS and Containment Heat Removal Pumps

1.3.1.1 Emergency core cooling and containment heat removal systems should be designed so that sufficient available NPSH is provided to the system pumps assuming no increase in containment pressure from that present prior to the postulated LOCAs. (See Regulatory Position 1.3.1.2).

1.3.1.2 For certain operating reactors for which the design cannot be practicably altered, compliance with Regulatory Position 1.3.1.1 may not be possible. In these cases, no more containment pressure should be included in the determination of available NPSH than is required to preclude pump cavitation. Calculation of available containment pressure should underestimate the expected containment pressure when determining available NPSH for this situation. Calculation of sump temperature should overestimate the expected temperature when determining available NPSH.

1.3.1.3 For certain operating reactors for which the design cannot be practically altered, if credit is taken for operation of an ECCS or containment heat removal pump in cavitation, prototypical pump tests must be performed along with post-test examination of the pump to demonstrate that pump performance will not be degraded such that the pump continues to meet all the performance criteria assumed in the safety analyses. The time period in the safety analyses during which the pump may be assumed to operate while cavitating should not be longer than the time demonstrated by the performance tests.

1.3.1.4 The decay and residual heat produced following accident initiation should be included in the determination of the water temperature. The uncertainty in the determination of the decay heat should be included in this calculation. The residual heat should be calculated with margin.

1.3.1.5 The hot channel correction factor specified in the American National Standard for Centrifugal Pumps for Nomenclature, Definitions, Application and Operation, ANSI/HI 1.1-1.5-1994, should not be used in determining the margin between the available and required NPSH for emergency core cooling system and containment heat removal system pumps.

1.3.1.6 The calculation of available NPSH should minimize the static head of water above the pump suction (i.e., the level of water on the containment floor). The amount of water in enclosed areas which cannot be readily returned to the sump should not be included in the calculated height of water on the containment floor.

1.3.1.7 The calculation of pipe and fitting resistance and the calculation of the nominal screen resistance without blockage by debris should be done in a recognized, defensible method or determined from applicable experimental data.

1.3.1.8 Sump screen flow resistance due to blockage by LOCA-generated debris or foreign material in the containment which is transported to the suction intake screens should be determined using the Regulatory Position 1.3.4.

1.3.1.9 Calculation of available NPSH should be performed as a function of time until it is clear that the available NPSH will not decrease further.

1.3.2 Debris Sources and Generation

1.3.2.1 Consistent with the requirements of 10 CFR 50.46, debris generation should be calculated for a number of postulated LOCAs of different sizes, locations, and other properties sufficient to provide assurance that the most severe postulated LOCAs are calculated. Some PWRs may require recirculation from the sump for licensing basis events other than LOCAs. Therefore, plants should review the licensing basis and include potential break locations in the main steam and main feedwater lines as well in determining the most limiting conditions for sump operation.

1.3.2.2 An acceptable method for estimating the amount of debris generated by a postulated LOCA is to use the zone of influence. Examples of this approach are provided in NUREG/CR-6224 and Boiling Water Reactor Owners' Group (BWROG)Utility Resolution Guidance (NEDO-32686 and the staff's Safety Evaluation on the BWROG's response to NRC Bulletin 96-03). A representation of zone of influence for commonly used insulation materials is shown in Figure 3.

- The size and shape of the zone of influence should be supported by analysis or experiments for the break and potential debris.

- The volume of debris contained within the zone of influence should be used to estimate the amount of debris generated by a postulated break.

- The size distribution of debris created in the zone of influence should be determined by analysis or experiments.

- The shock wave generated during postulated pipe break and the subsequent jet should be the basis for estimating the amount of debris generated and the size or size distribution of the debris generated within the zone of influence.

1.3.2.3 A sufficient number of breaks in each high-pressure system that relies on recirculation should be considered to reasonably bound variations in debris generation by the size, quantity, and type of debris. As a minimum, the following postulated break locations should be considered.

- Breaks in the hot leg, cold leg, intermediate leg, and, depending on the plant licensing basis, main steam and main feedwater lines with the largest amount of potential debris within the postulated zone of influence,
- Large breaks with two or more different types of debris, including the breaks with the most variety of debris, within the expected zone of influence,
- Breaks in areas with the most direct path to the sump,
- Medium and large breaks with the largest potential particulate debris to insulation ratio by weight, and
- Breaks that generate an amount of fibrous debris that, after its transport to the sump screen, creates a minimum uniform thin bed (1/8-inch layer of fiber) to filter particulate debris.

1.3.2.4 All insulation (e.g., fibrous, calcium silicate, reflective metallic), painted surfaces, fire barrier materials, and fibrous, cloth, plastic, or particulate materials within the zone of influence should be considered debris sources. Analytical models or experiments should be used to predict the size of the postulated debris. For breaks postulated in the vicinity of the pressure vessel, the potential for debris generation from the packing materials commonly used in the penetrations and the insulation installed on the pressure vessel should be considered. Particulate debris generated from pipe rupture jets stripping off paint or coatings and eroding concrete at the point of impact should also be considered.

1.3.2.5 The cleanliness of the containment during plant operation should be considered when estimating the amount and type of debris available to block the ECC sump screens. The potential for such material (e.g., thermal insulation other than piping insulation, ropes, fire hoses, wire ties, tape, ventilation system filters, permanent tags or stickers on plant equipment, rust flakes from unpainted steel surfaces, corrosion products, dust/dirt, latent individual fibers) to impact head loss across the ECC sump screens should also be considered.

1.3.2.6 In addition to debris generated by jet forces from the pipe rupture, debris created by the resulting containment environment (thermal and chemical) should be considered in the analyses. Examples of this type of debris would be disbondment of coatings in the form of chips and particulates or formation of chemical debris (precipitates) caused by chemical reactions in the pool.

1.3.2.7 Debris generation that is due to continued degradation of insulation and other debris when subjected to turbulence caused by cascading water flows from upper regions of the containments or near the break overflow region should be considered in the analyses.

1.3.3 Debris Transport

1.3.3.1 The calculation of debris quantities transported from debris sources to the sump screen should consider all modes of debris transport including airborne debris transport, containment spray washdown debris transport, and containment sump pool debris transport.

1.3.3.2 The debris transport analyses should consider each type of insulation (e.g., fibrous, calcium silicate, reflective metallic) and debris size (e.g., particulates, fibrous fine, large pieces of fibrous insulation). The analysis should also consider potential for further decomposition of the debris as it is transported to the sump screen.

1.3.3.3 Bulk flow velocity from recirculation operations, LOCA-related hydrodynamic phenomena, and other hydrodynamic forces (e.g., local turbulence effects or pool mixing) should be considered for both debris transport and ECC sump screen velocity computations.

1.3.3.4 An acceptable analytical approach to predict debris transport within the sump pool is to use computational fluid dynamics (CFD) simulations in combination with the experimental debris transport data. Examples of this approach are provided in NUREG/CR-6772 and NUREG/CR-6773.

1.3.3.5 Curbs can be credited for removing heavier debris that has been shown analytically or experimentally to travel by sliding along the containment floor and that cannot be lifted off the floor within the calculated water velocity range.

1.3.3.6 All debris (e.g., fine fibrous, particulates) that is assumed or demonstrated to suspend indefinitely or to sink very slowly should be considered to reach the sump screen.

1.3.3.7 The time to switch over to sump recirculation and the operation of containment spray should be considered in the evaluation of debris transport to the sump screen.

1.3.3.8 In lieu of performing debris transport analyses, it should be assumed that all debris will be transported to the sump screen.

1.3.4 Debris Accumulation and Head Loss

1.3.4.1 ECC sump screen blockage should be evaluated based on the amount of debris estimated using the assumptions and criteria described in Regulatory Position 1.3.2 and on the debris transported to the ECC sump per Regulatory Position 1.3.3. This volume of debris should be used to estimate the rate of accumulation of debris on the ECC sump screen.

1.3.4.2 Consideration of ECC sump screen submergence (full or partial) at the time of switchover to ECCS should be given in calculating the available (wetted) screen area. Unless otherwise shown analytically or experimentally, debris should be assumed to be uniformly distributed over the available sump screen surface. Debris mass should be calculated based on the amount of debris estimated to reach or to be in the ECC sump. (See Revision 1 of NUREG-0897, NUREG/CR-3616, and NUREG/CR-6224.)

1.3.4.3 For fully submerged sump screens, the NPSH available to the ECC pumps should be determined using the conditions specified in the plant's licensing basis.

1.3.4.4 For partially submerged sumps, NPSH margin may not be the only failure criterion as discussed in Appendix A. For partially submerged sumps, credit should only be given to the portion of the sump screen that is expected to be submerged at the beginning of recirculation.

1.3.4.5 Estimates of head loss caused by debris blockage should be developed from empirical data based on the sump screen design (e.g., surface area and geometry), postulated combinations of debris (i.e., amount, size distribution, type), and approach velocity. Because debris beds that form on sump screens can trap debris that would pass through an unobstructed sump screen opening, any head loss correlation should conservatively account for filtration of particulates by the debris bed, including particulates that would pass through an unobstructed sump screen.

1.3.4.6 Consistent with the requirements of 10 CFR 50.46, head loss should be calculated for the debris beds formed of different combinations of fibers and particulate mixtures (e.g., minimum uniform thin-bed of fibers supporting layer of particulate debris) based on assumptions and criteria described in Regulatory Positions 1.3.2 and 1.3.3.

