UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

OCT 27 1982

MEMORANDUM FOR: Victor Stello, Jr., Deputy Executive Director for Regional Operations and Generic Requirements

FROM: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

SUBJECT: CRGR REVIEW OF PROPOSED REVISIONS TO SRP SECTION 6.2.2 AND RG 1.82 AND THE SUPPORTING TECHNICAL INFORMATION DOCUMENT NUREG-0897, AS RELATED TO USI A-43, "CONTAINMENT EMERGENCY SUMP PERFORMANCE"

The staff has completed its technical evaluation of Unresolved Safety Issue A-43, "Containment Emergency Sump Performance" with the conclusion that this issue is not as significant as previously postulated. This conclusion is based on over two years of extensive experimental and generic study efforts which are detailed in the reports summarized in Enclosure 1 (USI A-43 references) and NUREG-0897 (Enclosure 6). NUREG-0897 and proposed revisions to SRP Section 6.2.2 and RG 1.82 are hereby submitted for consideration by the Committee to Review Generic Requirements prior to publication for public comment. Enclosure 2 is a value-impact analysis associated with implementing the technical findings of NUREG-0897 via proposed revisions to SRP Section 6.2.2 and RG 1.82 (Enclosures 4 and 5). Enclosure 2 also contains a "draft" generic letter proposed for implementing these requirements on OL's and NTOL's. Background information to assist your review is provided in Enclosure 3 and is in the format specified in the Commission approved CRGR Charter dated June 16, 1982. These proposed actions are outlined below.

The overall safety concern embodied in USI A-43 relates to the capability of the containment emergency sump to provide an adequate water source to sustain long-term recirculation cooling following a large LOCA. The problem can be subdivided into: sump hydraulic performance; LOCA-generated debris effects; and RHR pump performance under post-LOCA conditions. These aspects have been extensively studied and the technical findings are reported in NUREG-0897 and associated references.

The findings reveal that: (a) degradation of sump performance due to air ingestion (or vortices) is not severe; (b) LOCA-generated debris effects are dependent on the types and quantities of insulation employed and plant layout, but use of unencapsulated mineral wool or fiberglass insulations can lead to severe sump screen blockage with attendant loss of NPSH margin; and (c) the types of RHR and CSS pumps commonly used in plants can tolerate low levels of air ingestion (i.e., 2%) and the type of debris (or particulates) which would pass through the sump screens. Although these findings reveal less severe effects relative to sump air ingestion and pump operation, selective plant calculations reveal a potential for severe sump screen

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blockage for a limited number of operating plants. Thus, modifications to current sump review guidelines in RG 1.82 (like removal of the 50% blockage rule) are proposed, plus a determination as to which plants might have a debris problem.

Based on the technical findings contained in NUREG-0897 and the supporting reports, we recommend that NUREG-0897, the proposed revision to SRP Section 6.2.2, "Containment Heat Removal Systems" and the proposed revision to RG 1.82, "Sumps for Emergency Core Cooling and Containment Spray Systems" be issued for public comment. A detailed discussion of proposed actions, implementation impacts, estimates of averted public dose associated with sump failure, etc. are contained in Enclosure 2. Both staff and subcontracted efforts were utilized to develop the cost data and carry out the risk analysis. This value-impact analysis (see Enclosure 2) indicates a positive benefit to be gained even if some retrofitting is required. The proposed generic requirements and attendant implementation matters are further discussed in Enclosure 3. In addition, the Division of Licensing solicited review comments from several licensees. Several licensees commented that plant specific cost estimates were low. Followup action is underway to improve the cost estimates. The public comment process will provide additional improved cost information.

In accordance with prior discussions with you, we have deleted proposed review guidelines from the NUREG-0897 report and have incorporated them as Appendix A to the revised RG 1.82. The revised SRP Section 6.2.2 also references the revised RG 1.82. At the present time we are proposing only to issue NUREG-0897 and the proposed revisions to RG 1.82 and SRP Section 6.2.2 for public comment, and that received comments will be evaluated prior to returning to the CRGR with recommendation to make the new requirements effective.

The actions proposed above are Category 2, and do not warrant accelerated actions. Therefore, it is requested that the CRGR complete review of these proposed actions within two weeks.

For further information on these reports, contact Karl Kniel, Chief, Generic Issues Branch (ext. 27359) or A. W. Serkiz, USI Task Manager (ext. 24217).

Harold R. Denton, Director
Office of Nuclear Reactor Regulation

Enclosures:
1) Summaries of USI A-43 References
2) Value-Impact Analysis, USI A-43
3) Background Information for CRGR Review of USI A-43 Resolution
4) Proposed Revisions to SRP Section 6.2.2
5) Proposed Revisions to RG 1.82
6) NUREG-0897, Containment Emergency Sump Performance, September 1982

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ENCLOSURE 1

SUMMARIES OF USI A-43 REFERENCES

1. Serkiz, A.W., "Containment Emergency Sump Performance," Technical Findings Related to USI A-43, NUREG-0897, September 1982 - "For Public Comment."

This report is a staff NUREG which: (a) provides the staff's assessment of the safety significance of USI A-43 in light of extensive experimental and generic study efforts, (b) summarizes key technical findings derived from the NUREG/CR reports listed below in a singular document, and (c) provides technical findings which were used to develop the recommended changes to SRP Section 6.2.2 and RG 1.82. The results presented reveal a significantly reduced safety concern and reveal the need to change old guidelines (like the 50% screen blockage rule in RG 1.82.)

2. Weigand, G. G., et. al., "A Parametric Study of Containment Emergency Sump Performance," SAND82-0624/NUREG/CR-2758. Sandia National Laboratories, Albuquerque, NM, July 1982.

This report presents the results of experiments at ARL designed to characterize the hydraulic behavior of full-scale emergency core cooling system (ECCS) sumps under a broad range of geometric configurations and flow conditions. The effects of potential accident situations included screen blockage, non-uniform approach flows, break flow and ice condenser drain flow impingement, and obstructions. In addition, the effects of elevated water temperature and the performance of vortex suppression devices were established. The results showed that the vortices are unstable and that vortex size and type is not a reliable indicator to adjudge air ingestion or swirl behavior. Measured air withdrawal rates were generally less than 1-2 percent and the measured swirl in the outlet pipes was small. An envelope curve analysis of the data was developed, and it gives the "bounded" performance response of the sump as a function of the flow variables which can be used for sump design acceptability. This report presents data for "side-suction" sump designs.

3. "Results of Vertical Outlet Sump Tests," Joint ARL/Sandia Report, ARL47-82/SAND82-1286/NUREG/CR-2759, September 1982.

This report presents the results of a structured test program designed to characterize the hydraulic performance of full-scale ECCS sumps with vertical outlets. In addition to a parametric evaluation of the vertical outlet sumps, the effects of perturbations to the approach flow, such as those which could develop during an accident situation have also been considered. These approach flow perturbations include sump screen blockage, non-uniform approach flows and break-flow jet impingement. The effectiveness of two vortex suppression devices under these conditions was also demonstrated.

4. Padmanabhan, M. and Hecker, G.E., "Assessment of Scale Effects on Vortexing, Swirl, and Inlet Losses in Large Scale Pump Models," NUREG/CR-2760, Alden Research Laboratory, Worcester Polytechnic Institute, Holden, MA, June 1982.

The hydraulic performance of geometrically scaled models (1:2 and 1:4) of a full size sump (1:1) was investigated and model test results substantiated that hydraulic models with large scales such as 1:2 to 1:4 reliably predicted the sump hydraulic performance; namely, vortexing, air-ingestion from free surface vortices, pipe flow swirl and inlet loss coefficient. No scale effects were apparent on vortexing or air ingestion within the tested prediction range for scale models. However, a good prediction of pipe flow swirl and inlet loss coefficient was found to require that the approach flow Reynolds number and pipe Reynolds number be above certain limits.

5. Padmanabhan, M., "Hydraulic Performance of Pump Suction Inlet for Emergency Core Cooling Systems in Boiling Water Reactors," NUREG/CR-2772, Alden Research Laboratory, Worcester Polytechnic Institute, Holden, MA, June 1982.

This document reports on the hydraulic intake performance of Boiling Water Reactor Residual Heat Removal suction inlet configurations; namely, those of the Mark I, Mark II, and Mark III designs. Air-ingestion levels, vortex, suction pipe swirl, and the inlet pressure loss coefficients containment activities were measured.

Zero air-withdrawal was measured for both configurations for Froude numbers equal to or less than 0.8 even under non-uniform approach flows. Likewise, no air-core vortices were observed for the same flow conditions. At a Froude number above 1.0 and with non-uniform approach flows, air-withdrawals up to 4 percent by volume were observed in the Mark II and Mark III designs. Swirl levels in the pipe up to 7 degrees were measured in Mark II and Mark III and up to 3 degrees were measured in Mark I. Inlet loss coefficients were about 1.7 for Mark II and Mark III and about 1.0 for Mark I.

6. Padmanabhan, M., "Results of Vortex Suppressor Tests, Single Outlet Sump Test and Miscellaneous Sensitivity Tests," NUREG/CR-2761, Alden Research Laboratory, Worcester Polytechnic Institute, Holden, MA, September 1982.

Full-scale tests of flow conditions in containment recirculation sumps were conducted to provide sump hydraulic design and performance data; namely, effects on vortex suppressors, single outlet sumps, double outlet sumps with partition walls, pump overspeed, outlet pipe diameter and bellmouth entrances.

Principal findings indicate: (1) vortex suppressors were very effective in reducing air-ingestion to zero, (2) single outlet sump designs indicate air-withdrawal less than 1 percent by volume and, (3) no significant changes were seen in air-withdrawals, vortex types or pipe swirl for the pump overspeed, bellmouth entrance or double outlet sump tests. Test data on the single and double outlet sumps were used to obtain maximum bounding envelopes on air-ingestion, pipe swirl and inlet loss coefficients versus Froude number.

7. Reyer, R., et.al., "Survey of Insulation Used in Nuclear Power Plants and the Potential for Debris Generation," NUREG/CR-2403, Burns and Roe, Inc., Oradell, NJ, October 1981.

Eleven nuclear power plants (representative of different U. S. reactor manufacturers and architect-engineers) were surveyed to identify and document the types and amounts of insulation used, location within containment, components insulated, material characteristics, and methods of installation and attachment. The results indicated a wide variability in plant layouts, insulations employed and sump designs. Therefore, a follow-up survey for older plants was undertaken. A preliminary assessment was made of the potential effects of insulation debris migrating to the containment emergency sump.

8. Kolbe, R. and Gahan, E., "Survey of Insulation Used in Nuclear Power Plants and the Potential for Debris Generation," NUREG/CR-2403, Supplement 1, Burns and Roe, Inc., Oradell, NJ, May 1982.

Eight nuclear power plants (representative of different U.S. reactor manufacturers and architect-engineers) were surveyed to identify and document the types and amounts of insulation used, location within containment, components insulated, material characteristics, and methods of installation and attachment. These plants were selected to obtain survey information on "older" plants and supplements information previously reported in NUREG/CR-2403. A preliminary assessment was made of the potential for migration to the emergency sump.

9. Wysocki, J. J. et. al., "Methodology for Evaluation of Insulation Debris," NUREG/CR-2791, Burns and Roe, Inc., Oradell, NJ, September 1982.

This report developed a methodology for estimating quantities of insulation which the pipe break jet might destroy or dislodge, for estimating debris migration during the recirculation mode and for estimating the degree of screen blockage that might occur. These debris calculational methods were applied to five PWRs and clearly illustrated the dependency on plant containment layout, sump location and design, and types and quantities of insulation employed.

10. Kamath, P., Tantillo, T. and Swift, W., "An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions," NUREG/CR-2792, Creare, Inc., Hanover, NH, September 1982.

This report presents an assessment of the performance of Residual Heat Removal and Containment Spray pumps during the recirculation phase of reactor core and containment cooldown following a LOCA. Findings show that for pumps at normal flow rates operating with sufficient Net Positive Suction Head margin, pump performance degradation is negligible if air ingestion quantities are less than 2 percent by volume. Degradation increases with increased air ingestion, becoming severe at void fractions of 8-10 percent. For the types and quantities of debris likely to be present in the recirculation fluid (i.e., insulation), pumping degradation is expected to be negligible.

ENCLOSURE 2
VALUE-IMPACT ANALYSIS
FOR
USI A-43, CONTAINMENT EMERGENCY
SUMP PERFORMANCE

Enclosure 2

VALUE-IMPACT ANALYSIS
USI A-43, CONTAINMENT EMERGENCY
SUMP PERFORMANCE

I. The Proposed Action(s)

A. Summmary of Problem and Proposed Action

Unresolved Safety Issue (USI) A-43 deals with safety concerns related to containment emergency sump performance during the post-LOCA period wherein long-term recirculation cooling must be maintained to prevent core melt. These safety concerns can be summarized in the following question:

> "In the recirculation mode, will the sump design provide water to the RHR pumps in sufficient quantity, and will this water be sufficiently free of LOCA-generated debris and air ingestion so as not to impair pump performance, while providing adequate net positive suction head (NPSH)?"

These concerns have been addressed in three parts, namely:

a. Sump hydraulic performance under post-LOCA adverse conditions such as air ingestion, elevated temperatures, break and drain flow, etc.

b. LOCA-generated debris arising from the break jet destroying large quantities of insulation, this insulation debris being transported to the sump screen(s), and the resulting screen blockage being sufficient to reduce NPSH significantly below that required to maintain adequate pumping.

c. The performance capability of RHR and CSS pumps to continue pumping when subjected to air ingestion, debris ingestion and effects of particulates.

These concerns have been investigated on a generic basis, and the findings can be summarized as follows:

a. Measurements in extensive, full-scale sump hydraulic tests have shown low levels of air ingestion (i.e., 1-2%) and demonstrated that vortex observations cannot be used to quantify sump performance. These experimental results have been used to develop sump hydraulic design guidelines and acceptance criteria.

b. Generic plant insulation surveys and development of debris calculational methods have shown that debris effects are dependent on the type and quantities of insultion employed and plant layout. The results also show that the 50% screen blockage guidance provided in the current Regulatory Guide (RG) 1.82, "Sumps for Emergency Core Cooling and Containment Spray Systems," should be replaced with a more comprehensive requirement to assess debris effects on a plant-specific basis.

c. Reviews of available data on pump air ingestion effects and discussions with the U. S. manufacturers of RHR and CSS pumps show that low levels of air ingestion ($\leq$ 2%) will not significantly degrade pumping performance, and that the types of pumps employed will tolerate ingestion of insulation debris and other types of post-LOCA particulates, which can pass through sump screens.

These results reveal a significantly lesser safety concern with respect to vortex formation and sump hydraulic effects than previously hypothesized but a greater concern for loss of recirculation cooling capability from debris effects. Thus, the results warrant the recommendations set forth. The following actions are proposed:

1. Revise the NRC Standard Review Plan, Section 6.2.2, "Containment Heat Removal Systems," and Section 6.3, "Emergency Core Cooling Systems" to incorporate the technical findings and sump design review guidelines set forth in NUREG-0897. This action will provide for review consistency based on the extension data base acquired for the resolution of USI A-43, and can remove the need for "in-plant" sump tests or sump model tests.