2. BOILING WATER REACTORS

2.1 Features Needed To Minimize the Potential for Loss of NPSH

The suppression pool, which is the source of water for such functions as emergency core cooling and containment heat removal following a LOCA, in conjunction with the vents and downcomers between the drywell and the wetwell, should contain an appropriate combination of the following features and actions to ensure the availability of the suppression pool for long-term cooling. The adequacy of the combinations of the features and actions taken should be evaluated using the criteria and assumptions in Regulatory Position 2.2.

2.1.1 Net Positive Suction Head of ECCS and Containment Heat Removal Pumps

2.1.1.1 Emergency core cooling and containment heat removal systems should be designed so that sufficient available NPSH is provided to the system pumps assuming no increase in containment pressure from that present prior to the postulated LOCAs. (See Regulatory Position 2.1.1.2).

2.1.1.2 For certain operating reactors for which the design cannot be practicably altered, compliance with Regulatory Position 2.1.1.1 may not be possible. In these cases, no more containment pressure should be included in the determination of available NPSH than is necessary. Calculation of containment pressure should underestimate the expected containment pressure when determining available NPSH for this situation. Calculation of suppression pool water temperature should overestimate the expected temperature when determining available NPSH.

2.1.1.3 For certain operating reactors for which the design cannot be practically altered, if credit is taken for operation of an ECCS or containment heat removal pump in cavitation, prototypical pump tests and post-test examination of the pump must demonstrate that pump performance will not be degraded such that the pump continues to meet all the performance criteria assumed in the safety analyses. The time period in the safety analyses during which the pump may be assumed to operate while cavitating should not be longer than the time demonstrated by the performance tests.

2.1.1.4 The decay and residual heat produced following accident initiation should be included in the determination of the water temperature. The uncertainty in the determination of the decay heat should be included in this calculation. The residual heat should be calculated with margin.

2.1.1.5 The hot channel correction factor specified in the American National Standard for Centrifugal Pumps for Nomenclature, Definitions, Application and Operation, ANSI/HI 1.1-1.5-1994 should not be used in determining the margin between the available and required NPSH for emergency core cooling system and containment heat removal system pumps during recirculation following a LOCA.

2.1.1.6 The level of water in suppression pools should be the minimum value given in the technical specifications reduced by the drawdown due to suppression pool water in the drywell and the sprays.

2.1.1.7 The calculation of pipe and fitting resistance and the calculation of the nominal screen resistance without blockage by debris should be done in a recognized, defensible method or determined from applicable experimental data.

2.1.1.8 Suction strainer screen flow resistance due to blockage by LOCA-generated debris or foreign material in the containment which is transported to the suction intake screens should be determined using the methods given in this Regulatory Position 2.3.3.

2.1.1.9 Calculation of available NPSH should be performed as a function of time until it is clear that the available NPSH will not decrease further.

2.1.2 Passive Strainer

The inlet of pumps performing the above functions should be protected by a suction strainer placed upstream of the pumps; this is to prevent the ingestion of debris that may block restrictions in the systems served by the ECC pumps or damage components. The following items should be considered in the design and implementation of a passive strainer.

2.1.2.1 A suction strainer design (i.e., size and shape) should be chosen that will avoid the loss of NPSH from debris blockage during the period that the ECCS is required to operate in order to maintain long-term cooling or maximize the time before loss of NPSH caused by debris blockage when used with an active mitigation system (see Regulatory Position 2.1.5).

2.1.2.2 The size of openings in the suppression pool suction strainers should be based on the minimum restrictions found in systems served by the suppression pool. The minimum restriction should take into account the operability of the systems served. For example, spray nozzle clearances, coolant channel openings in the core fuel assemblies, the presence of fuel assembly inlet debris screens, and such pump design characteristics as seals, bearings, and impeller running clearances should be considered in the design to ensure long-term pump operability. The ECCS pumps should be assessed to determine their susceptibility to degradation from debris ingestion and abrasive effects; actions should be taken to minimize the potential for degradation of long-term recirculation pumping capacity.

2.1.2.3 ECC pump suction inlets 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).

2.1.2.4 All drains from the upper regions of the containment should terminate in such a manner that direct streams of water, which may contain entrained debris, will not impinge on the suppression pool suction strainers.

2.1.2.5 The strength of the suction strainers should be adequate to protect the debris screen from missiles and other large debris. The strainers and the associated structural support should be adequate to withstand loads imposed by missiles, debris accumulation, and hydrodynamic loads induced by suppression pool dynamics. To the extent practical, the strainers should be located outside the zone of influence of the vents, downcomers, or spargers to minimize hydrodynamic loads. The strainer design, vis-a-vis the hydrodynamic loads, should be validated analytically or experimentally.

2.1.2.6 The suction strainers should be designed to withstand the vibratory motion of seismic events without loss of structural integrity.

2.1.2.7 Material for suction strainers should be selected to avoid degradation during periods of inactivity and normal operations.

2.1.3 Minimizing Debris

The amount of potential debris (see Regulatory Position 2.3.1) that could clog the ECC suction strainers should be minimized. This may be accomplished by:

2.1.3.1 Containment cleanliness programs should be instituted to clean the suppression pool on a regular basis and plant procedures should be established for control and removal of foreign materials from containment.

2.1.3.2 Debris interceptors in the drywell in the vicinity of the downcomers or vents may serve effectively in reducing debris transport to the suppression pool. In addition to meeting Regulatory Position 2.1.2, debris interceptors between the drywell and wetwell should not reduce the suppression capability of the containment.

2.1.4 Instrumentation

If relying on operator actions to mitigate the consequences of the accumulation of debris on the suction strainers, safety-related instrumentation that provides operators with an indication and audible warning of impending loss of NPSH for ECCS pumps should be available in the control room.

2.1.5 Active Strainers

An active component or system (see Appendix B) may be provided to prevent the accumulation of debris on a suction strainer or to mitigate the consequences of accumulation of debris on a suction strainer. An active system should be able to prevent debris that may block restrictions found in the systems served by the ECC pumps from entering the system. The operation of the active component or system should not adversely affect the operation of other ECC components or systems. The use of active strainers should be validated by adequate testing.

2.1.6 Inservice Inspection

Inservice inspection requirements should be established that include (1) inspection during every refueling outage to ensure the cleanliness of the suppression pool, (2) a visual examination for evidence of structural degradation or corrosion of the suction strainers and strainer system, and (3) an inspection of the wetwell and the drywell, including the vents, downcomers, and deflectors, for the identification and removal of debris or trash that could contribute to the blockage of suppression pool suction strainers.

2.2 Evaluation of Alternative Water Sources

In order to demonstrate that a combination of the features and actions listed above are adequate to ensure long-term cooling and that the five criteria of 10 CFR 50.46(b) will be met following a LOCA, an evaluation using the criteria and assumptions in Regulatory Position 2.3 should be conducted. If a licensee is relying on operator actions to prevent the accumulation of debris on suction strainers or to mitigate the consequences of the accumulation of debris on the suction strainers, an evaluation should be performed to ensure that the operator has adequate indications, training, time, and system capabilities to perform the actions required. Procedures should be established to use alternative water sources. The valves needed to align the ECCS with an alternative water source should be periodically inspected and maintained.

2.3 Evaluation of Long-Term Recirculation Capability

During any evaluation of the susceptibility of a BWR to debris blockage, the considerations and events shown in Figures 4 and 5 should be addressed. The following techniques, assumptions, and criteria should be used in a deterministic evaluation to ensure that any implementation of a combination of the features and actions listed in Regulatory Position 2.1 are adequate to ensure a reliable water source for long-term recirculation after a LOCA. An assessment should be made of the susceptibility to debris blockage of the containment drainage flowpaths to the suppression pool, and flow restrictions in the ECCS and containment spray recirculation flowpaths downstream of the suction strainer to protect against degradation of long-term recirculation pumping capacity. Unless otherwise noted, the techniques, assumptions, and criteria listed below are applicable to an evaluation of passive and active strainers. The assumptions and criteria listed below can also be used to develop test conditions for suction strainers or strainer systems.

2.3.1 Debris Sources and Generation

2.3.1.1 Consistent with the requirements of 10 CFR 50.46, debris generation should be calculated for a number of postulated LOCAs of different sizes, locations, and other properties sufficient to provide assurance that the most severe postulated LOCAs are calculated.

2.3.1.2 An acceptable method for determining the shape of the zone of influence of a break is described in NUREG/CR-6224 and Boiling Water Reactor Owners' Group Utility Resolution Guidance. The volume contained within the zone of influence should be used to estimate the amount of debris generated by a postulated break. The distance of the zone of influence from the break should be supported by analysis or experiments for the break and potential debris. The shock wave generated during postulated pipe break and the subsequent jet should be the basis for estimating the amount of debris generated and the size or size distribution of the debris generated within the zone of influence.

2.3.1.3 All sources of fibrous materials in the containment such as fire protection materials, thermal insulation, or filters that are present during operation should be identified.

2.3.1.4 All insulation, painted surfaces, and fibrous, cloth, plastic, or particulate materials within the zone of influence should be considered debris sources. Analytical models or experiments should be used to predict the size of the postulated debris.

2.3.1.5 As a minimum, the following postulated break locations should be considered.

- Breaks on the main steam, feedwater, and recirculation lines with the largest amount of potential debris within the expected zone of influence,
- Large breaks with two or more different types of debris within the expected zone of influence,
- Breaks in areas with the most direct path between the drywell and wetwell,
- Medium and large breaks with the largest potential particulate debris to insulation ratio by weight, and
- Breaks that generate an amount of fibrous debris that, after its transport to the suction strainer, creates a minimum uniform thin bed (1/8-inch layer of fiber) to filter particulate debris.

2.3.1.6 The cleanliness of the suppression pool and containment during plant operation should be considered when estimating the amount and type of debris available to block the suction strainers. The potential for such material (e.g., thermal insulation other than piping insulation, ropes, fire hoses, wire ties, tape, ventilation system filters, permanent tags or stickers on plant equipment, rust flakes from unpainted steel surfaces, corrosion products, dust and dirt, latent individual fibers) to impact head loss across the suction strainer should also be considered.

2.3.1.7 The amount of particulates estimated to be in the pool prior to a LOCA should be considered to be the maximum amount of corrosion products (i.e., sludge) expected to be generated since the last time the pool was cleaned. The size distribution and amount of particulates should be based on plant samples.

2.3.2 Debris Transport

2.3.2.1 It should be assumed that all debris fragments smaller than the clearances in the gratings will be transported to the suppression pool during blowdown. Credit may be taken for filtration of larger pieces of debris by floor gratings and other interdicting structures present in a drywell (NEDO-32686 and NUREG/CR-6369). However, it should be assumed that a fraction of large fragments captured by the gratings would be eroded by the combined effects of cascading break overflow and the drywell spray flow. The fraction of the smaller debris generated and thus transported to the suppression pool during the blowdown, as well as the fraction of the larger debris that may be eroded during the washdown phase, should be determined analytically or experimentally.

2.3.2.2 It should be assumed that LOCA-induced phenomena (i.e., pool swell, chugging, condensation oscillations) will suspend all the debris assumed to be in the suppression pool at the onset of the LOCA.

2.3.2.3 The concentration of debris in the suppression pool should be calculated based on the amount of debris estimated to reach the suppression pool from the drywell and the amount of debris and foreign materials estimated to be in the suppression pool prior to a postulated break.

2.3.2.4 Credit should not be taken for debris settling until LOCA-induced turbulence in the suppression pool has ceased. The debris settling rate for the postulated debris should be validated analytically or experimentally.

2.3.2.5 Bulk suppression pool velocity from recirculation operations, LOCA-related hydrodynamic phenomena, and other hydrodynamic forces (e.g., local turbulence effects or pool mixing) should be considered for both debris transport and suction strainer velocity computations.

2.3.3 Strainer Blockage and Head Loss

2.3.3.1 Strainer blockage should be based on the amount of debris estimated using the assumptions and criteria described in Regulatory Position 2.3.1 and on the debris transported to the wetwell per Regulatory Position 2.3.2. This volume of debris, as well as other materials that could be present in the suppression pool prior to a LOCA, should be used to estimate the rate of accumulation of debris on the strainer surface.

2.3.3.2 The flow rate through the strainer should be used to estimate the rate of accumulation of debris on the strainer surface.

2.3.3.3 The suppression pool suction strainer area used in determining the approach velocity should conservatively account for blockage that may result. Unless otherwise shown analytically or experimentally, debris should be assumed to be uniformly distributed over the available suction strainer surface. Debris mass should be calculated based on the amount of debris estimated to reach or to be in the suppression pool. (See Revision 1 of NUREG-0897, NUREG/CR-3616, and NUREG/CR-6224.)

2.3.3.4 The NPSH available to the ECC pumps should be determined using the conditions specified in the plant's licensing basis.

2.3.3.5 Estimates of head loss caused by debris blockage should be developed from empirical data based on the strainer design (e.g., surface area and geometry), postulated debris (i.e., amount, size distribution, type), and velocity. Any head loss correlation should conservatively account for filtration of particulates by the debris bed.

2.3.3.6 The performance characteristics of a passive or an active strainer should be supported by appropriate test data that addresses, at a minimum, (1) suppression pool hydrodynamic loads and (2) head loss performance.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this draft regulatory guide. No backfitting is intended or approved in connection with the issuance of this guide.

This draft guide has been released to encourage public participation in its development. Except in those cases in which an applicant or licensee proposes an acceptable alternative method for complying with the specified portions of the NRC's regulations, the methods to be described in the active guide reflecting public comments will be used in the evaluation of applications for construction permits and operating licenses. The active guide will also serve as guidance for the conduct of reviews under 10 CFR 50.59 that deal with plant modifications installed on primary coolant system piping and components when such modifications may affect the availability of water sources for long-term recirculation (e.g., altering potential sources of debris). The active guide will also be used by the NRC staff to evaluate licensees' compliance with 10 CFR 50.46.

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[2] Copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202)512-1800); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161; (telephone (703)487-4650; <http://www.ntis.gov/ordernow>. Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or (800)397-4209; fax (301)415-3548; email is PDR@NRC.GOV.

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Regulatory Guide 1.1, “Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal System Pumps,” USNRC (U.S. Atomic Energy Commission), November 2, 1970.[3]

Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Bulletin 96-03, Boiling Water Reactor Owners Group Topical Report NEDO-32686, ”Utility Resolution Guidance for ECCS Suction Strainer Blockage,” August 20, 1998. (Electronically available at <http://nrr10/projects/ser/1998/m96920.htm> .)

[3] Requests for single copies of draft or active regulatory guides (which may be reproduced) or for placement on an automatic distribution list for single copies of future draft guides in specific divisions should be made in writing to the U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Reproduction and Distribution Services Section, or by fax to (301)415-2289; email <DISTRIBUTION@NRC.GOV>. Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike (first floor), Rockville, MD; the PDR’s mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or 1-(800)397-4209; fax (301)415-3548; e-mail <PDR@NRC.GOV>.

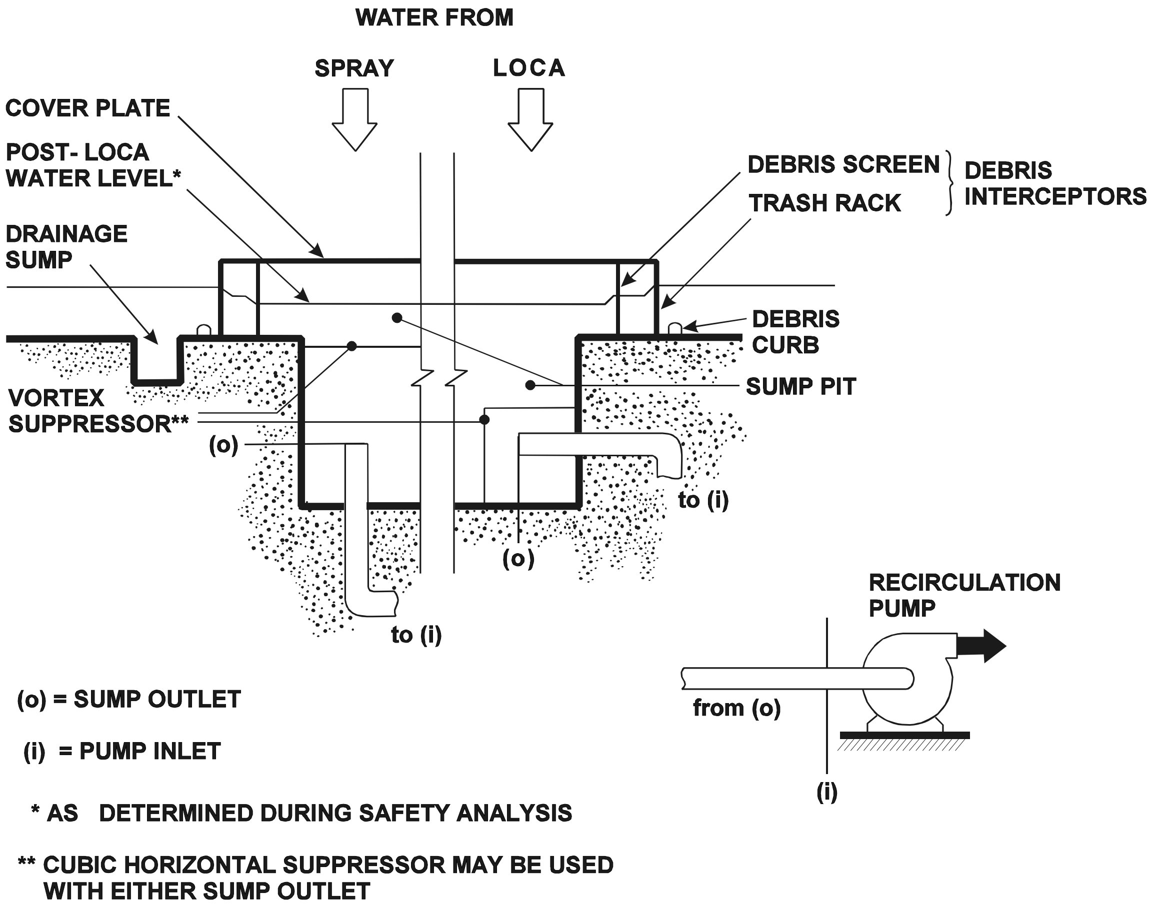
WATER FROM
SPRAY
LOCA
COVER PLATE
POST- LOCA WATER LEVEL*
DRAINAGE SUMP
DEBRIS SCREEN
TRASH RACK
DEBRIS INTERCEPTORS
DEBRIS CURB
SUMP PIT
VORTEX SUPPRESSOR**
(o)
to (i)
(o)
to (i)
RECIRCULATION PUMP
from (o)
(i)
(o) = SUMP OUTLET
(i) = PUMP INLET
* AS DETERMINED DURING SAFETY ANALYSIS
** CUBIC HORIZONTAL SUPPRESSOR MAY BE USED WITH EITHER SUMP OUTLET

Figure 1.