2. Revise RG 1.82, to reflect the findings contained in NUREG-0897, "Containment Emergency Sump Performance," July 1982. In particular, the 50% screen blockage guidance should be removed and replaced with a requirement for plant-specific debris evaluations based on the technical findings described in NUREG-0897.

3. Operating plants should be assessed for determination of the extent of debris blockage potential and based on the outcome of those plant analyses, action should be taken to correct unacceptable conditions.

The debris blockage concern stems from use of certain insulations such as mineral wool and/or fiberglass which can lead to excessive sump screen blockages with attendant loss of recirculation pump NPSH margin. The USI A-43 surveys (for 19 plants) have shown that some older plants employ such insulations, and plant-specific calculations reveal (i.e., Maine Yankee) that excessive screen blockage could occur. Thus operating plants (PWRs in particular) should be required to provide their assessment of debris induced screen blockage utilizing the criteria and guidelines set forth in Appendix A of the revised RG 1.82.

Generally speaking, it is not expected that BWRs will encounter a debris blockage problem, nor will PWRs that extensively use reflective metallic insulations. The unencapsulated fibrous insulations are believed to present the principal debris problem and it is estimated that six to ten PWRs may require some type of corrective action. BWR insulation debris problems are not expected to arise since BWRs make extensive use of reflective metallic insulation and the design of the suppression pool vent's missile cover is such that it will block insulation migration to the pool.

B. Need for Proposed Action(s)

The need for the proposed actions is as follows:

1. Issuance of the proposed revision to SRP Section 6.2.2 is needed to correct previous sump review criteria which are not supported by current findings (i.e., judgment of sump hydraulic acceptability principally on vortex formation). SRP Section 6.2.2 has been revised to reflect findings from full-scale sump tests and generic plant studies, the net result is the clear identification of the need to assess sump hydraulic performance, LOCA generated debris effects (i.e., sump screen blockage) and recirculation pump performance under post-LOCA conditions. Current findings do not support the

need for continued in-plant sump tests (per RG 1.79) or more sump model tests (w/o measurement of air ingestion)

2. RG 1.82 requires revision to incorporate the results of two years of sump testing and generic plant studies. There is also the need to correct deficiences in the current RG 1.82, such as the 50% screen blockage rule. Generic plant calculations addressing LOCA-generated debris effects have shown that the 50% blockage rule can be excessive in some plants, and non-conservative for other plants. Continued use (without revision) of this Regulatory guideline would permit the sump designer to bypass the need to assess debris blockage effects and to continue to show that a 50% blocked screen does not result in excessive head loss.

   Appendix A has been included in the revised RG 1.82 to provide guidance and acceptance criteria for assessing sump hydraulic performance, LOCA-induced debris effects and pump performance under adverse conditions. A combined consideration of these three aspects is necessary to determine overall sump performance and acceptability with respect to assurance that adequate pump NPSH margin will exist.

3. An assessment of the possible extent of debris blockage effects is needed since previous reviews have been based on the current RG 1.82 50% blockage guidance and (as noted above)

this has been shown to result in non-conservative assessments in some cases. Based on USI A-43 evaluations, it is concluded that the debris blockage question is dependent on the type of insulation employed (i.e., unencapsulated fibrous insulations transport and block screens) and containment design, or layout. Although these A-43 evaluations show plant-specific concerns (i.e., the Maine Yankee* plant insulation debris assessment), they do not suggest the existence of a widespread problem warranting immediate action. Newer plants employ mostly reflective metallic, or encapsulated insulations--some of the older plants employ a higher percentage of unencapsulated, or fibrous type insulations (see Table 1). BWRs appear to use predominantly reflective metallic insulation.

Since it is not clear which of the operating plants (or NTOL's) have addressed the debris blockage question adequately, it is recommended that a systematic plant evaluation for all operating reactors be undertaken utilizing the guidance provided in Appendix A of the revised RG 1.82. If such evaluations reveal plants where corrective actions should be undertaken, then such cases should be

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*It should be noted that Maine Yankee staff have indicated that some insulation replacement was planned and also the possibility of installing additional debris capture screens is being considered.

Table 1

Types of Insulation Used Within the Primary Coolant[1] System Shield Wall in Plants Surveyed

Plant	Reflective Metallic	Totally Encapsulated	Mineral Fiber/Wool Blanket	Calcium Silicate Block	Unibestos Block	Fiberglass
	Types of Insulation and Quantity in ft²					
Oconee Unit 3	14,500	--	--	--	--	300
Crystal River Unit 3	12,500	715	150	--	--	--
Midland Unit 2	15,750	--	--	--	--	4,400
Haddam Neck	450	--	--	--	14,200[3]	150
Robert E. Ginna	--	--	1,000	22,300	2,800	--
H. B. Robinson	--	--	--	3,800	21,800	--
Prairie Island Units 1 & 2	19,200	--	--	--	--	500
Kewaunee	5,200	--	--	--	4,500	--
Salem Unit 1	17,100	3,400	23,300[2]	--	--	--
McGuire Units 1 & 2	18,000	--	--	--	--	--
Sequoyah Unit 2	18,500	--	--	--	--	--
Maine Yankee	1,600	--	5,700	3,00	1,600	100
Millstone Unit 2	6,300	9,100	1,300	7,200	--	--
St. Lucie Unit 1	1,500	--	--	17,300	--	--
Calvert Cliffs Units 1 & 2	4,400	7,300	--	--	--	--
Arkansas Unit 2	6,300	7,400	--	--	--	200
Waterford Unit 3	2,300	15,500	--	--	--	--
Cooper	30 %	70 %	--	--	--	--
WPPSS Unit 2	100 %	--	--	--	--	--

1) Tolerance is ± 20 percent

2) Both totally and semi-encapsulated Cerablanket is used; however, inside containment only totally encapsulated is employed.

3) Unibestos is currently being replaced by Calcium Silicate. However, both types of insulation have the same sump blockage characteristics.

Enclosure 3

pursued accordingly. A generic letter requesting such evaluations would be used for such implementation.

C. Value-Impact of the Proposed Actions

1. Risk Analysis Results

A risk analysis was performed to assess the effects of loss of the containment emergency sump; for example: due to LOCA debris blockage. Three plants and their corresponding PRAs were selected, these being: Crystal River, IREP-PRA; Calvert Cliffs, RSSMAP-PRA; and Surry, RSS-PRA. The PRA event trees were reanalyzed to determine the effects of sump loss following a large LOCA. Whereas previously these event trees assumed availability of the sump, this analysis assumes total sump failure for 50% of the large LOCAs; the resulting core melt frequencies and release category frequencies were then computed. The 50% assumption reflects the fact that not all large LOCA's will result in total sump failure. Table 2 summarizes results obtained.

The release category frequencies were converted to public dose via the airborne pathway utilizing the following values:

Release Category	Core Melt Release (man-rem)
PWR 1	5,400,000
PWR 2	4,800,000
PWR 3	5,400,000

PWR 4	2,700,000
PWR 5	1,000,000
PWR 6	150,000
PWR 7	2,300

These values were derived using the CRAC code and assuming the guidelines and quantities of radioactive isotopes used in the Reactor Safety Study (WASH-1400), the meteorology at a typical mid-West site (Byron-Braidwood), a uniform population density of 340 people per square-mile (which is an average of all U.S. nuclear power plant sites) and no evacuation of population and are based on a 50 mile release radius model.

The release values used are similar to the those shown in WASH-1400, but with some modifications to arrive at a reference plant value. Generally speaking, release categories 2 and 3 were the major contributors to public dose. Averaging the change in calculated public dose (or change between w/o sump loss and w/sump loss) results in an average increase of public dose of 65 man-rem/plant year due to loss of the sump (see also Table 2).

TABLE 2, SUMMARY OF RISK ASSESSMENT CALCULATIONS

Calculated Core Melt Frequency $(\text{plant-yrs})^{-1}$:

	Base Case w/o Sump Loss	Adjusted Case w/Sump Loss[(3)]	Increase in Core Melt Frequency
Crystal River	3.7×10^{-4}	4.2×10^{-4}	5×10^{-5}
Calvert Cliffs[1]	2×10^{-3}	2.05×10^{-3}	5×10^{-5}
Calvert Cliffs[(2)]	4.0×10^{-4}	4.5×10^{-4}	5×10^{-5}
Surry	5×10^{-5}	1×10^{-4}	5×10^{-5}

Calculated Public Dose (man-rem/plant-year):

	Base Case w/o Sump Loss	Adjusted Case w/Sump Loss[(3)]	Calculated Increase In Public Dose
Crystal River	926	983	57
Calvert Cliffs[(1)]	7,617	7,698	81
Calvert Cliffs[(2)]	653	734	81
Surry	52	108	56
		Average =	65

[(1)] Calvert Cliffs w/o AFW improvement

[(2)] Calvert Cliffs w/AFW improvement

[(3)] These values are based on the assumption that only 50% of the large LOCAs lead to sump loss.

Reference: Probabilistic Risk Assessment of Unresolved Safety Issue A-43, September 1982, by Science Applications Inc. (Ref. 12)

Given the results of the risk analyses summarized above, and utilizing "averaged" numbers, the following quantities can be calculated:

$$\text{Public Dose Averted} = \left(65\ \frac{\text{man-rem}}{\text{plant-yr}}\right)\left(23\ \text{years outstanding plant life}\right)$$

$$= 1487\ \text{man-rem/plant}$$

The avoided on-site dose (due to core melt) can also be calculated as:

$$\text{Avoided On-site Dose} = \left(19{,}860\ \frac{\text{man-rem}}{\text{accident-yr}}\right) \cdot \left(\Delta f\ \text{core-melt}\right)\left(23\ \text{yrs}\right)$$

$$= 23\ \text{man-rem/plant}$$

The potential to avoid a public dose of 1500 man-rem/plant is a significant risk/consequence finding.

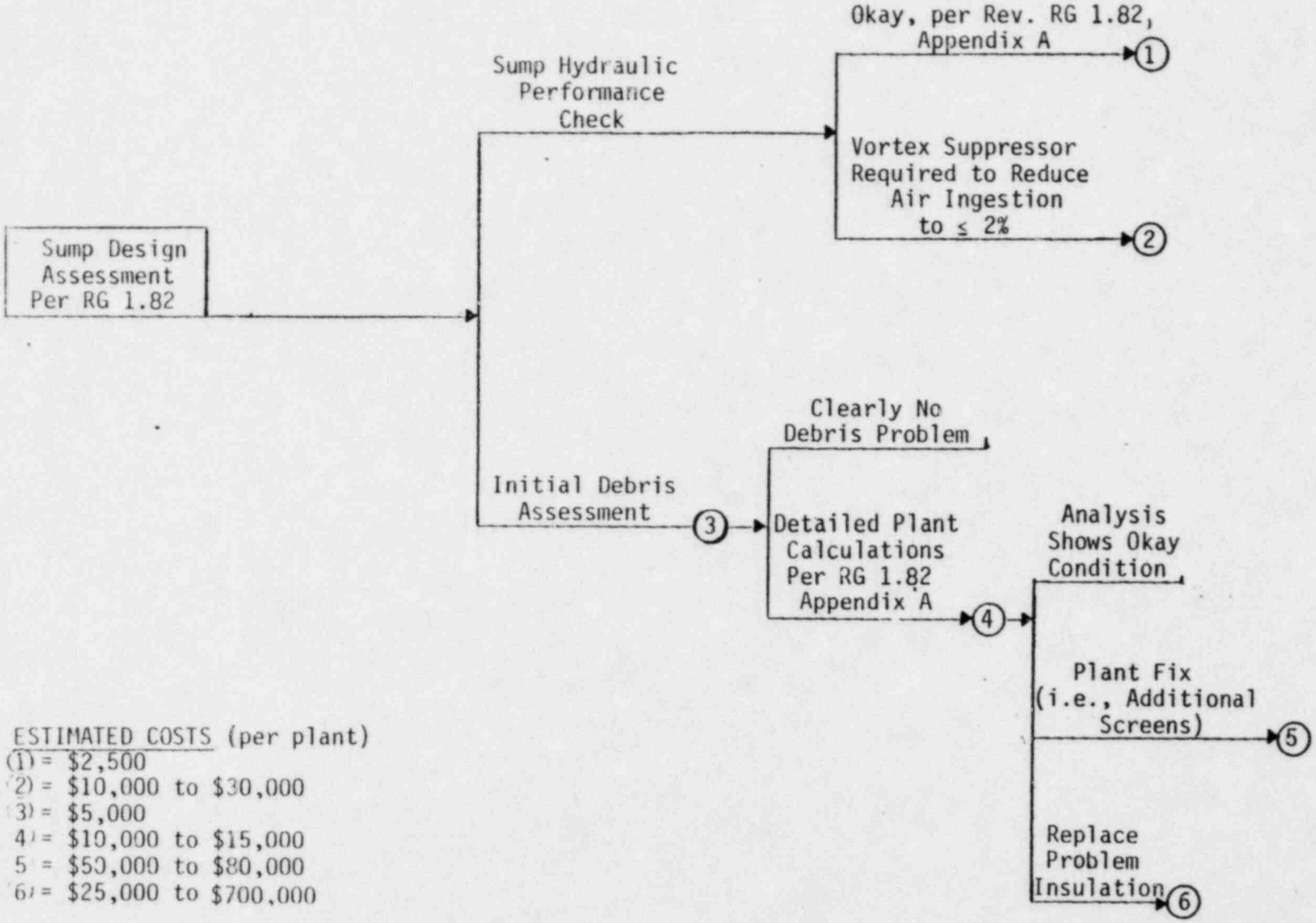
2. Industry Impact

Industry impact will vary from plant-to-plant. As stated previously, not all plants will be found to have large quantities of non-encapsulated fibrous insulations (the type which could lead to severe screen blockage and loss of NPSH). To facilitate understanding of potential impacts on industry, Figure 1 is provided. Also shown on Figure 1 are the estimated costs which might be incurred, depending on the extent of the problem. The major impact would result if the determination is made that large quantities of insulation must be replaced (e.g., 2,000-7,000 ft^2 of insulation). Actual determination of quantities and location of insulation requiring replacement would reduce the impact; also use of alternative methods such as intermediate screens should be evaluated. The sections which follow provide more insight into the expected impacts.

a. Given the guidelines set forth in revised RG 1.82, the initial sump hydraulic design evaluation will take very little time through use of acceptance criteria tables. If sump design and operating conditions show less than 2% air ingestion potential, and if predominantly reflective metallic insulation is employed, the methods and tables as contained in Appendix A of RG 1.82 will allow a sump design review in less than 1 man-day. A conservative impact would be 1 man-week of professional effort (est. $2,500), see also (1) in Figure 1.

b. If the results of the sump hydraulics evaluation show a need for fixes (i.e., the need for vortex suppressors to reduce the estimated air ingestion), an additional impact occurs. Design, fabrication and installation of a vortex suppressor

FIGURE 1. IDENTIFICATION OF IMPACTS RESULTING FROM PROPOSED CHANGES TO RG 1.82 AND SRP 6.2.2



ESTIMATED COSTS (per plant)

(1) = $2,500
(2) = $10,000 to $30,000
(3) = $5,000
(4) = $10,000 to $15,000
(5) = $50,000 to $80,000
(6) = $25,000 to $700,000

consisting of floor grating materials (either horizontally mounted, or formed into a cage) is estimated to cost $10,000 to $30,000 depending on installation complexity, see also (2) in Figure 1.

c. The initial debris assessment will need to consider the types, quantities, methods of fabrication and installation, mechanical attachments, and hygroscopic characteristics of the insulation employed on primary and secondary system piping, reactor pressure vessel, and major components (e.g., steam generators, reactor coolant pumps, pressurizer, tanks, etc.) that can become targets of expanding "break" jet(s) occurring in the primary coolant system. For plants employing essentially all reflective metallic insulations [which can better survive break jet loads and will transport only at high water velocities (_ 2.5 ft/sec)], this assessment can be done quickly. Assuming that the licensee knows what insulations are within containment, such an evaluation should not require over 1 man-week's effort. Reporting the results to NRC might require another week. An impact of $5,000 is estimated, see also (3) in Figure 3.

d. If Step "c" indicates a need for detailed plant calculations to determine quantities of debris generated, what fraction gets to the sump, screen blockage effects, etc., an estimated time of three to four man-weeks is projected based on the level of effort expended for the generic plant-specific studies carried out for USI A-43 resolution.