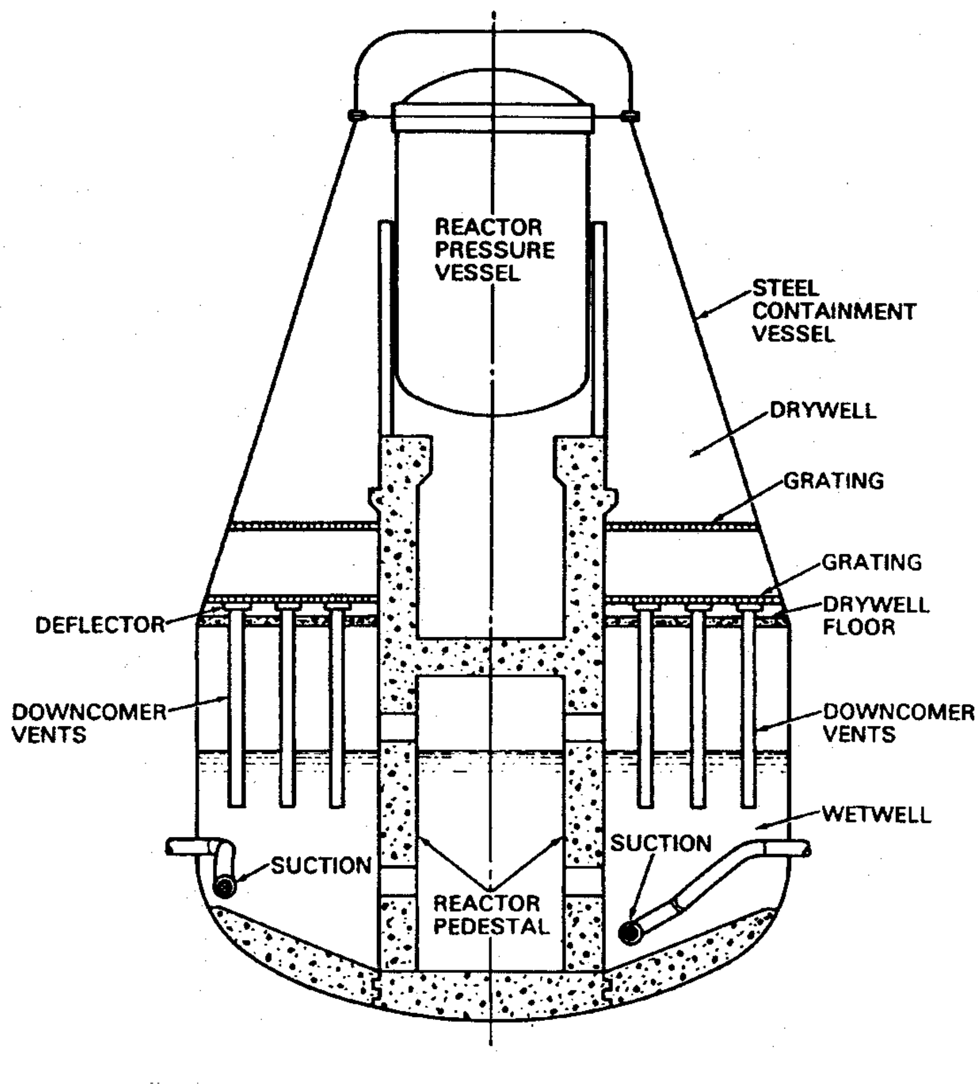
REACTOR
PRESSURE
VESSEL
STEEL
CONTAINMENT
VESSEL
DRYWELL
GRATING
GRATING
DEFLECTOR
DRYWELL
FLOOR
DOWNCOMER
VENTS
DOWNCOMER
VENTS
WETWELL
SUCTION
SUCTION
REACTOR
PEDESTAL

Figure 2.

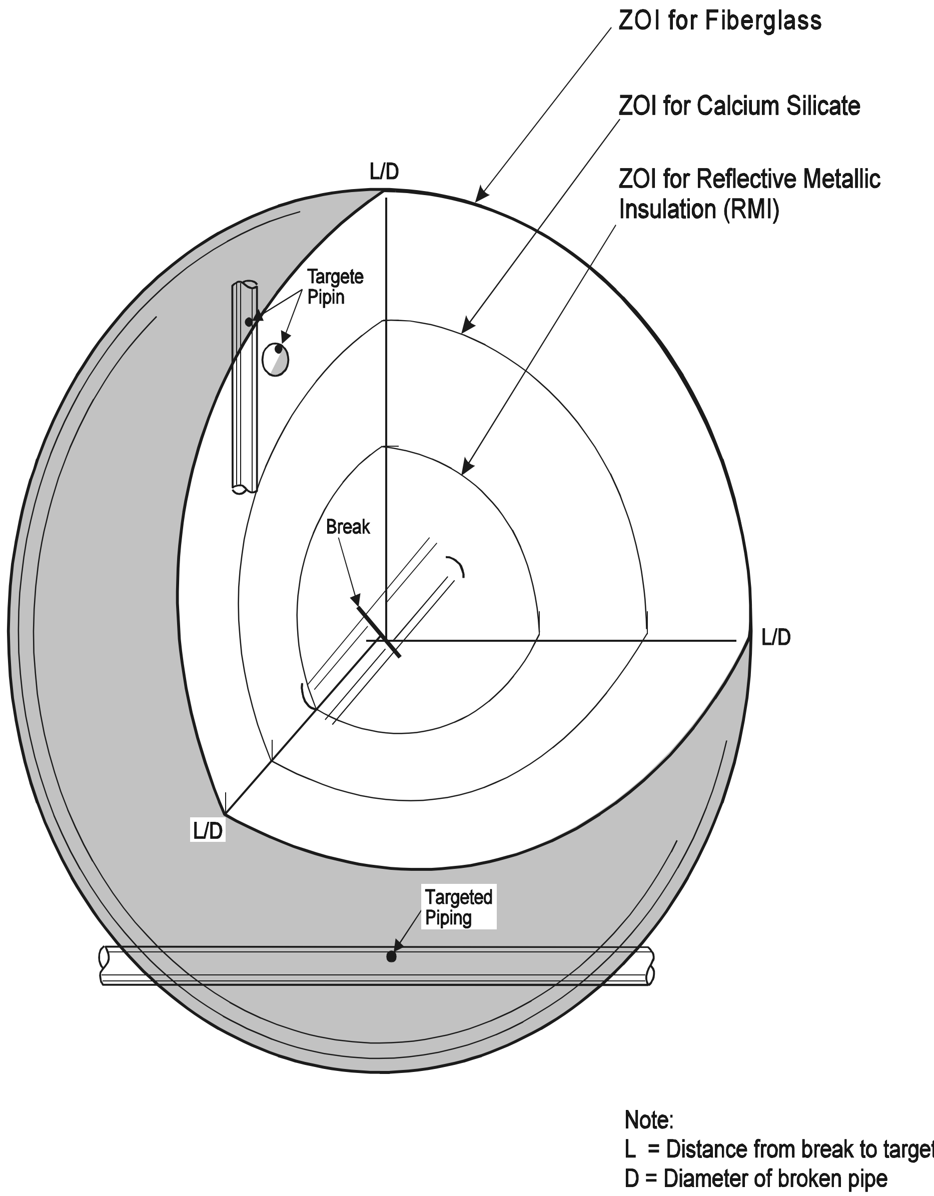

Figure 3. Zone of Influence (ZOI)