An impact of $10,000 to $15,000 per detailed plant analysis is projected, see also (4) in Figure 1. Since it is expected that this debris related analysis will be required for some of the older plants employing unencapsulated mineral wool, or fibrous insulations. A four to six plant estimate is projected, which would result in a total industry impact of $40,000 to $90,000.

e. If plant-specific calculations reveal unacceptable sump screen debris blockage, design modifications then need to be considered. Possible solutions include utilization of intermediate screens which would intercept the debris deposition on the local sump screen occurs, encapsulation of insulation, shielding structures to prevent break jet impingement, etc. Use of interception screens is estimated to cost $50,000 to $80,000 (see also (5) in Figure 1) and is based on a potential fix discussed that four to six plants may require corrective actions and this would place the total industry impact at $200,000 to $480,000.

It should be noted that the detailed plant calculations (per RG 1.82, Appendix A guidance) will reveal location and quantities of insulation requiring attention. The existence of such problem areas does not imply the need to replace all the insulation. A more cost effective alternative would be selective insulation replacement.

f. The most severe impact would result if it were found necessary to replace all fibrous insulation, see also (6) in Figure 1. This case is considered in this value-impact analysis since it represents the severest fiscal impact.

Table 3 illustrates cost estimates for insulation replacement for several plants to illustrate plant dependency and is based on cost and exposure data derived from actual man-hours and exposures for steam generator replacement at the Surry Units 1 and 2, plus follow-up discussions with onsite staff. Two additional cost estimates were developed from contacts with the insulation suppliers noted. Estimated cost impacts can range from $25,000 to $700,000 depending on insulation quantities requiring total replacement for the plant in question. Given the costs shown in Table 3, an "averaged" cost impact of $550,000/plant will be assumed for value-impact calculations which follow.

In addition to labor costs, the radiological exposure impact must be considered and is derived from the values shown in Table 2. The dependence on level of insulation replace must required is evident, with a range of 10 to 100 man-rem being forecast. An insulation replacement exposure impact of 50 man-rem/plant was therefore assumed for the value-impact analyses which follows.

In addition, the assumption is made that plant shut downs solely to replace undesirable insulations will not be required (thus purchase of replacement power has not been included) since the risk/consequence calculations do not support shutting down operating plants. Based on discussions with Maine Yankee staff, the plant owner indicated corrective actions (e.g., installation of additional screens and selective removal of mineral wool insulation) could be carried out during scheduled refueling outages. If necessary, the work involving replacement of insulation could be performed at two or more refueling outages.

With respect to new plants, or those applicants in the OL review cycle, the sump hydraulic performance data contained in NUREG-0897 and related references are a "value" since: (a) the extensive sump hydraulics data base (which has been incorporated into the revised RG 1.82) can remove the need for

TABLE 3, ESTIMATES OF INSULATION REPLACEMENT COSTS AND ASSOCIATED EXPOSURES

Plant	Unencapsulated Insulation (Ft²)	Cost Est.[1] No. 1 ($ x 10^3)	Cost Est.[2] No. 2 ($ x 10^3)	Cost Est.[3] No. 3 ($ x 10^3)	Estimated[4] Exposure (man-rem)
Salem Unit 1	13,200	281	238	660	99
Maine Yankee	6,700	142	121	335	47
Ginna	1,000	21	18	50	8
Millstone Unit 2	1,300	28	23	65	10

[1]These costs are derived from Surry Units 1 and 2 steam generator removal and reinstallation data, and discussions with onsite staff. A "per-unit" cost of $0.85/ft² for replaced insulation was derived and labor costs of $25.00/hr were assumed.

[2]Telephone estimates from New England Insulation Company (Maine Yankee has employed this firm) were: $3/ft² to remove, $11/ft² to fabricate new panels, $3-5/ft² to install.

[3]Telephone estimates of $35-50/ft² for mirror-insulation fabrication and installation were obtained from Diamond Power who supplies such insulation. A value of $50/ft² was employed.

[4]Exposure data were derived from Surry 1 and Surry 2 data. Discussions with Surry site staff indicates that a 50 man-rem exposure level for insulation replacement is realistic if the job is pre-planned. An equivalent dose of 7×10^{-3} man-rem/ft² of insulation replaced can be derived.

additional sump model tests which have previously cost $50,000 to $150,000 per plant, and (b) can remove the need for "in-plant" tests designed to demonstrate sump hydraulic design adequacy by visual observations for air-entraining vortex formation.

3. NRC Operation

The "impact" of proposed changes with respect to staff review time will be minimal making use of the guidelines contained in Appendix A of the Revised RG 1.82. NUREG-0897 and supporting reference provide additional technical information which will assist the staff reviewer. It is estimated that less than 1 man-week of staff review time would be required (Estimated cost = $1500/plant).

The experimental data and generic plant information and calculations contained in NUREG-0897 (and supporting references) represents a funding investment of approximately $3.0 million on the part of the NRC and DOE and this information is a "value" to both the NRC and industry. This extensive data base provides a basis for eliminating unnecessary in-plant testing, or sump model tests.

4. Other Government Agencies

Since sump design review and acceptance are carried out solely by NRC staff, no impact on other government agencies is projected.

5. Public

The "value" to the public would be avoidance of public dose from addditional core melts, due to sump failure, if the recommendations are adopted. Based on the PRA results noted in Table 1, the calculated average public dose which could be averted is 1500 man-rem/plant. Given the projection of six to ten plants which may have a debris blockage problem, the total public "value" is 9,000 to 15,000 man-rem potential reduction.

6. Overall Value-Impact of the Proposed Actions

These value-impact results can be summarized as follows:

Avoided Public Dose = 1500 man-rem/plant Avoided Plant Site Dose = 23 man-rem/plant Estimated Implementation Dose = 50 man-rem/plant Core Melt Frequency Decrease = 5×10^{-5}/(plant-yrs) Core Melt Reduction = 11.5×10^{-4} accidents/plant remaining life

The estimated present-worth of plant cost due to a core melt accident is $1.65 billion. Therefore, the proposed changes provide a means to avoid an accident cost of:

$$\text{Avoided Accident Cost} = (\text{Core Melt Reduction})(\text{Plant Cost})$$
$$= (11.5 \times 10^{-4})(\$1.65 \times 10^{9})$$
$$= \$1.9 \times 10^{6}/\text{plant}$$

or nearly $2 million per plant.

These "values" can be compared with estimated "impacts" of $100,000 for plant fixes (such as supplemental debris screens) to $400,000 to $700,000 per plant for replacement of large quantities of troublesome insulation.

The overall impact on operating reactors is shown in Figure 2, which follows the same implementation actions and costs identified in Figure 1. Assuming 75 OL's, the estimated impact for determining the extent of the screen debris blockage problem is $0.7M; another $3.0M is projected for plant fixes (or retrofits).

The above value-impact data can be viewed as a ratio of value gained versus cost to implement (or a V-I ratio), which is defined as:

$$V\text{-}I = \frac{\text{Avoided Public Dose}}{\text{Cost of Implementation}}$$

For operating plants, this ratio computes to:

$$V\text{-}I = \frac{(1500\ \text{man-rem/plant})\ (5\ \text{plants})}{\$(.7 + 2.5)M} = 2344\ \frac{\text{man-rem}}{\$\text{Million}}$$

FIGURE 2, ESTIMATE OF OVERALL INDUSTRY COST IMPACT FOR OL'S

75 OL's

- 25 BWR's = (25)($5000/plant) = $125,000
- 50 PWR's
  - (40)($7500/plant) = $300,000
  - (10)($22,500/plant) = $225,000

Total = $650,000

Determines Extent of Debris Problem ← → Plant Backfits Required

- (5)($80,000/plant) = $400,000
  (Alternate fixes, Rg-additional screens)
- (5)($500,000/plant)* = $2,500,000

Total = $2.9 Million

*for replacement of large amounts of troublesome insulations.

$$\text{or} = (1500)(5)/(.7 + .4) = 6818 \ \frac{\text{man-rem}}{\$\text{Million}}$$

The reader is cautioned against over optimism regarding values to be gained versus impacts from these V-I's. There are uncertainties attributable to costs and avoided doses. However, the V-I computed value supports moving forward with the proposed actions. Generic studies have already identified one plant having potential debris blockage problems. A systematic determination of the extent of the problem is warrented from safety consideration aspects. The V-I ratio, based on a single problem plant assumption would be:

$$\text{V-I} = \frac{(1500 \text{ man-rem/plant})}{(\$.525\text{M})} = 2857 \ \frac{\text{man-rem}}{\$\text{Million}}$$

The radiological impact versus local plant radiological gain (50 man-rem incurred versus 23 man-rem avoided) should be considered offsetting due to the averaging methods used in these analyses and associated uncertainties.

II. Technical Approach

A. Technical Alternatives

a. Proceed with the proposed recommendation, including backfit correction to operating plants, only where plant specific analysis reveal a change is needed.

b. Issue NUREG-0897 and the proposed changes to SRP Section 6.2.2 and RG 1.82, but with implementation required only on new plants.

c. Issue NUREG-0897 and associated references for information only, but take no other action.

B. Discussion and Comparison of Technical Alternatives

a. Proceeding with the proposed recommendations will incur the values and impacts discussed in Section I.C and as summarized in Section I.C.6. A value-impact ratio of 2300-6800 man-rem avoided per million $'s to backfit has been computed. It is clear (with the exception of massive insulation backfits) that the benefits outweigh the impacts. Maintaining the current versions of RG 1.82 and SRP Section 6.2.2 runs contrary to technical findings presented in NUREG-0897 and associated references which reveal a much less severe sump air ingestion picture, but also reveal a deficiency in current assessments of debris blockage effects on sump operation.

b. Accepting the proposed changes to RG 1.82 and SRP Section 6.2.2, for implementation on those plants where a SER will be issued following implementation of the proposed changes is the minimal route which should be considered. The technical findings presented in NUREG-0897 and references, reveal a significantly different picture then previously hypothesized and show that the prior accepted levels of risk may not exist in some plants. However, ignoring the implications of the results of the A-43 debris blockage effects with respect to OL's and NTOL's is not acceptable. ECCS analysis have assumed an operable sump findings indicate screen blockage potential for plants using unencapsulated fibrous insulations.

c. To continue to use the current RG 1.82 and SRP Section 6.2.2, would ignore the experimental data base and plant analyses which clearly point out the need for these recommended changes. This is not an acceptable alternative since A-43 plant-specific calculations have shown that the 50% screen blockage guidance in the current RG 1.82 can result in erroneous and non-conservative plant results.

C. Decision on Technical Approach

Given the positive-finding from the value-impact analysis (See Section I.C.6) and the need to correct current Regulatory technical deficiencies, the recommendation is, therefore, made to revise SRP Section 6.2.2 and RG 1.82 which reflect the technical findings contained in NUREG-0897, and also backfit the licensing positions set forth in Appendix A of RG 1.82 to operating plants and NTOL's which have received a SER.

III. Plan for Implementation

A. Safety or Environmental Significance of Proposed Action

As noted previously, the estimated avoided public dose is approximately 1500 man-rem/plant. Since it is projected that six to ten PWRs may be found to have debris blockage potential that requires corrective action, proposed changes have the potential for avoiding a 9,000 to 15,000 man-rem public dose due to a blocked (or failed) sump.

B. Decision on Plan for Implementation

Given the technical findings and these value-impact assessments, the recommendation is made to proceed with the recommended changes to SRP Section 6.2.2 and RG 1.82, both of which incorporate the technical findings contained in NUREG-0897 and related references. This will provide the necessary safety assurance for new plant designs, and as a "forward fit" would represent a minimum impact route.

With respect to operating plants, and NTOL's for which an SER has already been issued, the applicant or licensee should be required to show an acceptable sump design utilizing the guidelines and criteria set forth in Appendix A of the revised RG 1.82. In particular, the applicant/licensee should demonstrate that potential LOCA generated debris effects do not result in excessive screen blockage leading to loss of NPSH margin for the recirculation pumps. It is expected that a few of the older plants employing unencapsulated fibrous insulations will require follow-up on corrective measures which may be submitted. It is also expected that PWRs would incur the major impact of reanalysis via Appendix A of the revised RG 1.82.

Implementation would follow issuance of the revised SRP Section 6.2.2 and RG 1.82 following receipt and consideration of public comments on the proposed revisions, and resubmitted to the CRGR for review prior to implementation. The generic letter would result in a two step operation which:

a. Identifies the extent and severity of the problem, and proposed fixes if required.

b. Establishes of a schedule for implementation which minimizes impact on plant operation.

Although BWR's are not expected to incur insulation debris problems, operating BWRs should be required to show that plant insulations employed will not result in unacceptable debris blockages for the RHR suction intakes utilizing the methods outlined in the Revised RG 1.82, Appendix A, or an equivalent alternate.

A "draft" generic letter which would implement these requirements for OL's and NTOL's is provided at the end of this enclosure.

IV. Procedural Approach

A. Procedural Alternatives

a. Issue NUREG-0897, for information only; take no other action.

b. Implement use of the revised SRP Section 6.2.2 and RG 1.82, for only those plants not having a SER at time of implementation, or a "forward-fit" only.

c. Require that all plants (including operating plants and NTOL's) evlauate sump design adequacy per Appendix A of the revised RG 1.82, and in particular assess the sump screen blockage effects associated with LOCA generated debris.