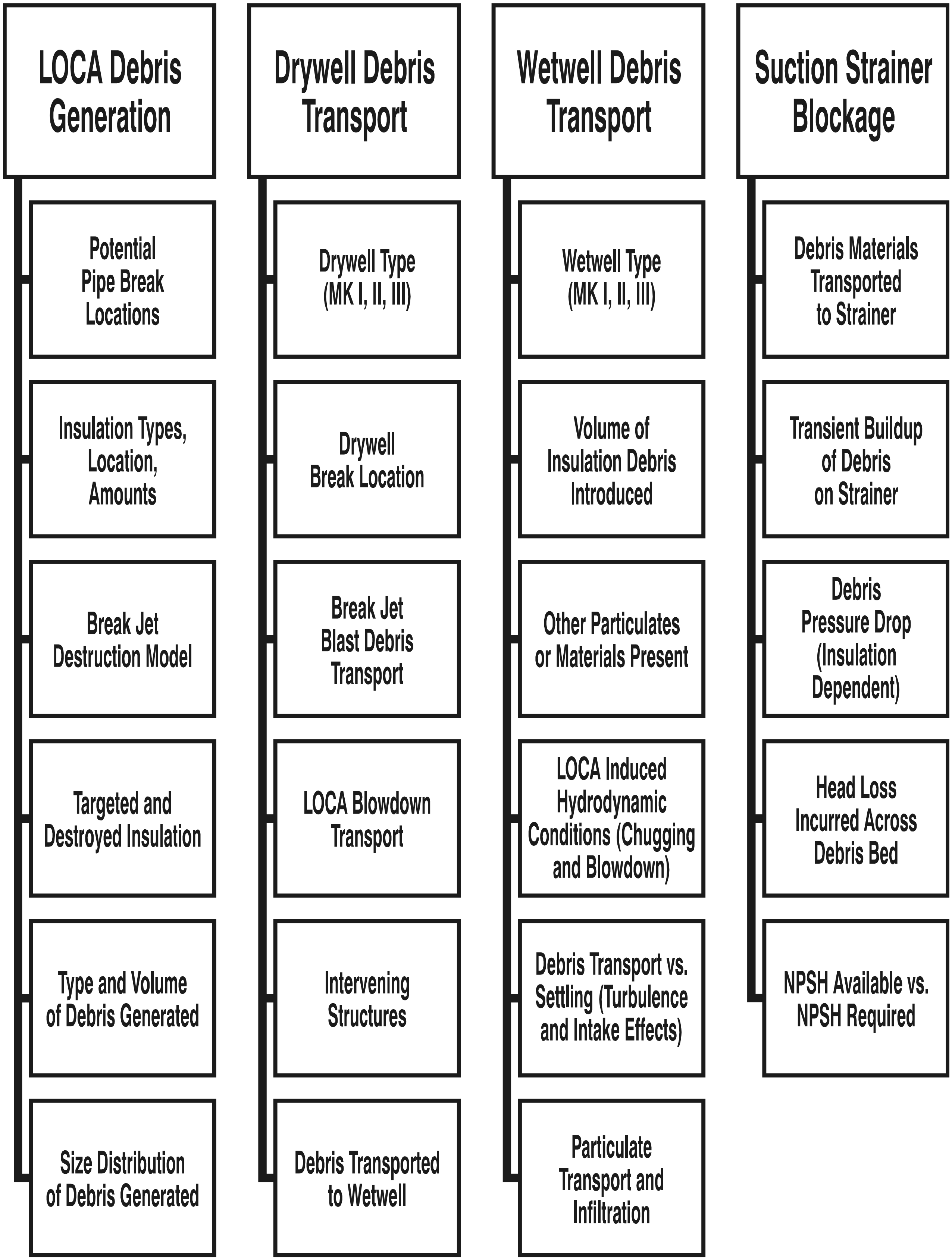

Figure 4. Debris Blockage Considerations

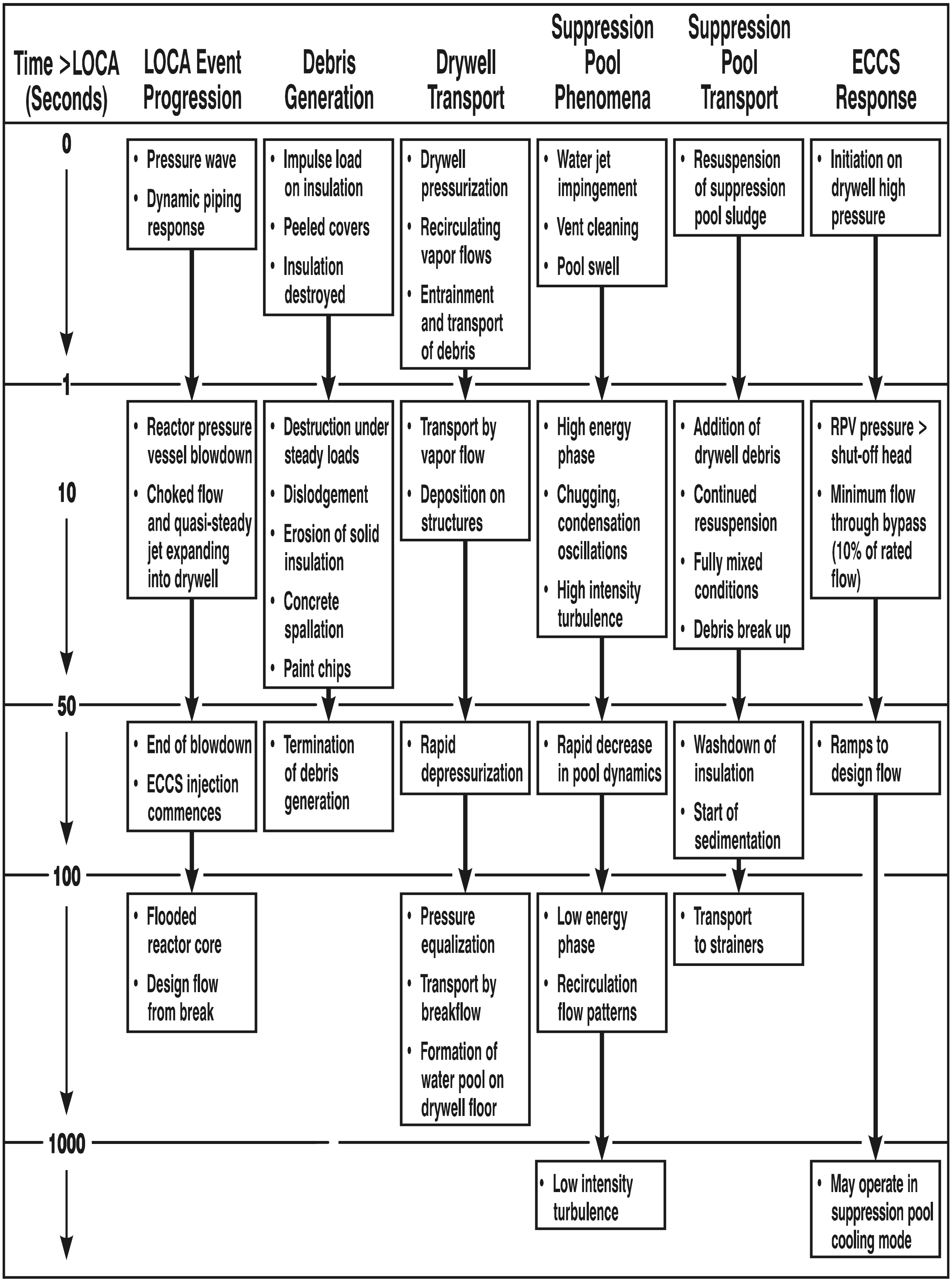

Figure 5. Events That May Effect Debris Blockage

APPENDIX A

GUIDELINES FOR REVIEW OF WATER SOURCES FOR EMERGENCY CORE COOLING

Water sources for long-term recirculation should be evaluated under possible post-LOCA conditions to determine the adequacy of their design for providing long-term recirculation. Technical evaluations can be subdivided into (1) sump hydraulic performance, (2) LOCA-induced debris effects, and (3) pump performance under adverse conditions. Specific considerations within these categories, and the combination thereof, is shown in Figure A-1. Determination that adequate NPSH margin exists at the pump inlet under all postulated post-LOCA conditions is the final criterion.

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 PWR sump or BWR suction strainer outlets) and required pumping capacity (or pump inlet velocity). The water depth above the pipe centerline(s) and the inlet pipe velocity (U) can be expressed non-dimensionally as the Froude number:

$$Froude\ number = \frac{U}{\sqrt{gs}}$$

where g is the acceleration due to gravity. Extensive experimental results have shown that the hydraulic performance of ECC sumps (particularly the potential for air ingestion) is a strong function of the 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:

1. Zero air ingestion, which requires no vortex suppressors or increase of the "required" NPSH above that from the pump manufacturer’s curves.
2. Air ingestion of 2% or less, a conservative level at which degradation of pumping capability is not expected based on an increase of the "required" NPSH.
3. Use of vortex suppressors to reduce air ingestion effects to zero.

For PWRs, zero air ingestion can be ensured by use of the design guidance set forth in Table A-l. Determination of those designs having ingestion levels of 2% or less can be obtained using correlations given in Table A-2 and the attendant sump geometric envelope. 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 that have shown the capability to reduce air ingestion to zero. These guidelines (Tables A-l through A-6) were developed from extensive hydraulic tests on full-scale sumps and provide a rapid means of assessing sump hydraulic performance. If the PWR sump design deviates significantly from the design boundaries noted, similar performance data should be obtained for verification of adequate sump hydraulic performance.

For BWRs, full-scale tests of suppression pool suction strainer screen outlet designs for recirculation pumps have shown that air ingestion is zero for Froude numbers less than 0.8 with a minimum submergence of 6 feet, and operation up to a Froude number 1.0 with the same minimum submergence may be possible before air ingestion levels of 2% may occur (NUREG-0897, Rev. 1, and NUREG-2772).

LOCA-INDUCED DEBRIS EFFECTS

Assessment of LOCA debris generation and the determination of possible debris interceptor 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 or suppression pool strainer location, the estimation of quantities of debris generated by a pipe break, and the migration of such debris to the interceptors. Thus blockage estimates (i.e., generation, transport, and head loss) are specific to the insulation material, the piping layout, and the plant design.

Since break jet forces are the dominant debris generator, the predicted jet envelope will determine the quantities and types of insulation debris. Figure A-2 provides a three-region model that has been developed from analytical and experimental considerations as identified in NUREG-0897, Rev. 1, and NUREG/CR-6224. The destructive results (e.g., volume of insulation and other debris generated, size of debris) of the break jet forces will be considerably different for different types of insulation, different types of installation methods, and distance from the break. Region I represents a total destruction zone; Region II represents a region where high levels of damage are possible depending on insulation type, whether encapsulation is employed, methods of attachment, etc.; and Region III represents a region where dislodgement of insulation in whole, or as-fabricated, segments is likely occur. NUREG-0897, Rev. 1, and NUREG/CR-6224 provide a more detailed discussion of these considerations. NUREG-0897, Rev. 1; NUREG/CR-6224; NUREG/CR-2982, Rev. 1; NUREG/CR-3170; NUREG/CR-3394, Vols. 1 and 2; and NUREG/CR-3616 provide more detailed information relevant to assessing debris generation and transport.

PUMP PERFORMANCE UNDER ADVERSE CONDITIONS

The pump industry historically has determined NPSH requirements for pumps on the basis of a percentage degradation in pumping capacity. The percentage has at times been arbitrary, but generally is in the range of 1% to 3%. A 2% limit on allowed air ingestion is recommended since higher levels have been shown to initiate degradation of pumping capacity.

The 2% by volume limit on sump air ingestion and the NPSH requirements act independently. However, air ingestion levels less than 2% can also affect NPSH requirements. If air ingestion is indicated, correct the NPSH requirement from the pump curves by the relationship:

$$NPSH_{required(\alpha p < 2\%)} = NPSH_{required(liquid)} \times ß$$

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

COMBINED EFFECTS

As shown in Figure A-l, three interdependent effects (i.e., sump or suction strainer performance, debris generation and transport, and pump operation under adverse conditions) require evaluation for determining long-term recirculation capability (i.e., loss of NPSH margin).

CRITERIA FOR EVALUATING SUMP FAILURE

The sump failure criterion applicable to each plant is determined primarily by sump submergence. Figures A-2(a) and A-2(b) illustrate the two basic sump configurations of fully and partially submerged screens. Although only vertical sump configurations are shown here, the same designations are applicable for inclined screen designs. The key distinction between the fully and partially submerged configurations is that partially submerged screens allow equal pressure above both the pit and the pool, which are potentially separated by a debris bed. Fully submerged screens have a complete seal of water between the pump inlet and the containment atmosphere along all water paths passing through the sump screen. The effect of this difference in evaluation of the sump failure criterion is described below.

Fully Submerged Sump Screens

Figure A-2(a) presents a schematic of a sump that is fully submerged at the time of switchover to ECCS. The most likely mode of failure for sumps in this configuration is due to cavitation within the pump housing when head loss caused by debris accumulation exceeds the $NPSH_{Margin}$. For this set of plants (in which sump screens are fully submerged at the time of switchover), the onset of cavitation is determined by comparing plant $NPSH_{Margin}$, which is part of plant's licensing basis, with the screen head loss calculated in the plant evaluations performed per Regulatory Position 1.3. For this case, therefore, the sump failure criterion is assumed to be reached when

$$\text{Head Loss Across the Debris Bed} \geq NPSH_{Margin.}$$

Partially Submerged Sump Screens

Figure A-2(b) presents a schematic of a sump that is partially submerged at the time of switchover. Failure can occur for sumps in this configuration in one of two ways: either by pump cavitation as explained above, or when head loss caused by debris buildup prevents sufficient water from entering the sump. This flow imbalance occurs when water infiltration through a debris bed on the screen can no longer satisfy the volumetric demands of the pump. Because the pit and the pool are at equal atmospheric overpressure, the only force available to move water through a debris bed is the static pressure head in the pool. Numeric simulations confirm that an effective head loss across a debris bed approximately equal to half the pool height is sufficient to prevent adequate water flow. For all partially submerged sump screens, the sump failure criterion is assumed to be reached when

$$\text{Head Loss Across the Debris Bed} \geq NPSH_{Margin} \quad \text{or} \geq \tfrac{1}{2} \text{ of pool height}$$

After switchover to ECCS recirculation, some plants can change their sump configuration from partially submerged to fully submerged. This can occur for a number of reasons including accumulation of containment-spray water, continued melting of ice-condenser reservoirs, and continued addition of RWST inventory to the containment pool. As the pool depth changes during recirculation, the “wetted area” (or submerged area) of the sump screens can also change. The wetted area of the screen determines the average approach velocity of water that may carry debris. Because information about time-dependent pool depths is difficult to obtain, and because the most significant debris transport will occur early in the scenario when the pool is shallow, analysis should preferably be based on the pool depth at the time of switchover to ECCS recirculation.

APPENDIX A REFERENCES

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NUREG/CR-2758, G.G. Weigand et al., "A Parametric Study of Containment Emergency Sump Performance" (SAND82-0624), USNRC, July 1982.[1]

NUREG/CR-2759, M.S. Krein et al., "A Parametric Study of Containment Emergency Sump Performance: Results of Vertical Outlet Sump Tests" (SAND82-7062), USNRC, October 1982.[1]

NUREG/CR-2760, M. Padmanabhan and G.E. Hecker, "Assessment of Scale Effects on Vortexing, Swirl, and Inlet Losses in Large Scale Sump Models" (ARL-48-82), USNRC, June 1982.[1]

NUREG/CR-2772, M. Padmanabhan, "Hydraulic Performance of Pump Suction Inlets for Emergency Core Cooling Systems in Boiling Water Reactors" (ARL-398A), USNRC, June 1982.[1]

NUREG/CR-2982, D.N. Brocard, "Buoyancy, Transport, and Head Loss of Fibrous Reactor Insulation" (SAND82-7205), Revision 1, USNRC, July 1983.[1]

NUREG/CR-3170, W.W. Durgin and J. Noreika, "The Susceptibility of Fibrous Insulation Pillows to Debris Formation Under Exposure to Energetic Jet Flows" (SAND83-7008), USNRC, March 1983.[1]

NUREG/CR-3394, J.J. Wysocki, "Probabilistic Assessment of Recirculation Sump Blockage Due to Loss-of-Coolant Accidents," Volumes 1 and 2 (SAND83-7116), USNRC, July 1983.[1]

NUREG/CR-3616, D.N. Brocard, "Transport and Screen Blockage Characteristics of Reflective Metallic Insulation Materials" (SAND83-7471), USNRC, January 1984.[1]

NUREG/CR-6224, G. Zigler et al., "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris" (SEA No. 93-554-06-A:1), USNRC, October 1995.[1]

[4] Copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202)512-1800); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161; (telephone (703)487-4650; <http://www.ntis.gov/ordernow>. Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or (800)397-4209; fax (301)415-3548; email is PDR@NRC.GOV.

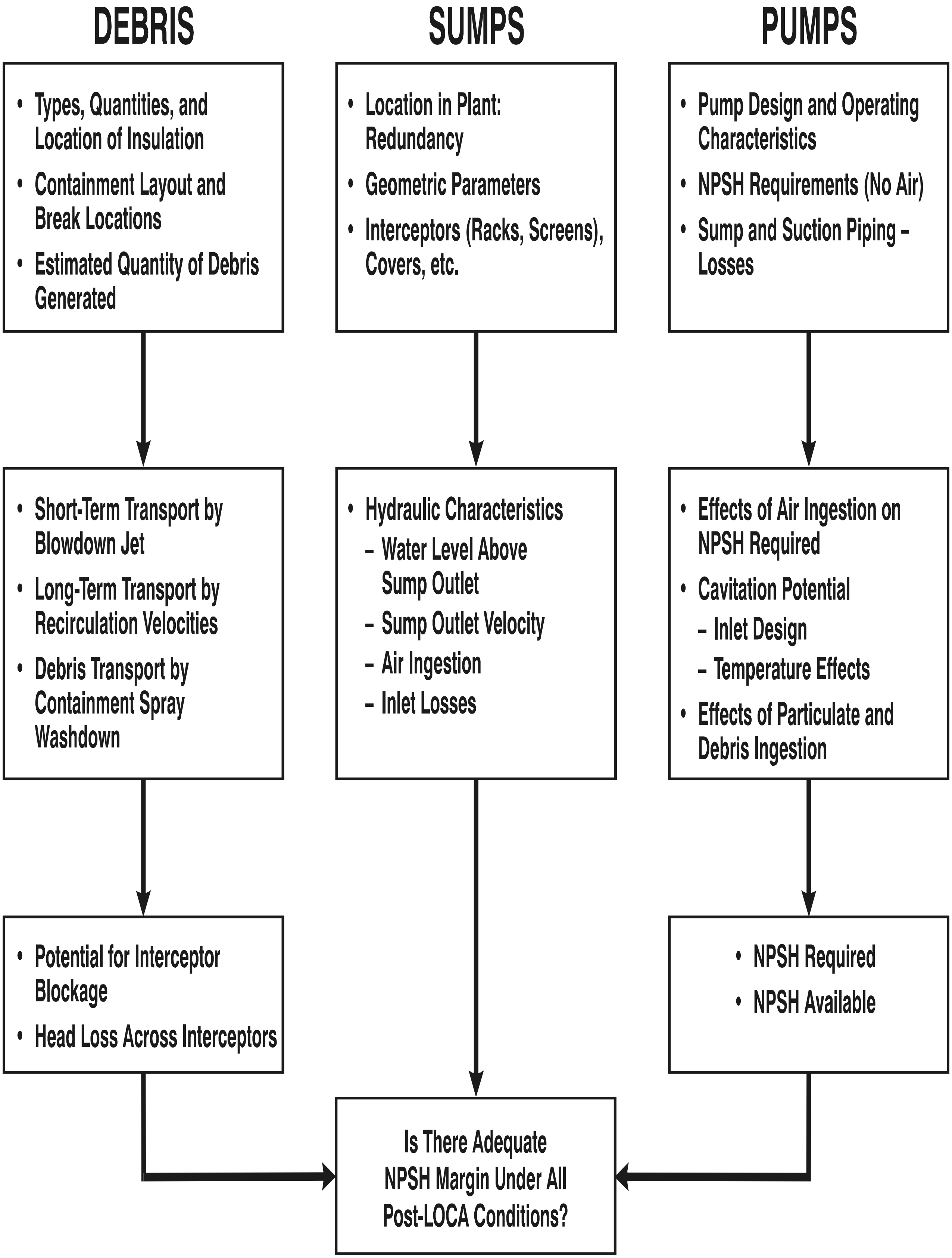
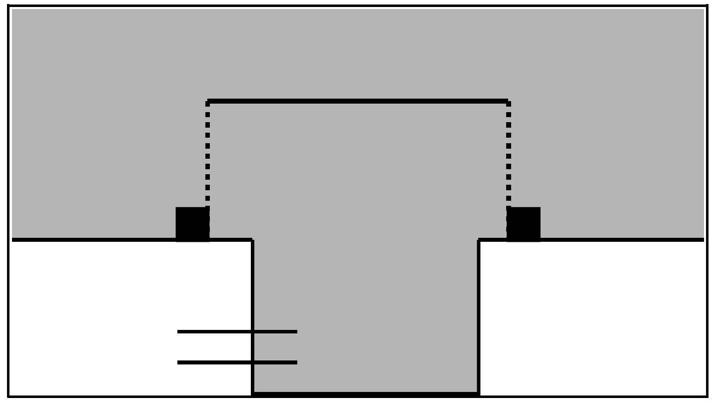
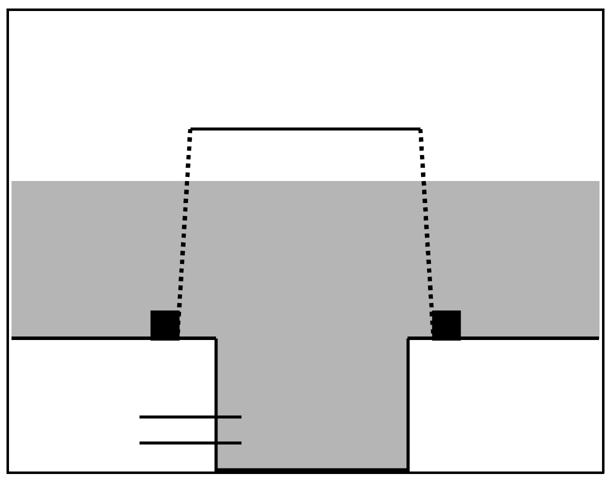