B. Value-Impact of Procedural Atlernatives

a. The "impact" of alternative (a) is zero since no changes are implemented. There is a "value" associated with the information provided in NUREG-0897 and related references. This option is, however, unacceptable since deficiences have been identified in the current version of RG 1.82 with respect to debris assessment.

b. The "value" associated with alternative (b) is related to the data contained in NUREG-0897 (and references) which can replace in-plant and sump model tests. The "impacts" are associated with designing for avoidance of sump air ingestion, use of less troublesome insulations, etc. Since option (b) is a forward fit, plant cost impacts should be minimal. An "impact" of $10,000 to $15,000/plant is estimated (see also Section I.C.2).

c. Alternative "c", which is the recommended action, would have a "value" of an avoided accident dose of 1500 man-rem/plant (overremaining plant life) with an attendant impact of $100,000 to 550,000/plant (see again Section I.C.6). In addition, avoidance of any accident situation which could lead to core melt should be pursued. Failure of the sump for those accidents requiring long-term recirculation capability can lead to core melt. The calculated reduction in core melt frequency attributable to sump failure was 5 x 10^{-5}/reactor-year.

C. <u>Decision on Procedural Approach</u>

Given the results of this "value-impact" assessment on the procedural approaches, the recommendation is made to proceed with Alternative "c"; namely, require that plants show by analysis that sump design is adequate and that debris blockage effects do not lead to excessive sump screen blockage per Appendix A of the Revised RG 1.82. As noted previously, the severity of the identified problem should be reviewed by both applicant and staff prior to embarking in extensive fixes.

V. Statutory Considerations

A. NRC Authority

Since the proposed changes are revisions to RG 1.82 and SRP Section 6.2.2, these actions fall within the statutory authority of the NRC. Furthermore, the recommendation to require applicants to demonstrate adequate sump performance falls within the statutory authority of the NRC to regulate and assure the safe operation of nuclear power plants.

B. Need for NEPA Statement

The proposed changes and potential plant retrofits do not warrant a NEPA statement.

VI. Summary and Conclusions

1. Issue the Revised SRP Section 6.2.2 and RG 1.82 for public comment.
2. Issue NUREG-0897 for public comment. This staff report summarizes USI A-43 technical findings.
3. After resolution of public comments and CRGR approval to proceed, issue the Revised RG 1.82 and SRP Section 6.2.2 and require that

new plants, operating plants, NTOL applicants* assess their sump design and debris blockage potential as outlined in Appendix A of the Revised RG 1.82, or by other equivalent methods.

4. Upon receipt of the findings submitted under Item 3, and staff evaluations, determine what (if any) corrective plant actions may be required.

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*If the staff Safety Evaluation Report has already been issued at the time the RG 1.82 revision is issued in effective form, the assessment for a NTOL would be made after issuance of the OL.

REFERENCES

1. Revised Standard Review Plan Section 6.2.2, "Containment Heat Removal Systems."

2. Revised Regulatory Guide 1.82, "Sumps for Emergency Core Cooling and Containment Spray Systems."

3. NUREG-0897, "Containment Emergency Sump Performance," Technical Findings Related to USI A-43, September 1982, "For Public Comment."

4. Padmanabhan, M. and Hecker, G.E., "Assessment of Scale Effects on Vortexing, Swirl, and Inlet Losses in Large Scale Sump Models," NUREG/CR-2760, Alden Research Laboratory, Worcester Polytechnic Institute, Holden, MA, June 1982.

5. Padmanabhan, M., "Hydraulic Performance of Pump Suction Inlet for Emergency Core Cooling Systems in Boiling Water Reactors," NUREG/CR-2772, Alden Research Laboratory, Worcester Polytechnic Institute, Holden, MA, June 1982.

6. Padmanabhan, M., "Result of Vortex Suppressor Tests, Single Outlet Sump Test and Miscellaneous Sensitivity Texts," NUREG/CR-2761, Alden Research Laboratory, Worcester Polytechnic Institute, Holden, MA, September 1982.

References (Continued)

7. "Results of Vertical Outlet Sump Tests", Joint ARL/Sandia Report, ARL47-82/SAND82-1286/NUREG/CR-2759, September 1982.

8. Reyer, R., et.al., "Survey of Insulation Used in Nuclear Power Plants and the Potential for Debris Generation," NUREG/CR-2403, Burns and Roe, Inc., Oradell, NJ, October 1981.

9. Kolbe, R. and Gahan, E., "Survey of Insulation Used in Nuclear Power Plants and the Potential for Debris Generation," NUREG/CR-2403, Supplement I, Burns and Roe, Inc., Oradell, NJ, May 1982.

10. Wysocki, J. J., et.al., "Methodology for Evaluation of Insulation Debris," NUREG/CR-2791, Burns and Roe, Inc., Oradell, NM, (to be published).

11. Kamath, P., Tantillo, T., and Swift, W., "An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions," NUREG/CR-2792, Creare, Inc., Hanover, NH, (to be published).

12. Ferrell, W. L. et al, "Probabilistic Assessment of USI A-43," Science Applications Inc. report, September 1982.

DRAFT GENERIC LETTER

TO: All Licensees of Operating Reactor Plants and Holders of Construction Permits

Gentlemen:

SUBJECT: ASSESSMENT OF CONTAINMENT EMERGENCY SUMP PERFORMANCE DURING THE RECIRCULATION MODE (GENERIC LETTER)

This letter is to provide you with the latest information and methodology developed by the staff in the process of resolving questions related to containment sump performance (USI A-43 "Containment Emergency Sump Performance"). We request that you review the containment sump design and installation in your facility(ies) in order to reconfirm containment emergency sump operability in the post-LOCA period wherein recirculation must be maintained. Our principal concern relates to LOCA generated debris which could lead to severe screen blockage and result in loss of pump net positive suction head (NPSH). The technical aspects of this issue (namely sump hydraulic performance, debris effects and pump operation under adverse conditions) have been extensively studied and the results are contained in NUREG-0897, "Containment Emergency Sump Performance." Non-encapsulated fibrous insulations appear to pose the potential for excessive screen blockage. These technical findings have been incorporated into NRC's Standard Review Plan, Section 6.2.2, Revision 4 and RG 1.82, Revision 1. Appendix A of RG 1.82 provides evaluation guidelines which can be used to evaluate sump performance. These revised documents form the criteria for licensing reviews and will be applied to plants for which the NRC Safety Evaluation Report is not yet issued. Copies of these documents are provided for your use.

For operating reactors and for those plants where the NRC Safety Evaluation Report (SER) has already been issued, an assessment of the containment emergency sump performance must be made in accordance with the requirements enumerated below.

(1) Sump hydraulic performance, including an assessment of levels of air ingestion. (i.e., ≤2 volume % is considered acceptable.)

(2) The amount of insulation debris that might be generated by the postulated pipe break(s), the transport of such debris to the sump screen and attendant screen blockage which might occur. The resulting screen blockage calculated must be used to determine estimated head loss for estimating NPSH impact. The previously employed 50% blockage guidance no longer applies and should not be used as an assumption in your calculations.

(3) The available NPSH margin for the recirculation pumps when the combined effects of Items (a) and (b) are considered, must be sufficient to assure acceptable pump performance during the required period of operation.

Appendix A of RG 1.82, Revision 1 provides an acceptable method, or guidelines, for carrying out the analyses requested above.

As indicated above, the primary purpose of your evaluation is to reconfirm using the latest available information and methodology that NPSH margins are consistent with the NPSH requirements established in your previous safety analysis. If you calculations identify deficiencies in performance or operability, your response must identify corrective measures or plant modifications that are needed in order to assure acceptable sump performance.

Accordingly, licensees of operating plants and applicants who have received an OLSER, should submit their evaluation of sump performance and available NPSH within 150 days from the date of this letter, or submit within 30 days an alternate schedule for your analysis and response to this generic letter. If corrective measures or modifications are identified as being needed, your proposed schedule for implementing any modifications should also be provided.

This request for information has been approved by the Office of Management and Budget under clearance number ____________ which expires ____________.

Sincerely,

Darrell G. Eisenhut, Director
Division of Licensing
Office of Nuclear Reactor Regulation

ENCLOSURE 3

BACKGROUND INFORMATION FOR CRGR REVIEW

OF USI A-43 RESOLUTION

The following information is provided in the format specified in the Charter, "Committee to Review Generic Requirements," dated June 16, 1982, as approved by the Commission. For each item of information, the request is stated as given in the reference followed by a discussion of the response. Further supporting information for questions related to value/impact of the proposed requirements is contained in Enclosure 2, "Value Impact Analysis for USI A-43."

(i) The proposed generic requirement as it is proposed to be sent out to licensees.

The proposed generic requirements are set forth in the revised RG 1.82 (Enclosure 5) and revised SRP Section 6.2.2 (Enclosure 4). Table 3-1, summarizes "present" versus "proposed" regulatory positions regarding evaluation of containment emergency sump performance. Following receipt of public comments received and final revisions to RG 1.82, Rev. 1 and SRP Section 6.2.2, Rev. 4, these documents would be submitted to the CRGR for review and approval for implementation. Both "forward fit" on new applications, and "backfit" to operating reactors and NTOL's is proposed.

Implementation for OL's and NTOL's will be carried out via a generic letter such as enclosed with the value-impact analysis (Enclosure 2). This generic requirement would be a two-step procedure wherein:

(a) The licensees will be requested to perform analyses (per Appendix A of RG 1.82, Rev. 1) and to identify sump performance adequacy or deficiencies, to identify corrective measures necessary for compliance with the guidelines of Appendix A of RG 1.82, Rev. 1, and to propose a schedule for implementing corrective measures.

(b) Based on the responses received, an implementation schedule will be established for corrective actions required and integrated into overall plant schedules, thus minimizing industry impact.

For those applicants where a SER has not been issued at the time of implementation of the revised RG 1.82 and SRP Section 6.2.2, the generic requirements contained therein will apply.

It should be clearly noted that this proposed implementation is not a request for instant, or massive retrofits. Analytical assessments should be made to identify extent and severity of problem(s). Our review of nineteen plants indicates that some plants (i.e., 4-6 plants) may have a blockage problem. A more detailed discussion of potential actions, and attendant impacts, is presented in the value-impact analysis (see Enclosure 2).

(ii) Draft staff papers or other underlying staff documents supporting the requirements.

o The underlying technical information is contained in NUREG-0897, and related references listed therein. Enclosure 1 summarizes findings contained in these references. Copies of the references have been distributed routinely through the NRC's Standard Distribution for Unclassified U. S. Nuclear Regulatory Commission Publications (NUREG-0550, Rev. 2), Category 1S, Utility and Reactor Vendor Executives. Copies of any references listed in NUREG-0897 (or Enclosure 1) will be provided upon request, or can be obtained through TIDC.

(iii) A brief description of each of the steps anticipated that applicants must carry out in order to complete the requirements.

o Are there separate short-term requirements?

There are no short-term requirements.

o Is it the definitive, comprehensive position on the subject or is it the first of a series of requirements to be issued in the future?

The staff's technical position on this subject is contained in NUREG-0897 (Enclosure 6) and has been embodied in the proposed revisions to SRP Section 6.2.2 and RG 1.82. These documents present a comprehensive position on containment sump performance requirements and design acceptance. It is not expected that additional requirements will be issued in the future.

o How does this requirement affect other requirements? Does the requirement mean that other items or systems or prior analyses need to be reassessed?

Although it is not expected that other systems (i.e., ECCS) will require reassessment, the containment emergency sump must provide an adequate water source for long-term recirculation and successful sump operation has been implicitly assumed in LOCA analyses. Generic plant studies have shown that the 50% debris blockage rule from RG 1.82 to be non-conservative for some plants. Thus some reassessments may result; however, it is felt that corrective actions can be taken to handle debris effects as discussed in the value-impact analysis (see Enclosure 2).

o Is it only computation? Or does it require or may it entail engineering design of a new system or modification of any existing systems?

It is expected that the impact will be primarily manifested as additional computation. In particular, if calculations show an unacceptable screen blockage potential, then plant modifications will be required. These modifications may range from installation of additional debris screens to replacement of those portions of plant insulation which could lead to severe blockages (i.e., unencapsulated fibrous insulations). The A-43 value-impact analysis (provided as Enclosure 2) details these potential actions and attendant impacts.

o Is plant shutdown necessary? How long?

Plant shutdown for an immediate fix is not felt to be necessary. Risk evaluations (See Enclosure 2), based on the assumption of loss of recirculation capability because of sump failure due to debris blockage, do not support a plant shutdown with attendant replacement power purchase costs. Discussions with some A-E's and utility staff indicate that plant shutdown for A-43 retrofits (which might result) would not be necessary. With proper planning, corrective measures could be integrated into the overall plant schedule and accomplished during planned outages.

o Does design need NRC approval?

It is expected that some OL reassessments (per generic letter directive) will show a need to correct plant designs to avoid debris blockage problems. As noted in the generic requirements, the second step would be an assessment of proposed corrective action(s); this review and approval would be subjected to the normal NRC licensing review.

o Does it require new equipment? Is it available for purchase in sufficient quantity by all affected licensees or must such equipment be designed? What is the lead time for availability?

If debris blockage problems are identified, changes in insulation materials may be indicated. Satisfactory insulations (currently used in other plants) can be substituted and these insulations can be purchased from the commercial market. If needed, vortex suppressors can be constructed from floor grating materials, such as currently used in plants. Additional debris entrapment screens (a possible alternate fix) can be fabricated from currently employed screening materials.

o May it be used upon installation or does it need staff approval before use? Does it need technical specification changes before use?

Staff review and approval would be as stated above which is a review and approval of the corrective design changes. No additional review after installation is contemplated. No technical specification changes are required.

(iv) Identification of the category of reactors to which the generic requirement is to apply.

This generic requirement applies to both PWRs and BWRs, although it should be recognized that USI A-43 was derived from safety concerns related to containment emergency sumps in PWRs. However, both PWRs and BWRs must be designed to maintain long-term recirculation cooling. Thus, the guidelines set forth can be applied to all LWRs. It is not expected that BWRs will be significantly impacted by the recommended evaluations. As noted previously, a small number of older PWRs may require corrective action.

(v) For each such category:

o A risk reduction assessment performed using a data base and methodology commonly accepted within NRC (for example, similar to that outlined in SECY-81-513).

A risk assessment (in accordance with SECY 81-513) of the effect of losing the recirculation sump was performed for three reference PWRs using current PRA techniques. The results are presented in Enclosure 3, Section I.C. Briefly stated, these calculations show a potential public dose reduction of 1500 man-rem/plant, for a population of six to ten plants. The estimated cost for implementation is $100,000 to $550,000/plant. The estimated radiological impact for implementation (i.e., insulation replacement) is 50 man-rem/plant.

- o An assessment of costs to NRC; an assessment of costs to licensees, including resulting occupational dose increase or decrease, added plant and operational complexity, as well as total financial costs.

An assessment of NRC and licensee costs is provided in Enclosure 2, USI A-43 Value-Impact Analysis. This analysis details implementation actions which might result, associated costs, occupational dose increases, etc. Enclosure 2 details more fully actions that may be required on the part of both NRC and utilities.

- o Consistent with the first two items above, provide the basis for requiring or permitting implementation by a given date or on a particular schedule.

A value-impact (V-I) ratio can be defined as follows:

$$V\text{-}I = \frac{\text{Avoided Public Dose}}{\text{Industry Costs \& NRC Costs}}$$

and is further detailed in Enclosure 2, Section I.C.6. Without adjustment for avoided industry accident costs, the calculated V-I ratio is approximately 2700 man-rem/$M for the situation requiring extensive insulation replacement, and approximately 6500 man-rem/$M if less drastic fixes would suffice (e.g., use of supplemental debris screens). It should be recognized that differences of opinion will likely exist regarding costs and avoided public dose; however, the range of V-I noted does indicate a benefit to be gained.

The Division of Licensing has obtained verbal comments from one licensee that the costs for installation of supplemental debris screens would be $300,000 vs. the $80,000 that we estimated in Enclosure 2. The same licensee also indicated that our cost estimates for insulation replacement were low by a factor of 4 to 8. Another comment from a different licensee was that our person-rem estimates for retrofits appear to be low. No basis for any of these comments was provided.

We believe our cost estimates which are based on industry and vendor sources cited in Enclosure 2 to be reasonable and that they will serve as a basis for industry and public comment. We expect that comments in this area will assist us in providing a more comprehensive view of the value-impact before the final requirements are issued and before any retrofits are required. The CRGR will, review this issue after we have received and addressed the comments received.

The value-impact noted above supports proceeding with the recommendation to obtain public comment on the recommended revisions to SRP Section 6.2.2, RG 1.82. In addition, this issue should also be viewed as requiring attention, but not requiring shutdown, of operating plants, for immediate implementation. After consideration of public comments and assuming CRGR approval to implement SRP Section 6.2.2 and RG 1.82, and to backfit via the proposed generic letter to licensees, plant assessments would be made to determine what plant modifications are needed on what schedule, for plants affected.

o Other suggested implementation schedule and the basis therefor. This should include sufficient information to demonstrate that the schedule is realistic and provides sufficient time for indepth engineering, evaluation, design, procurement, installation, testing, development of operating procedures, and training of operators.

No alternate implementation schedule is suggested. As noted above, immediate action is not warranted since the initial step proposed is to solicit public comment.

o Schedule of staff actions involved in completion of requirement (based on hypothesized effective date of approval).

The generic letter to licensees would request an evaluation in 5 months, staff review would likely take 3 months (if the procedures outlined in Appendix A of the revised RG 1.82 are employed). Concluding actions related to acceptance of the proposed schedule for any corrective actions needed should be completed in another 4 months. Thus a 1 year evaluation and conclusion cycle is projected.

o Prioritization of the proposed requirement considered in light of all other safety-related activities under way at all affected facilities. This prioritization shall be based on the guidance and direction from time to time by DEDROGR. Until such time as such advice is provided, each proposing office shall use its best technical judgment and explain the basis therefor.

It should be noted that the proposed requirement, namely reassessment of sump performance (particulary from debris blockage considerations) is a confirmation that previously assumed ECCS availability is met.

Although this issue is treated as a risk reduction in the value-impact analysis (Enclosure 2) the net effect will be to determine which plants are not now evaluated as meeting performance requirements for ECCS recirculation. Thus we recommend proceeding with the actions proposed.

The value-impact analysis carried out indicates a positive benefit to be gained at a relatively low impact and also supports proceeding with issuance of a generic letter requesting plant-specific assessments.

o For proposed requirements involving reports and/or recordkeeping, an assessment of whether such reporting or recordkeeping is the best means of implementation and the appropriate degree of formality and detail to be imposed.

The use of a generic letter requesting assessment of sump performance via Appendix A of the revised RG 1.82 will result in individual plant evaluation responses, identification of any corrective actions needed plus a proposed schedule for implementation. This approach basically closes on the issue and should not result in extensive record keeping, presupposing that the implementation schedule is found acceptable.

o To the extent that the category contains plants of different types or vintages, the items listed above shall be provided for each type and vintage, or justification shall be provided demonstrating that the analysis of each item is valid for all types of vintages covered.

These requirements apply to all commercials LWRs. However, it is expected that PWRs, and in particular older PWRs, will require closer attention than BWRs. The BWR plant design affords inherent debris protection since long-term cooling is drawn from the suppression pool, for which the standpipe design will minimize debris migration, also BWR's generally utilize reflective metallic insulation.

(vi) Each proposed requirement shall contain the sponsoring office's position as to whether the requirement implements existing regulations or goes beyond them.

The proposed requirements are within existing regulations; namely, 10 CFR Part 50, Appendix A; GDC 38, "Containment Heat Removal;" GDC 39, "Inspection of Containment Heat Removal System;" and GDC 40, "Testing of Containment Heat Removal System." Also as previously noted, these proposed requirements will confirm that previously assumed functional performance (based on an operational sump assumption) are valid.

(vii) The proposed method of implementation along with the concurrence (and any comments) of ELD on the method proposed.

The proposed requirements are being reviewed with ELD and ELD requirements will be incorporated into the "public comment" package. In addition, we are reviewing with ELD the possibility of utilizing a certification method for easing the utility burden for responding to the proposed requirements.

(viii) Regulatory analysis sufficient to address the Paperwork Reduction Act, the Regulatory Indemnability Act and Executive Order 12291.

OMB clearance is not required to send the "For Comment" documents to licensees and applicants since there are no new requirements at this time. The response by licensees or applicants is optional.

TABLE 3-1, PRESENT AND PROPOSED REGULATORY POSITION

	Present Regulatory Position	Proposed Regulatory Position
Sump Hydraulic Performance	(a) Prior to issuance of RG 1.82 (6/74) sump tests were conducted at the plant (per RG 1.79); transition was made to 1/3-1/1 scale sump model hydraulic testing.	(a) Revised RG 1.82 contains sump hydraulic design and acceptance criteria derived from an extensive full scale experimental data base. Removes the dependence on scale model tests, visual observations and staff deductions.
	(b) RG 1.82 was employed and supplemented by "scaled" hydraulics testing. Judgements were made on visual observations of vortex formation.	(b) Provides a basis for elimination of model testing and in-plant tests.
Insulation Debris Effects	(a) Current RG 1.82 provides general comments relative to debris effects, does not deal with issue directly.	(a) Revised RG 1.82 eliminates 50% blockage rule and requires plant specific calculations to assess debris effects.

TABLE 3-1, PRESENT AND PROPOSED REGULATORY POSITION

	Present Regulatory Position	Proposed Regulatory Position
	(b) Current 50% screen blockage guidance in RG 1.82 allows circumvention to calculate plant specific debris effects. Generic studies have shown the 50% rule can be non-applicable and non-conservative.	(b) Revised RG 1.82 provides guidelines for evaluating debris generation, transport, estimating screen blockage and attendant head loss.
Pump Performance	(a) General NPSH requirements of RG 1.1 utilized and plant tests per RG 1.79.	(a) Revised RG 1.82 provides air ingestion data and criteria for assessing pump effects.
	(b) Vortex formation (particularly presence of air core vortices) used to infer excessive air ingestion conditions leading to pump cavitation.	(b) Revised RG 1.82 provides guidelines for combining sump hydraulic efforts and debris effects to arrive at determining on NPSH availability.
	(c) 50% screen blockage rule (per RG 1.82) used to calculate head loss and attendant NPSHR impact.	
Overall Sump Performance	Handled by application of RG 1.82 considerations, with emphasis on air ingestion effects. Debris effects not analyzed.	Revised RG 1.82 provides guidance and acceptance criteria for sump hydraulics, debris generation and blockage effects, pump performance under adverse conditions and integrates these considerations for determination of available NPSH.

ENCLOSURE 4

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

Proposed Revision to

Standard Review Plan

PSRP-6.2.2, Rev. 4

This proposed revision of the Standard Review Plan and its supporting value/impact statement and associated technical documentation have not received a complete staff review and approval and do not represent an official NRC staff position. The proposed revision to the Standard Review Plan incorporates the resolution of generic issue USI A-43, "Containment Emergency Sump Performance." Public comments are being solicited on the proposed SRP section, proposed Regulatory Guide 1.82 and their associated value/impact analysis and technical support document NUREG-0897 (including any implementation schedules) prior to a final review and decision by the Office of Nuclear Reactor Regulation as to whether this proposed revision should be approved. Comments should be sent to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch. All comments received by will be considered, and all of the associated documents and comments considered will be made publicly available prior to a decision by the Director, Office of Nuclear Reactor Regulation, on whether to implement this revision. Copies of each of these documents are available upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

NUREG-0800
(Formerly NUREG-75/087)

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

Proposed Revision 4 to

6.2.2 CONTAINMENT HEAT REMOVAL SYSTEMS

REVIEW RESPONSIBILITIES

Primary - Containment Systems Branch (CSB)

Secondary - None

I. AREAS OF REVIEW

The CSB reviews the information in the applicant's safety analysis report (SAR) concerning containment heat removal under post-accident conditions to assure conformance with the requirements of General Design Criteria 38, 39, and 40 (Ref. 1, 2 and 3). The types of systems provided to remove heat from the containment include fan cooler systems, spray systems, and residual heat removal systems. These systems remove heat from the containment atmosphere and the containment sump water, or the water in the containment wetwell. The CSB review includes the following analyses and aspects of containment heat removal system designs:

1. Analyses of the consequences of single component malfunctions.

2. Analyses of the available net positive suction head (NPSH) to the containment heat removal system pumps.

3. Analyses of the heat removal capability of the spray water system.

4. Analyses of the heat removal capability of fan cooler heat exchangers.

5. The potential for surface fouling of fan cooler, recirculation, and residual heat removal heat exchangers, and the effect on heat exchanger performance.

6. The design provisions and proposed program for periodic inservice inspection and operability testing of each system or component.

7. The design of sumps for emergency core cooling and containment spray systems, including an assessment for potential sump blockage that might result from debris such as thermal insulation.

8. The effects of debris such as thermal insulation on recirculating fluid systems.

The CSB will coordinate other branch evaluations that interface with the overall review of the containment heat removal systems as follows: the Auxiliary Systems Branch (ASB) wll review the secondary cooling systems, which provide cooling water to the heat exchangers in the containment heat removal systems, as part of its primary review responsibility for SRP Section 9.2.2. The Instrumentation and Control Systems Branch (ICSB) will review the sensing and actuation instrumentation provided for the containment heat removal systems as part of its primary review responsibility for SRP Section 7.3. The Equipment Qualification Branch (EQB) will review the qualification test program for the active components of the fan cooler system, and the sensing and actuation instrumentation for the containment heat removal system as part of its primary review responsibility for SRP Section 3.11. The Chemical Engineering Branch (CMEB) will evaluate the quantity of unqualified paint that can potentially reach the emergency sump(s) under design basis pipe break accident review responsibility for SRP Section 6.1.2. The Accident Evaluation Branch (AEB) will review fission product control features of containment heat removal systems as part of its primary review responsibility for SRP Section 6.5.2. The Mechanical Engineering Branch (MEB) will review the system seismic design and quality group classification as part of its primary review responsibility for SRP Section 3.2.1 and SRP Section 3.2.2, respectively. The Licensing Guidance Branch (LGB) will review the proposed technical specifications for each system at the operating license stage of review as part of the primary review responsibility for SRP Section 16.0.

For those areas of review identified above being reviewed as part of the primary review responsibility of other branches, the acceptance criteria necessary for the review and their methods of application are contained in the referenced SRP section of the corresponding primary branch.

II. ACCEPTANCE CRITERIA

CSB acceptance criteria for the design of the containment heat removal system is based on meeting the relevant requirements of General Design Criterion 38, 39, and 40. The relevant requirements are as indicated below.

1. General Design Criterion 38 as it relates to:

   a. Containment heat removal system being capable of reducing rapidly the containment pressure and temperature following a LOCA, and maintaining them at acceptably low levels.

   b. The containment heat removal system performance being consistent with the function of other systems.

   c. The containment heat removal system being safety-grade design; i.e., have suitable redundancy of components and features, and interconnections, to assure that for either a loss of onsite as a loss of offsite power, the system function can be accomplished assuming a single failure.

d. Leak detection, isolation and containment capabilities being incorporated in the design of the containment heat removal system.

2. General Design Criterion 39, as it relates to the containment heat removal system being designed to permit periodic inspecton of components.

3. General Design Criterion 40, as it relates to the containment heat removal system being designed to permit periodic testing to assure system integrity, and the operability of the system, and active components.

Specific acceptance criteria necessary to meet the relevant requirement of GDC 38, 39, and 40 are as follows:

1. The containment heat removal systems should meet the redundancy and power source requirements for an engineered safety feature; i.e., the systems should be designed to accommodate a single active failure. The results of failure modes and effects analyses of each system should assure that the system is capable of withstanding a single failure without loss of function. This is conformance with the requirements of General Design Criterion 38.

2. With regard to General Design Criterion 38 as it relates to the capability of containment system to accomplish its safety function, the spray system should be designed to accomplish this without pump cavitation occurring. Therefore, the net positive suction head available to the pumps in both the injection and recirculation phases of operation should be greater than the required NPSH. A supporting analysis should be presented in sufficient detail to permit the staff to determine the adequacy of the analysis and should show that the available NPSH is greater than the required NPSH. The supporting analysis should also include an evaluation of the increase in the required NPSH margin due to the sump performance effects (e.g., air ingestion, etc.) and post LOCA debris effects (e.g., debris generation, migration and screen blockage).

   In the recirculation phase; i.e., in the long term (after about one hour) following a LOCA, the containment spray system is required to circulate the water in the containment. The NPSH analysis will be acceptable if the sump is designed in accordance with the guidelines set forth in Regulatory Guide 1.82 (Ref. 5) and (2) if it is designed in accordance with the guidelines of Regulatory Guide 1.1 (Ref. 4) i.e., is based on maximum expected temperature of the pumped fluid and with atmospheric pressure in the containment. For clarification, the analysis should be based on the assumption that the containment pressure equals the vapor pressure of the sump water. This ensures that credit is not taken for containment pressurization during the transient.

   The recirculation spray system for a subatmospheric containment is designed to start about five minutes after a loss-of-coolant accident, i.e., during the injection phase of spray system operation. For subatmospheric containments, the guidelines of Regulatory Guide 1.1 as defined above will apply after the injection phase has terminated, which occurs about one hour after the accident. Prior to termination of the injection phase the NPSH analyses should include conservative predictions of the containment atmosphere pressure and sump water temperature transients.

3. In evaluating the performance capability of the containment spray system, to satisfy GDC 38, analyses of its heat removal capability should be based on the following considerations:

   a. The locations of the spray headers relative to the internal structures.

   b. The arrangement of the spray nozzles on the spray headers and the expected spray pattern.

   c. The type of spray nozzles used and the nozzle atomizing capability, i.e., the spray drop size spectrum and mean drop size emitted from each type of nozzle as a function of differential pressure across the nozzle.

   d. The effect of drop residence time and drop size on the heat removal effectiveness of the spray droplets.

   The spray systems should be designed to assure that the spray header and nozzle arrangements produce spray patterns which maximize the containment volume covered and minimize the overlapping of the sprays.