Figure A-1. Technical Considerations Relevant to PWR ECC Sump Performance



(a) Fully submerged screen configuration showing solid water from pump inlet to containment atmosphere.



(b) Partially submerged screen configuration showing containment atmosphere over both the external pool and the internal sump pit with water on lower portion of screen.

Figure A-2 Sump Screen Schematics

TABLE A-1

PWR HYDRAULIC DESIGN GUIDELINES FOR ZERO AIR INGESTION

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

NOTE: These guidelines were established using experimental results from NUREG/CR-2772, NUREG/CR-6224, and NUREG/CR-2982 and are based on sumps having a right rectangular shape.

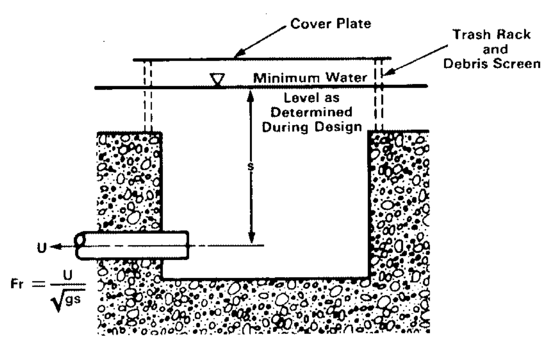


TABLE A-2

PWR HYDRAULIC DESIGN GUIDELINES FOR AIR INGESTION <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	10.0
(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

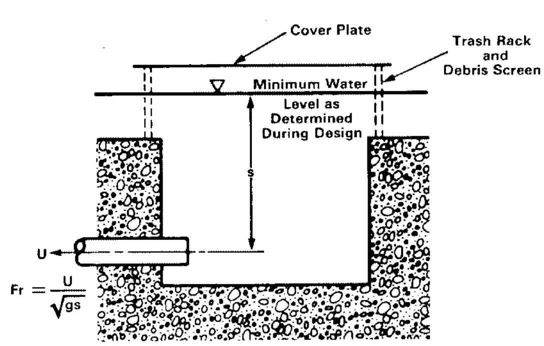


Table A-3.1

PWR GEOMETRIC DESIGN ENVELOP GUIDELINES FOR HORIZONTAL SUCTION OUTLETS

<table>
<tr><th rowspan="2">Sump Outlet</th><th colspan="6">Sump Outlet Position*</th></tr>
<tr><th>e_y/d</th><th>$(B-e_y)/d$</th><th>c/d</th><th>b/d</th><th>f/d</th><th>e_x/d</th></tr>
<tr><td>Dual</td><td rowspan="2">>1</td><td rowspan="2">>3</td><td rowspan="2">>1.5</td><td rowspan="2">>1</td><td>>4</td><td rowspan="2">>1.5</td></tr>
<tr><td>Single</td><td>-</td></tr>
</table>

* Preferred location.

Note: Dimensions are always measured to pipe centerline

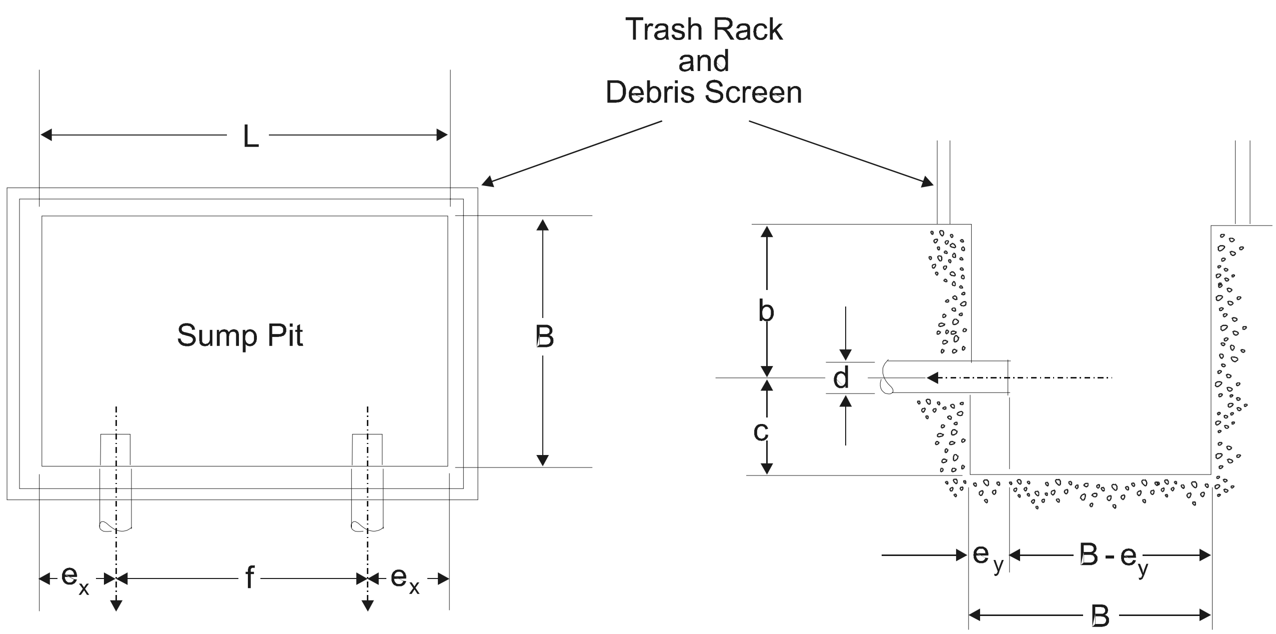


Table A-3.2

PWR GEOMETRIC DESIGN ENVELOP GUIDELINES FOR VERTICAL SUCTION OUTLETS

Sump Outlet	Sump Outlet Position*					
	e_y/d	$(B-e_y)/d$	c/d	b/d	f/d	e_x/d
Dual	>1	>1	>0	>1	>4	>1.5
Single	>1	>1	>1.5	>1	-	>1.5

* Preferred location.