4. In evaluating the performance capability of the fan cooler system, to satisfy GDC 38, the design heat removal capability (i.e., heat removal rate vs. containment temperature) of fan coolers should be established on the basis of qualification tests on production units or acceptable analyses that take into account the expected post-accident environmental conditions and variations in major operating parameters such as the containment atmosphere steam-air ratio, condensation on finned surfaces, and cooling water temperature and flow rate. The equipment housing and ducting associated with the fan cooler system should be analyzed to determine that the design is adequate to withstand the effects of containment pressure following a loss-of-coolant accident (see SRP Section 6.2.5). Fan cooler system designs that contain components which do not have a post-accident safety function should be designed such that a failure of non-safety-related equipment will not prevent the fan cooler system from accomplishing its safety function.

5. In evaluating the heat removal capability of the containment heat removal system, to satisfy GDC 38, the potential for surface fouling of the secondary sides of fan cooler, recirculation, and residual heat removal heat exchangers by the cooling water over the life of the plant and the effect of surface fouling on the heat removal capacity of the heat exchangers should be analyzed and the results discussed in the SAR. The analysis will be acceptable if it is shown that provisions such as closed cooling water systems are provided to prevent surface fouling or surface fouling has been accounted for in establishing the heat removal capability of the heat exchangers.

6. To satisfy the requirement of GDC 38 regarding the long-term spray system(s) and emergency core cooling system(s), the containment emergency sump(s) should be designed to provide a reliable, long-term water source for recirculation pumps. Provision should be made in the containment design to allow drainage of spray and emergency core cooling water to the emergency sump(s), and for recirculation of this water through the containment sprays and emergency core cooling systems. The design of the sumps, and

the protective screen assemblies is a critical element in assuring long term recirculation capability. Therefore, adequate design consideration of: a) sump hydraulic performance, b) evaluation of potential debris generation and associated screen blockage, c) RHR and CSS pump performance under postulated post-LOCA conditions is necessary. The design of protective screen assemblies around recirculation piping suction points will be acceptable if it is capable of preventing debris from entering the recirculation piping which could impair the performance of system pumps, valves, heat exchangers, or spray nozzles. Regulatory Guide 1.82 (Ref. 5) provides guidance on the design of sumps for emergency core cooling and containment spray systems.

6. ~~----To-satisfy-the-requirement-of-GDC-38-regarding-the-long-term-safety-functions-of-the-containment-spray-system;-provisions-should-be-made-to-allow drainage-of-spray-and-emergency-core-cooling-water-to-the-sumps-(recirculation-piping-suction-points).~~

7. In meeting the requirements of GDC 39 and 40, regarding inspection and testing, provisions should be made in the design of containment heat removal systems for periodic inspection and operability testing of the systems and system components such as pumps, valves, duct pressure-relieving devices, and spray nozzles.

8. To satisfy the system design requirements of GDC 38, instrumentation should be provided to monitor containment heat removal system and system component performance under normal and accident conditions. The instrumentation should be capable of determining whether a system is performing its intended function, or a system train or component is malfunctioning and should be isolated.

III. REVIEW PROCEDURES

The procedures described below provide guidance for the review of containment heat removal systems. The reviewer selects and emphasizes material from the review procedures as may be appropriate for a particular case. Portions of the review may be done on a generic basis for aspects of heat removal systems common to a class of containments, or by adopting the results of previous reviews of plants with essentially the same system.

Upon request from CSB, the secondary review branches will provide input for the areas of review stated in subsection I of this SRP section. CSB obtains and uses such input as required to assure that this review procedure is complete. CSB assures that the design and functional capability of the containment heat removal system conform to the requirements of General Design Criteria 38, 39 and 40.

CSB determines the acceptability of a containment heat removal system design by reviewing failure modes and effects analyses of the system to be sure that all potential single failures have been identified and no single failure could incapacitate the entire system; verifying that engineered safety feature design standards have been applied; reviewing the system design provisions for periodic inservice inspection and operability testing to ensure that the system and components are accessible for inspection and all active components can be tested; and reviewing the capability to monitor system performance and control active components from the control room so that the operator can exercise control over system functions or isolate a malfunctioning system component.

CSB reviews analyses of the net positive suction head available to the spray system pumps. CSB assures that the analyses for the recirculation phase are done in accordance with the guidelines of Regulatory Guide 1.1, i.e., are based on maximum expected temperature of the pumped fluid and with atmospheric pressure in the containment. For clarification, the analyses should be based on the assumption that the containment pressure equals the vapor pressure of the sump water. This ensures that credit is not taken for containment pressurization during the transient. CSB assures that calculations of the available NPSH are based on transient values of the suction head and the friction head. The CSB reviews information provided by the applicant to identify and justify the conservatisms applied in determining the water level in the containment and the friction losses in the recirculation system suction piping. For example, the uncertainty in determining the free volume in the lower part of the containment that may be occupied by water, and the quantity of water that may be trapped by the reactor cavity and the refueling canal, should be factored into the calculation of the suction head.

The CSB reviews analyses of the available NPSH for subatmospheric containments for the period prior to termination of the injection phase of containment spray to determine that containment pressure and sump water temperature transients have been conservatively used in the NPSH calculations. The CSB reviews information provided by the applicant to identify and justify the conservatisms in the analysis of the containment atmosphere pressure and sump water temperature transients. The CSB also reviews the conservatisms used in determining the water level in the containment and the friction losses in the recirculation system piping.

The CSB compares the NPSH requirements for the containment heat removal system pumps to the minimum calculated NPSH available to the pumps to assure that a positive margin is maintained. The CSB also reviews the preoperational test programs, and periodic inservice inspection and test programs, to verify that adequate NPSH is available to the pumps and the continuing operability of the pumps during the lifetime of the plant.

If in the judgment of the CSB, the NPSH analyses were not done in a sufficiently conservative manner, confirmatory analyses are performed using the CONTEMPT-LT computer code.

The CSB also reviews the evaluation of the volume of the containment covered by the sprays and the extent of overlapping of the sprays with respect to heat removal capabilities. A judgment will be made regarding the acceptability of the spray coverage and extent of overlapping; the volume of the containment covered by the sprays should be maximized and the extent of overlapping kept to a minimum. Elevation and plan drawings of the containment showing the spray patterns are used to determine coverage and overlapping.

In general, the design requirements for the spray systems with respect to spray drop size spectrum and mean drop size, spray drop residence time in the containment atmosphere, containment coverage by the sprays, and extent of overlapping of the sprays are more stringent when the acceptability of the system is being considered from an iodine removal capability standpoint rather than from a heat removal capability standpoint. Consequently, when the iodine removal capability of the system is satisfied, the heat removal capability will be found acceptable. The Accident Evaluation Branch is responsible for determining the acceptability of the iodine removal effectiveness of the sprays (See Standard Review Plan

Section 6.5.2). Since all plants do not use the containment sprays as a fission product removal system, the CSB reviews the system for cases where the system is used only as a heat removal system.

CSB reviews analyses of the heat removal capability of the spray system. This capability is a function of the degree of thermal equilibrium attained by the spray water and the volume of the containment covered by the spray water. The spray drop size and residence time in the containment atmosphere determine the degree of thermal equilibrium attained by the spray water. The CSB confirms the validity of the degree of thermal equilibrium attained using the following information: an elevation drawing of the containment showing the locations of the spray headers relative to the internal structures, including fall heights, and the results of the spray nozzle test program to determine the spectrum of drop sizes and mean drop size emitted from the nozzles as a function of pressure drop across the nozzles.

Reference 6 contains information regarding the heating of spray drops in air-steam atmospheres which can be used to determine the validity of the degree of thermal equilibrium of the spray water used in the analyses.

CSB reviews the adequacy of provisions made to prevent overpressurization of fan cooler ducting following a loss-of-coolant accident (Standard Review Plan Section 6.2.5). CSB reviews the heat removal capability of the fan coolers. The test programs and calculation models used to determine the performance capability of fan coolers are reviewed for acceptability. If the secondary side of a fan cooler heat exchanger is not a closed system, the CSB reviews the potential for surface fouling. The CSB determines whether or not surface fouling impairs the heat removal capability of a fan cooler.

CSB reviews the system provided to allow drainage of containment spray water and emergency core cooling water to the recirculation suction points (sumps). CSB reviews the design of the protective screen assemblies around the suction points. CSB reviews plan and elevation drawings of the protective screen assemblies, showing the relative positions and orientations of the trash bars or grating and the stages of screening, to determine that the potential for debris clogging the screening is minimized. CSB also reviews the drawings to determine that suction points do not share the same screened enclosure. The effectiveness of the protective screen assembly will be determined by comparing the smallest mesh size of screening provided to the clogging potential of pumps, heat exchangers, valves, and spray nozzles. The methods of attachment of the trash bars or grating and the screening to the protective screen assembly structure should be discussed in the SAR and shown on drawings. A discussion of the adequacy of the surface area of screening with respect to assuring a low velocity of approach of the water to minimize the potential for debris in the water being sucked against the screening should be presented. Regulatory Guide 1.82 (Ref. 5) provides presents guidelines for the acceptability of the design of containment sumps.

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided and that his evaluation supports conclusions of the following type, to be included in the staff's safety evaluation report:

6.2.2 Containment Heat Removal Systems

The containment heat removal systems include (identify the systems).

The scope of review of the containment heat removal systems for the (plant name) has included system drawings and descriptive information. The review has included the applicant's proposed design bases for the containment heat removal systems, and the analyses of the functional capability of the systems.

The staff concludes that the design of the containment heat removal systems is acceptable and meets the requirements of General Design Criteria 38, 39 and 40. The conclusion is based on the following: [The reviewer should discuss each item of the regulations or related set of regulations as indicated.]

1. The applicant has met the requirements of (cite regulation) with respect to (state limits of review in relation to regulation) by (for each item that is applicable to the review state how it was met and why acceptable with respect to the regulation being discussed):

   a. meeting the regulatory positions in Regulatory Guide _____ or Guides;

   b. providing and meeting an alternative method to regulatory positions in Regulatory Guide ____, that the staff has reviewed and found to be acceptable;

   c. meeting the regulatory position in BTP _____;

   d. using calculational methods for (state what was evaluated) that has been previously reviewed by the staff and found acceptable; the staff has reviewed the impact parameters in this case and found them to be suitably conservative or performed independent calculations to verify acceptability of their analysis; and/or

   e. meeting the provisions of (industry standard number and title) that has been reviewed by the staff and determined to be appropriate for this application.

2. Repeat discussion for each regulation cited above.

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plan for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 38, "Containment Heat Removal."

2. 10 CFR Part 50, Appendix A, General Design Criterion 39, "Inspection of Containment Heat Removal System."

3. 10 CFR Part 50, Appendix A, General Design Criterion 40, "Testing of Containment Heat Removal System."

4. Regulatory Guide 1.1, "Net Positive Suction Head for Emergency Core Cooling and Containment Heat Removal System Pumps."

5. Regulatory Guide 1.82, "Sumps for Emergency Core Cooling and Containment Spray Systems."

6. L. F. Parsly, "Design Considerations of Reactor Containment Spray Systems - Part VI, The Heating of Spray Drops In Air-Steam Atmospheres," ORNL-TM-2412, Oak Ridge National Laboratory, January 1970.

Enclosure 5

September 1982
Revision No. 1
Draft No. 1

NOTE: This proposed revision is provided in comparative text format. Additions are underlined, deletions are crossed out.

U. S. Nuclear Regulatory Commission

Office of Nuclear Regulatory Research

Proposed Revision No. 1 to:
Regulatory Guide 1.82

Sump for Emergency Core Cooling
and Containment Spray Systems

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, "Licensing of Production and Utilization Facilities," require that a system be provided to remove the heat released to the containment following a postulated design basis accident (DBA) and that this system be designed to permit appropriate periodic inspection and testing to assure its integrity, capability, and operability. General Design Criterion 1, "Quality Standards and Records," of Appendix A to 10 CFR Part 50, requires that structures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. This guide describes a method acceptable to the Regulatory staff for implementing these requirements with regard to design, fabrication, and testing of sump or suction inlet conditions for pumps in the emergency core cooling and containment spray systems. This guide applies to pressurized water reactors. ~~The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.~~

B. DISCUSSION

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

For optimum use of the available coolant, the sumps should be placed at the lowest level practical. There may be numerous places within the containment structure where coolant could accumulate during containment spray application, and these areas should be provided with drains or flow paths to the sump location to minimize coolant holdup in areas away from the sumps. This guide does not address design of the drains. Because of certain amount of debris may flow toward the sump, the drains entering the sump area should terminate in such a manner that the emerging flow would not tend to impinge upon the coolant sump.

Debris resulting from a loss-of-coolant accident has the potential for blocking the sump screens; the corresponding increase in head loss could result in a loss of net positive suction head (NPSH) margin. The debris generation and transport should be analyzed to determine screen blockage and attendant head losses. Appendix A provides guidelines for evaluating insulation debris effects; References (1) and (2) provide additional information.

The debris resulting from a loss-of-coolant accident (LOCA) may be divided into two categories: (1) the pieces that by virtue of weight and volume will tend to float or sink slowly and (2) the heavy pieces that will drop to the floor surface. Every effort should be made to prevent either category of debris from accumulating at the sump location. Because the small drainage sump for collecting and monitoring normal leakage within the containment is separate from the coolant sump intended to serve the ECCS and CSS pumps, the floor would normally slope down toward the drainage sump. These sumps for routine building drainage should be at a slightly lower elevation than the coolant sumps so that water from minor leaks and spills cannot enter the ECCS-CSS sumps. The coolant sump location should be away from the drainage sump, so that the normal floor slope would assist in preventing heavier debris from accumulating at the coolant sump. In addition, the floor around the coolant sump should slope down and away from that sump to discourage debris from collecting on any part of the sump structure.

Pump intakes should be protected by screens and trash racks (coarse outer screens) of sufficient strength to resist impact loads that could be imposed by missiles that may be generated by the initial LOCA or by trash. Isolation of the coolant sump from high-energy pipe lines is an important consideration in missile protection; the sump screens and trash racks should be adequately shielded from impacts from ruptured high-energy piping. The screen and trash rack structures should be located above floor level to minimize the adverse effects from debris collecting on the screen structure. Redundant coolant sump screens and pump suction pipes should be separated as much as practical to reduce the possibility that a partially clogged screen or missile damage to one screen could adversely affect other pump circuits. In addition, the design of suction intakes should consider the avoidance of flow degradation by vortex formation.

Sump and suction intake placement should consider the avoidance of undesireable hydraulics effects, such as vortex formation. It has been experimentally determined that air ingestion can be minimized or eliminated if the guidelines provided in Appendix A are followed. References (1), (3), (4), (5), (6), and (7) provide further technical information relevant to sump hydraulic performance and design findings.

In addition, design of sump suction intakes should consider avoidance of vortex formation which could lead to air ingestion. However, for small amounts of air ingestion, the recirculation pumps can still be considered operable provided sufficient NPSH margin is demonstrated. Appendix A provides guidance for correcting NPSH margin if estimated levels of air ingestion are low (i.e., $< 2\%$). References 1 and 8 provide additional technical findings relevant to pump operation and NPSH effects.

It is expected that the water surface will be above the top of the screen structure after completion of the safety injection. However, the uncertainties about the extent of water coverage on the screen structure, the amount of floating debris that may accumulate, and the potential for early clogging do not favor the use of the horizontal top screen. Therefore, no credit should be taken in computation of the available surface area for any top horizontal screen, and the top of the screen structure should preferably be a solid deck designed to provide for the removal of trapped air.