Note: Dimensions are always measured to pipe centerline

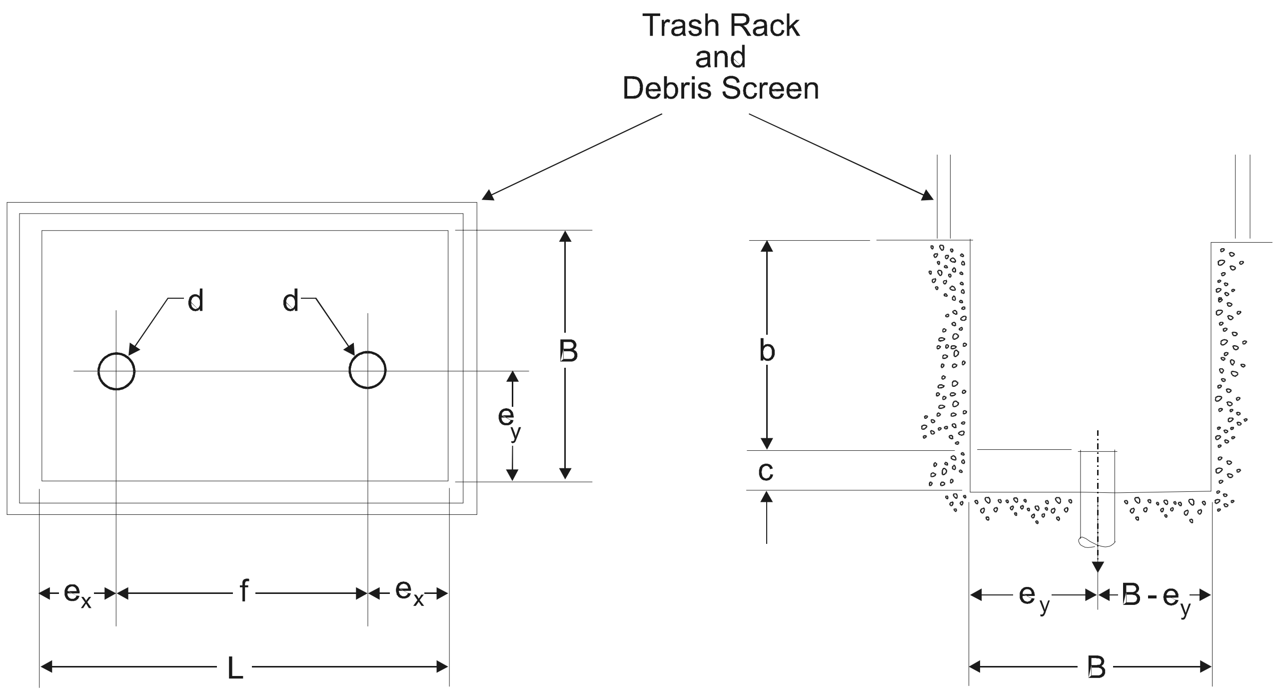


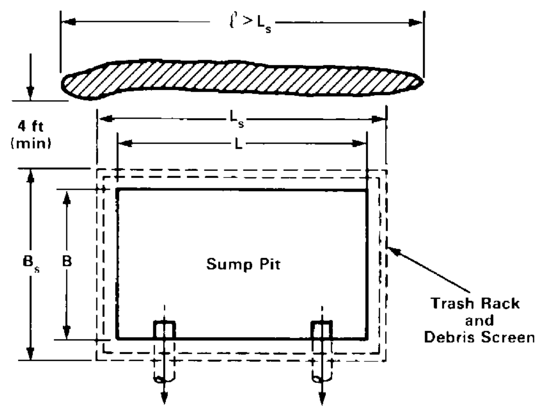
TABLE A-4

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 feet (1.2 meters).

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.



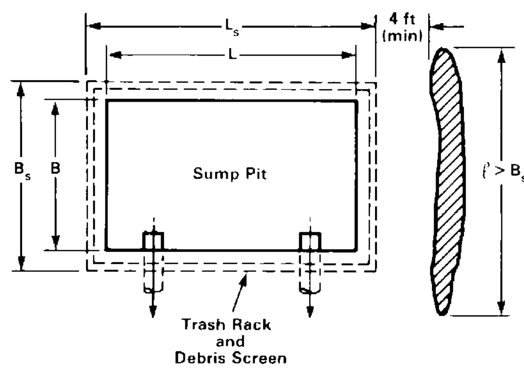


TABLE A-5

PWR DESIGN GUIDELINES FOR INTERCEPTORS AND COVER PLATE

1. Minimum height of interceptors should be 2 feet (0.61 meters).

2. Distance from sump side to screens, g_s, may be any reasonable value.

3. Screen mesh size (see Regulatory Position 1.1.1.12)

4. Trash racks should be vertically or nearly vertically oriented 1- to 1½-inch (25- to 38-mm) standard floor grate or equivalent.

5. The distance between the debris screens and trash racks should be 6 inches (15.2 cm) or less.

6. 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).

NOTE: See NUREG-0897.

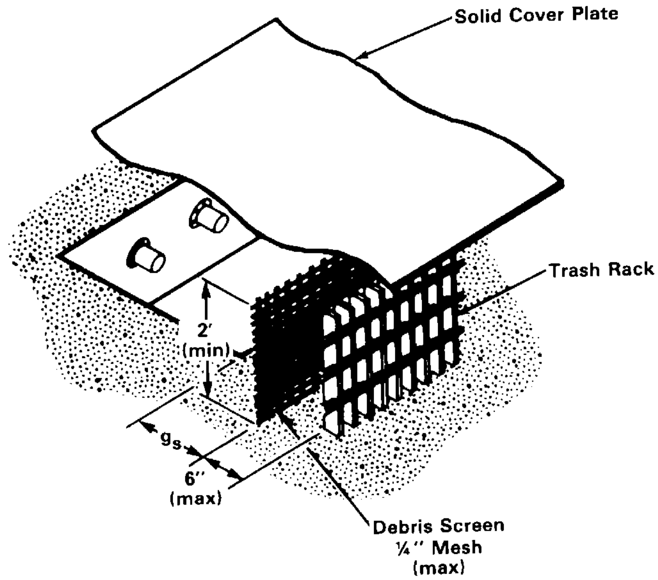


TABLE A-6

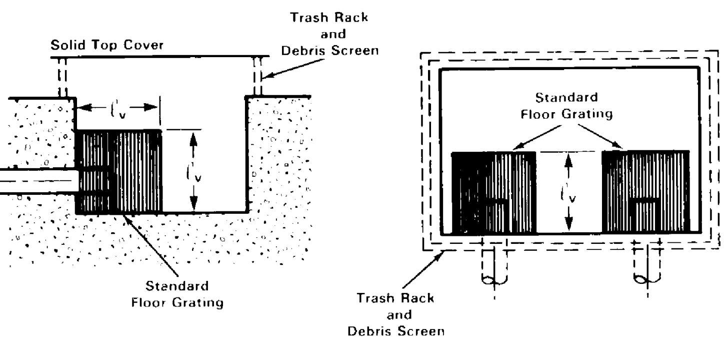
PWR GUIDELINES FOR SELECTED VORTEX SUPPRESSORS

1. Cubic arrangement of standard 1½-inch (30-mm) deep or deeper floor grating (or its equivalent) with a characteristic length, ℓ_v, that is at least 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 ℓ_v > 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.

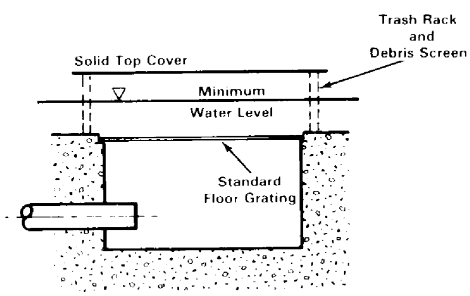
2. Standard 1½-inch (38-mm) or deeper floor grating (or its equivalent) located horizontally over the entire sump and containment floor inside the screens and located below the lip of the sump pit.

NOTE: 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.

Design #1:



Design #2:



APPENDIX B

EXAMPLES OF ACTIVE MITIGATION SYSTEMS

In-Line (or Pipeline) Strainer

A strainer installed in the piping system, upstream of equipment, that will remove harmful objects and particulates from the fluid stream by a backwashing action.

Self-Cleaning Strainer

A strainer that is used upstream of equipment to filter out harmful objects and particulates and is designed to clean itself without the aid of external help.

Strainer Backwashing System

A system designed to dislodge objects and particulates from the surface of a strainer by directing a fluid stream in the opposite direction of the flow through the strainer.

REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this proposed Revision 3 of Regulatory Guide 1.82 since the revised guidance for pressurized water reactors and minor changes to guidance for boiling water reactors is intended to ensure compliance with the existing applicable regulatory requirements. Therefore a new regulatory analysis is not needed. The regulatory analysis (NUREG-0869, Revision 1, "USI A-43 Regulatory Analysis," October 1985[1]) that was prepared for the resolution of USI A-43, "Containment Emergency Sump Performance," is applicable to this proposed Revision 3 of Regulatory Guide 1-82.

In addition, the pertinent regulatory guidance in Regulatory Guide 1.1, also referred to as NRC Safety Guide (SG) 1, “Net Positive Suction Head For Emergency Core Cooling and Containment Heat Removal System Pumps,” is incorporated into this proposed Revision 3 of Regulatory Guide 1.82. Generic Letter 97-04, “Assurance of Sufficient Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal Pumps,” dated October 7, 1997, requested licensees of nuclear power plants to respond to several questions related to the net positive suction head of the ECCS and containment heat removal system pumps in their power plants. The staff reviewed these responses and wrote letters to the licensee of each power plant providing the staff’s conclusions based on these reviews. Based on its review of GL 97-04 responses, the staff determined that all operating plants satisfy the guidance in SG 1. The criteria used for these reviews were discussed in the generic letter and its regulatory analysis, in meetings with the NRC’s Committee to Review Generic Requirements and Advisory Committee on Reactor Safeguards, and with licensees during the NRC’s review of the generic letter responses. These criteria are now incorporated into this proposed Revision 3 of Regulatory Guide 1.82. The portion of the guidance related to the use of containment pressure for the determination of available NPSH is taken from the guidance in SG 1 which will be deleted when this guidance is incorporated into the proposed Revision 3 of Regulatory Guide 1.82.

[1] Copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202)512-1800); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161; (telephone (703)487-4650; <http://www.ntis.gov/ordernow>. Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR’s mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or (800)397-4209; fax (301)415-3548; email is PDR@NRC.GOV.