Slowly settling debris which is small enough to pass through the trash rack openings could clog the inner screens if the coolant flow velocity is too great to permit the bulk of the debris to sink to the floor level. The inner screen should be vertically mounted to minimize settling of debris on the screen surface, and sufficient unblocked screen area should be provided to keep the coolant flow velocity at the screen approximately 6 cm/sec (0.2 ft/sec). Such a velocity will allow debris with a specific gravity of 1.05 or more to settle before reaching the screen surface.

Size of openings in the fine screens should be determined by the physical restrictions, including spray nozzles, that may exist in the systems which are supplied with coolant for the emergency sump. As a minimum, consideration should be given to building spray nozzles, coolant channel openings, and pump running clearances in sizing the fine screen. If the coolant channel openings in the core represent the smallest flow restriction, the minimum opening in the core channels which will allow unblocked design operation of the ECCS should be used in sizing the fine screen mesh size.

Consideration should also be given to partial screen blockage in sizing the fine screen in order to assure an adequate margin of conservatism on free flow area.

A significant consideration is the potential for degraded pump performance which could be caused by a number of factors, including the loss net positive suction head (NPSH) margin. If he NPSH available to a pump is not sufficient, cavitation may significantly reduce the capability of the system to accomplish its safety function. For the recommended design velocity at the fine inner screens considered in this guide, a negligible pressure drop is anticipated across the screens. The effect of partially blocked screens should be considered in the evaluation of the overall NPSH.

To assure the readiness and integrity of the rack and screens, access openings should be provided to permit inspection of the inside structures and pump suction inlet openings. Inservice inspection for trash racks, screens, and pump suction inlet openings should be performed on a regular basis at every refueling period downtime, and it should include visual examination for evidence of structural distress or corrosion. Inspection of the coolant sump components should be made late in the refueling program and thus help to ssure the absence of construction debris in the coolant sump area. Any requirements for preoperational or periodic substantiation of adequate NPSH should be considered in the location and layout of the sump.

C. REGULATORY POSITION

Reactor building sumps which are designed to be a source of water for the emergency core cooling system (ECCS) and/or the containment spray system (CSS) following a loss-of-coolant accident (LOCA) should meet the following criteria:

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

2. The redundant sumps should be physically separated from each other and from high-energy piping systems by structural barriers, to the extent practical, to preclude damage to the sump intake filters by whipping pipes or high-velocity jets of water or steam.

3. The sumps should be located on the lowest floor elevation in the containment exclusive of the reactor vessel cavity. At a minimum, the sump intake should be protected by two screens: (1) an outer trash rack and (2) a fine inner screen. The sump screens should not be depressed below the floor elevation.

4. The floor level in the vicinity of the coolant sump location should slope gradually down away from the sump.

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

6. A vertically mounted outer trash rack should be provided to prevent large debris from reaching the fine inner screen. The strength of the trash rack should be considered in protecting the inner screen from missiles and large debris.

7. A vertically mounted fine inner screen should be provided. The design coolant velocity at the inner screen should be approximately 6 cm/sec (0.2 ft/sec). ~~The available surface area used in determining the design coolant velocity should be based on one half of the free surface area of the fine inner screen to conservatively account for partial blockage.~~ The available screen surface area used in determining the design coolant velocity should be calculated to conservatively account for sump screen blockage which might result from debris generation and transport. Only the vertical screens should be considered in determining available surface area.

8. An evaluation of: (a) sump design effects (e.g., geometric effects, air ingestion, etc.), (b) LOCA generated debris effects (e.g., debris transport and screen blockage), and (c) pump NPSH margin requirements should be performed to ensure that long-term recirculation cooling can be accomplished. Any increases, due to sump hydraulic performance or debris considerations, with respect to NPSH margin should be considered in the sump pump performance evaluation.

~~8.~~ 9. A solid top deck is preferable, and the top deck should be designed to be fully submerged after a LOCA and completion of the safety injection. The solid deck should be designed to ensure the removal of air trapped underneath.

~~9.~~ 10. The trash rack and screens should be designed to withstand the vibratory motion of seismic events without loss of structural integrity.

~~10.~~ 11. The size of openings in the fine screen should be based on the minimum restriction found in systems served by the pump. The minimum restriction should take into account the requirements of the systems served.

~~11.~~ 12. Pump intake locations in the sump should be carefully considered to prevent degrading effects such as vortexing on the pump performance.

~~12.~~ 13. Materials for trash racks and screens should be selected to avoid degradation during periods of inactivity and operation and should have a low sensitivity to adverse effects such as stress-assisted corrosion that may be induced by the chemically reactive spray during LOCA conditions.

~~13.~~ 14. The trash rack and screen structure should include access openings to facilitate inspection of the structure and pump suction intake.

14. 15. Inservice inspection requirements for coolant sump components (trash racks, screens, and pump suction inlets) should include the following:

a. Coolant sump components should be inspected during every refueling period downtime, and

b. The inspection should be a visual examination of the components for evidence of structural distress or corrosion.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants regarding the NRC staffs plans for using this regulatory guide. Except in those cases in which the applicant proposes an acceptable alternative method for complying with the specified portions of the Commission's regulation, the methods described herein will be used by the NRC staff in the evaluation of all construction permit applications and all operating license applications under review by the staff for which an NRC Safety Evaluation Report (SER) has not been issued at the time of implementation of this Regulatory Guide. With respect to operating plants and near term operating license (NTOL's) applicants, a generic letter will be sent to licensees and operating license applicants whose SER's have already been issued requesting that an assessment of sump screen blockage and associated impact on pump NPSH margin be performed utilizing the guidelines provided in Appendix A of RG 1.82. If the determination is made that excessive screen blockage or inadequate NPSH could occur using the guidelines in Appendix A, the respondee should also indicate what corrective actions will be pursued.

This draft regulatory guide has been published to encourage public participation in its development.

REFERENCES

(1) NUREG-0897, "Containment Emergency Sump Performance," Technical Findings Related to USI A-43, September 1982-"For Public Comment."

(2) NUREG/CR-2791, "Methodology for Evaluating of Insulation Debris," September 1982.

(3) NUREG/CR-2758, "A Parametric Study of Containment Emergency Sump Performance," July 1982.

(4) NUREG/CR-2759, "Results of Vertical Outlet Sump Tests," September 1982.

(5) NUREG/CR-2760, "Assessment of Scale Effects on Vortexing, Swirl and Inlet Losses in Sarge Scale Pump Models," June 1982.

(6) NUREG/CR-2761, "Results of Vortex Suppressor Tests, Single Outlet Sump Tests and Miscellaneous Sensitivity Tests," September 1982.

(7) NUREG/CR-2772, "Hydraulic Performance of Pump Suction Inlets for Emergency Core Cooling Systems in Boiling Water Reactors," June 1982.

(8) NUREG/CR-2792, "An Assessment of Residual Heat Removal and Containment Spray Pump Performance Under Air and Debris Ingesting Conditions," September 1982.

APPENDIX A TO RG 1.82

CONTAINMENT EMERGENCY SUMP REVIEW GUIDELINES

1. General

The containment emergency sump should be evaluated to determine design adequacy for providing a reliable water source to the ECCS and CSS pumps during a post-LOCA period. Both sump hydraulic performance under adverse conditions, and potential LOCA-induced insulation debris effects require adequate technical assessment to assure that long-term recirculation can be maintained. Technical considerations can be subdivided into: (a) Sump Hydraulic Performance, (b) LOCA-Induced Debris Effects, and (c) Pump Performance Under Adverse Conditions. Specific considerations and the combining thereof are shown in Figure A-1.

2. Sump Hydraulic Performance

Sump hydraulic performance can be evaluated on the basis of submergence level (or water depth above the suction outlets) and required pumping capacity (or sump suction outlet velocity). The water depth(s) and suction pipe velocity (V) parameters can be combined as a Froude number:

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

where g is the gravitational constant. The Froude number concept has been shown to be an acceptable correlation for determining sump hydraulic performance.

Sump hydraulic performance can be judged on the basis of:

(a) zero air ingestion, thus avoiding pump cavitation -

(b) air ingestion $\leq$2%, a conservative level where degradation of pumping capability is not expected

(c) use of vortex suppressors to reduce air ingestion effects to a negligible level.

Zero air ingestion can be assured by use of the design criteria set forth in Table A-1. Determination of air ingestion levels $\leq$2% can be obtained using Table A-2, and the attendant envelope, placement and screen guidelines contained in Tables A-3, A-4, and A-5. Table A-6 presents design guidelines for vortex suppression devices which have shown the capability to reduce air ingestion to zero. These guidelines (Tables A-1 through A-6) have been developed from extensive full scale sump hydraulic tests and provide a concise means to assess sump hydraulic performance. If the sump design deviates significantly from the boundaries noted, then similar performance data should be obtained for verification of sump hydraulic performance.

3. LOCA-Induced Debris Effects

Determination of LOCA debris generation and the effect of debris migration is complex and plant specific. Thus debris assessments require consideration of the initiating mechanisms (pipe break locations, orientations, and break jet energy content), evaluation of the amount of debris that can be generated, short- and long-term transport, the potential for sump screen blockage, and head loss that could degrade available NPSH. Table A-7 outlines considerations requiring evalutions to determine potential screen blockage and attendant head loss.

The evaluation of debris generation and screen blockage requires a systematic evaluation similar to that shown in Figure A-2. Types, quantities and locating of insulation employed, along with plant layout (or design) have been shown to result in plant specific results, thus the need for calculations as described in Figure A-2. References (1) and (2) provide more information relevant to assessment of debris effects.

4. Pump Performance Under Adverse Conditions

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

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

$$NPSH_{required}(air/water) = NPSH_{required}(liquid) \times \beta$$

where:

$$\beta = 1 + 0.50\alpha_p$$

and α_p is the air ingestion rate (in percent by volume) at the pump inlet flange.

5. Combined Effects

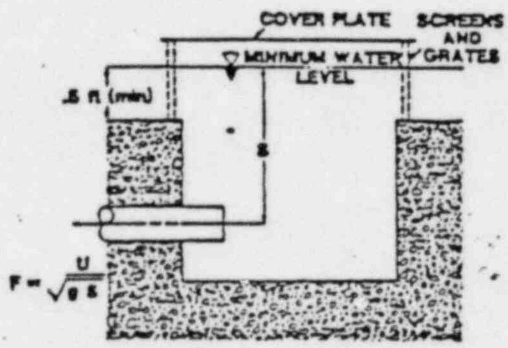
As introduced in Figure A-1, these three effects (e.g., sump hydraulic considerations, debris effects and pump performance) require combination for determining long-term recirculation capability.

The combined interactions of these effects is shown in Figure A-4. Use of this guidance and criteria provided can be used to determine sump design acceptability. If the proposed design falls outside of the data constraints noted, the applicant will need to address the need for additional data, or calculations to arrive at a sump evaluation position.

TABLE A-1

Zero Air Ingestion
Hydraulics Design Findings

Item	Horizontal Outlets		Vertical Outlets	
	Dual	Single	Dual	Single
Minimum Submergence, s (ft)	10		10	
Maximum Froude Number, F	0.25		0.25	
Maximum Pipe Velocity, U(ft/s)	4		4	



Aspect Ratio: 1-5

Minimum Perimeter: $\geq$ 16 ft
B - e_y/d: $\geq$ 3 ft
C/d: $\geq$ 1.5 for Horizontal Outlets, $\leq$ 1 for vertical inlets

Minimum Screen Area: $\geq$ 34 ft^2

NOTE: See Tables A-3 and A-4 for definition of dimensions noted above.

TABLE A-2
Hydraulics Design Findings

For Air Ingestion ≤ 2%

Item	Horizontal Outlets		Vertical Outlets	
	Dual	Single	Dual	Single
Minimum Submergence, s (ft)	7.0	8.0	8.0	10
Maximum Froude Number, F	0.53	0.40	0.41	0.33
Maximum Pipe Velocity, U(ft/s)	8.0	6.5	7.0	6.0
Maximum Screen Face Velocity (Blocked and minimum submergence) (ft/s)	3.0	3.0	3.0	3.0
Minimum Water Level (inside screens and grates)	Sufficient to cover 1.5 ft of open screen			
Sump Loss Coefficient, C_L	1.2	1.2	1.2	1.2
Air Withdrawal, α_s, α_o	-2.47	-4.75	-4.75	-9.35
$\alpha_s = \alpha_o + \alpha_1 \times F$ (% air by Volume) α_1	9.38	13.04	18.69	35.95

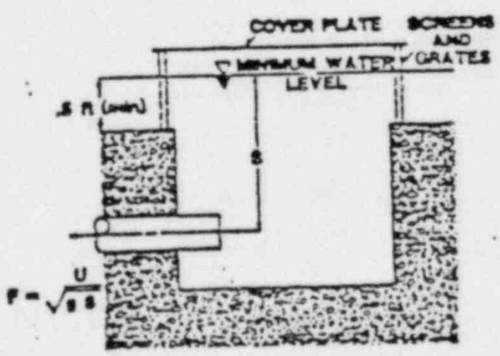
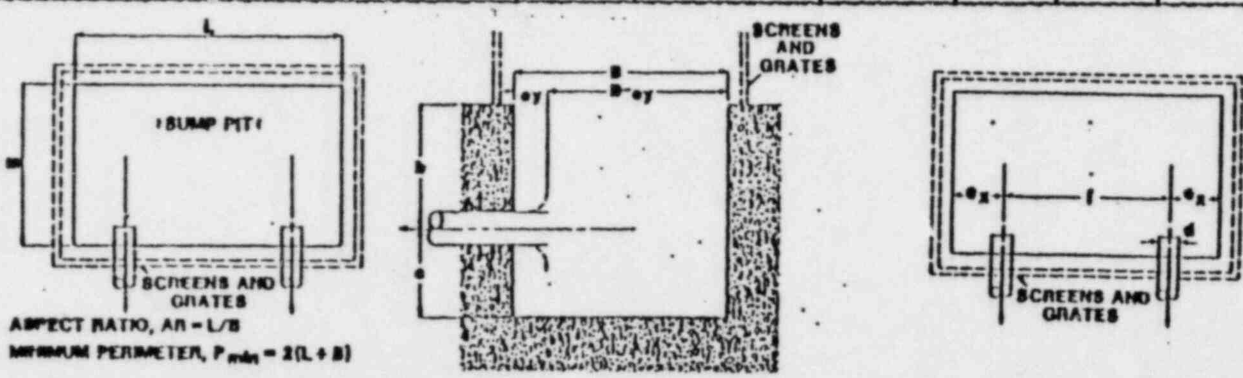


TABLE A-3

Geometric Design Experimental Envelop Contraints

		Size and Placement		Inlet Position**						Screens & Grates
		Aspect Ratio	Min. Perimeter	e_y/d	$(B-e_y)/d$	c/d	b/d	f/d	e_x/d	Min. Screen Area (Plane face)
Horizontal Outlets	Dual	1 to 5	36 ft	≥ 0	≥ 3	≥ 1.5	≥ 1	≥ 4	1.5* or	75 ft^2
	Single	1 to 5	16 ft	≤ 1				-	> 1.5	35 ft^2
Vertical Outlets	Dual	1 to 5	36 ft	1.5* or	≤ 1	≥ 0	≥ 1	≥ 4	1.5* or	75 ft^2
	Single	1 to 5	16 ft	> 1.5		≤ 1		-	> 1.5	35 ft^2

Definitions

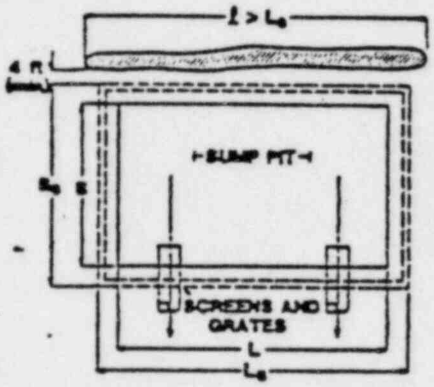


**Preferred location.

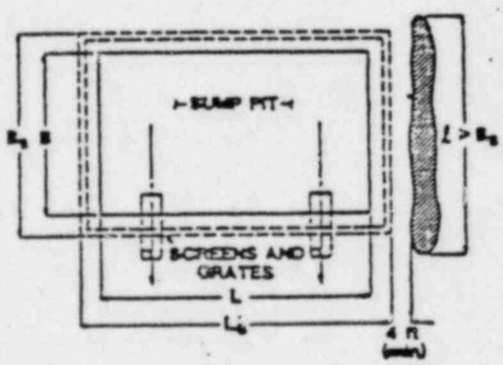
*Dimensions are always measured to pipe centerline.

TABLE A-4

Additional Considerations Related To Sump Size and Placement*



1. Aspect Ratio, see Table A-3
2. Minimum Sump Perimeter, see Table A-3.
3. Sump clearance of 4 ft between the screens/grates and any wall or obstruction of length ℓ equal to or greater than the adjacent screen/grates length (B_s or L_s).
4. A solid wall or large obstruction may form the boundary of the sump on one side only, i.e., the sump must have three (3) sides open to the approach flow.



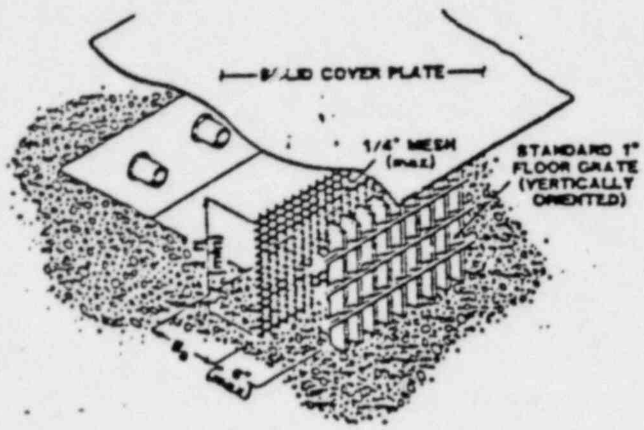
*These additional considerations are provided to ensure that the experimental data boundaries (upon which Tables A-2 and A-3 are based) resulting from the experimental studies at Alden Research Laboratory are noted.

TABLE A-5

Screen, Grate, and Cover Plate Design Findings*

1. Minimum plane face screen area, see Table A.2.

2. Minimum height of open screen should be 2 feet.



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

4. Screens should be 1/4 inch mesh or finer.

5. Gratings should be vertically oriented 1 to 1-1/2 inch standard floor grate or equivalent.

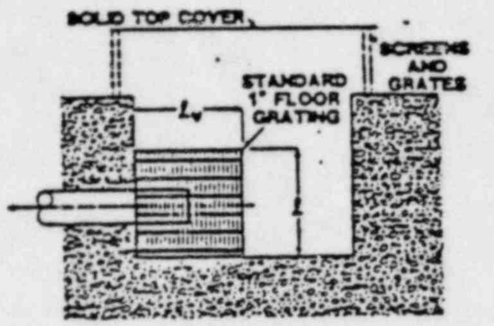
6. The distance between the screens and grates shall be 6 inches or less.

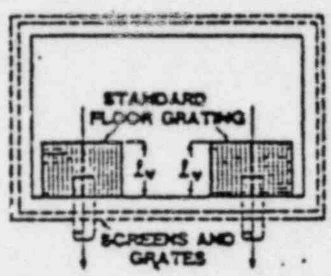
7. A solid cover plate above the sump and extending to the screens and grates is required; the cover plate must be designed to ensure the release of air trapped below the plate (a cover plate located below the minimum water level is preferable).

*These additional details are pertinent to the Alden Research Laboratory's full scale tests and were found to yield satisfactory sump hydraulic performance.

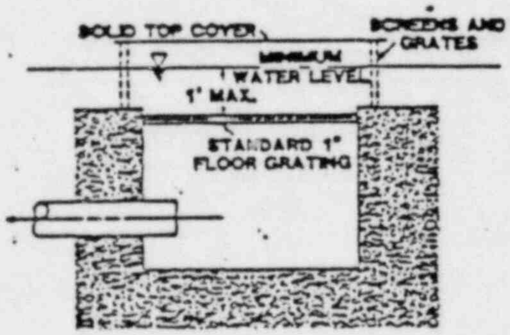
TABLE A-6

Findings For Selected Vortex Suppression Devices*





1. Cubic arrangement of standard 1-1/2 inch or deeper floor grating (or its equivalent) with a characteristic length, ℓ_v, that is $\geq$ 3 pipe diameters; the top of the cube must be submerged a minimum of 6 inches below the minimum water level. Non-cubic designs, where ℓ_v is $\geq$ 3 pipe diameters for the horizontal upper grate, satisfying the depth and distances to the water minimum water surface given for cubic designs are acceptable.



2. Standard 1-1/2 inch or deeper floor grating (or its equivalent) located horizontally over the entire sump and containment floor inside the screens and located between 3 inches and 12 inches below the minimum water level.

*These types of vortex suppressors were tested at Alden Research Laboratory and have demonstrated the capability to reduce air ingestion to 0%, even under the most adverse conditions simulated.

TABLE A-7

Debris Assessment Considerations

CONSIDERATION	EVALUATE
1) Debris Generator (Pipe Breaks & Location as identified in SRP Section 3.6.2)	o Major Pipe Breaks & Location o Pipe Whip & Pipe Impact o Break Jet Expansion Envelope (This is the major debris generator)
2) Expanding Jets	o Jet Expansion Envelope o Piping & Plant Components Targeted (i.e., steam generators) o Jet Forces on Insulation o Insulation Which Can Be Destroyed or Dislodged by Blowdown Jets. o Sump Structure (i.e., screen) Survivability Under Jet Loading
3) Short-Term Debris Transport (transport by blowdown jet forces)	o Jet/Equipment Interaction o Jet/Crane Wall Interaction o Sump Location Relative to Expanding Break Jet
4) Long-Term Debris Transport (transport to the sump during the recirculation phase)	o Containment Layout & Sump Location o Heavy (or "Sinking") Debris o Floating Debris o Neutral Buoyancy Debris
5) Screen Blockage Effects (impairment of flow and/ or NPSH margin)	o Screen Design o Sump Location o Water Level Under Post LOCA Conditions o Flow Requirements

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Key Elements for Assessment of Debris Effects	o Estimated Amount of Debris That Can Reach Sump o Screen Blockage o ΔP Across Blocked Screens

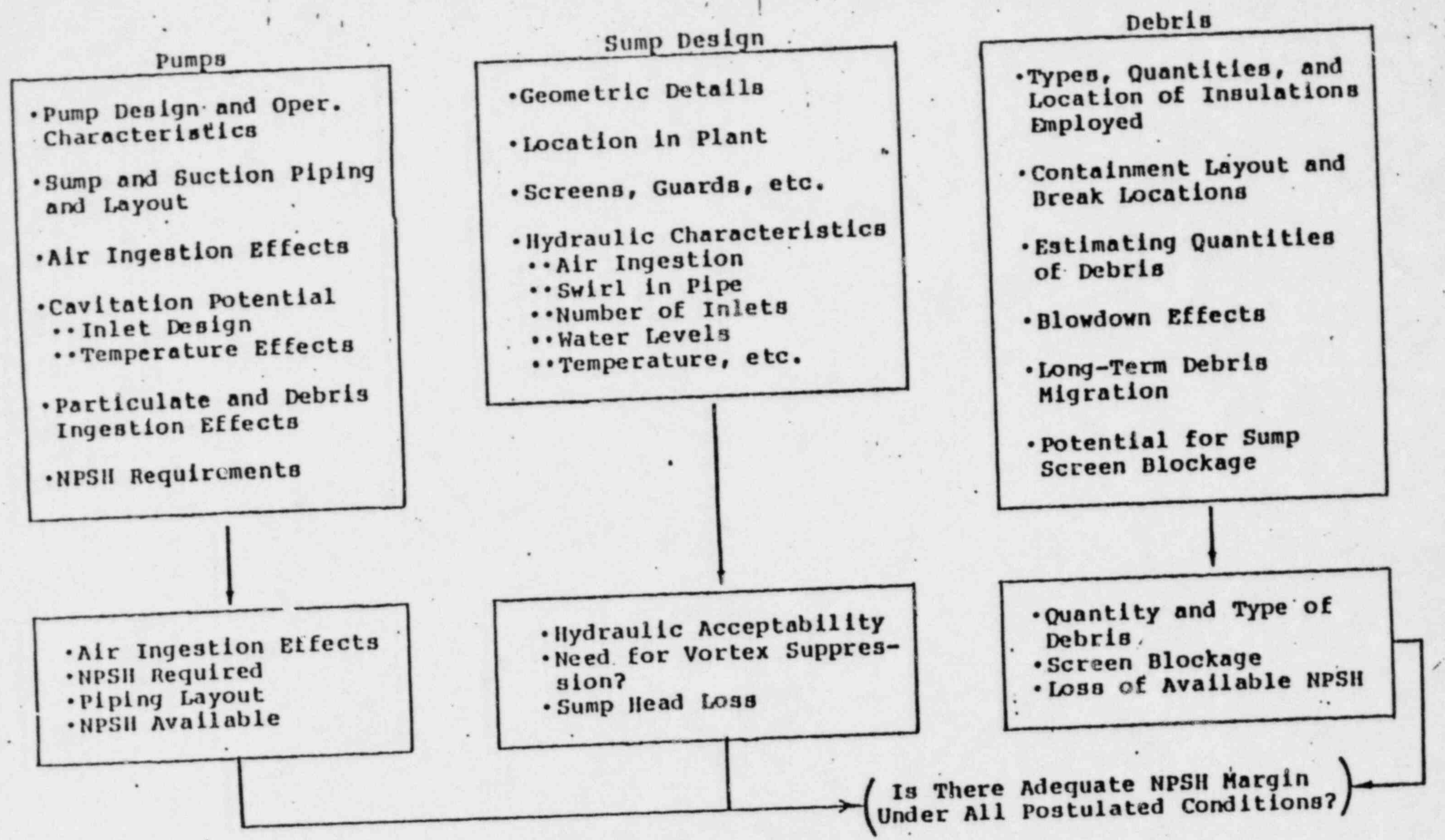
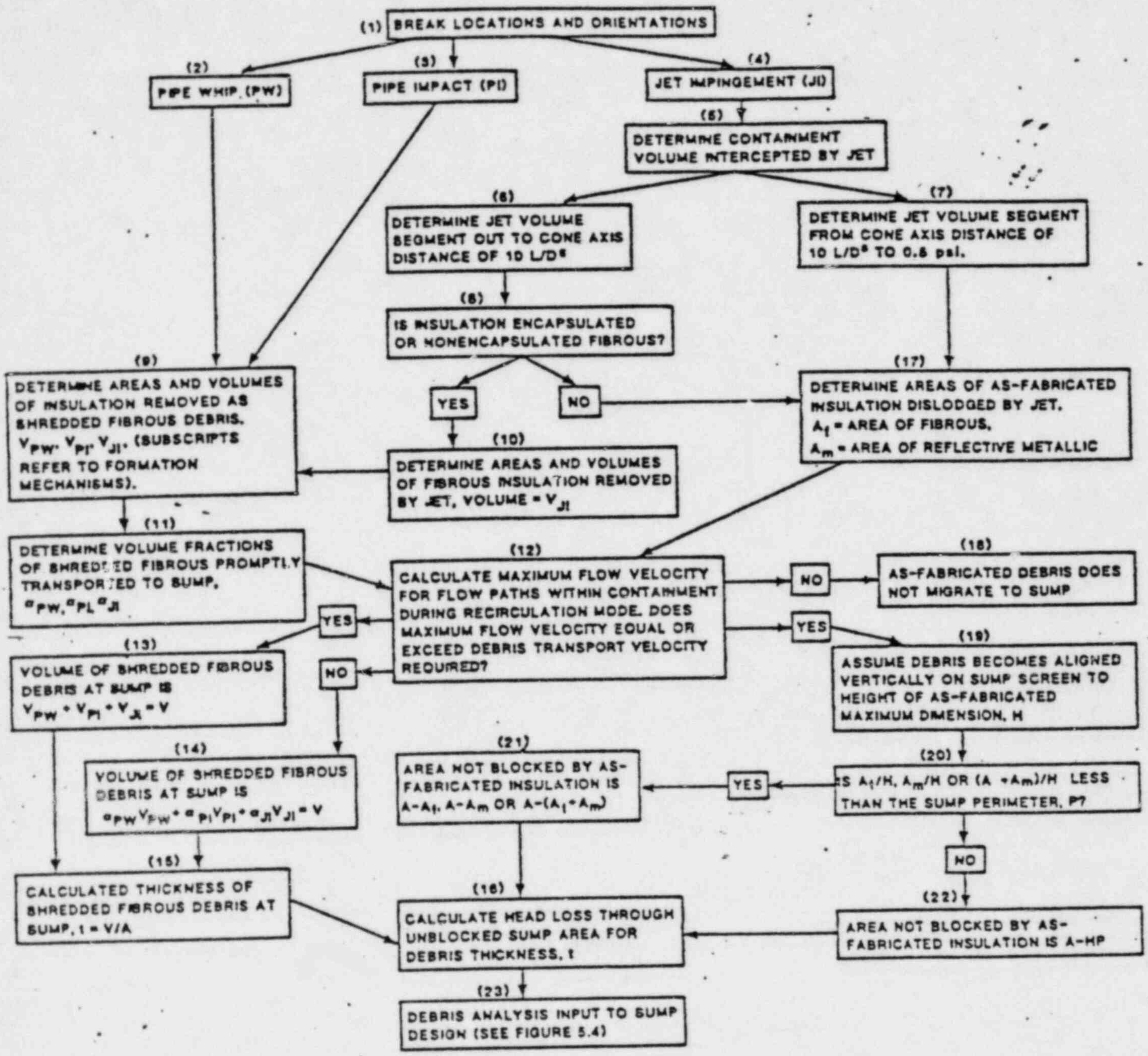


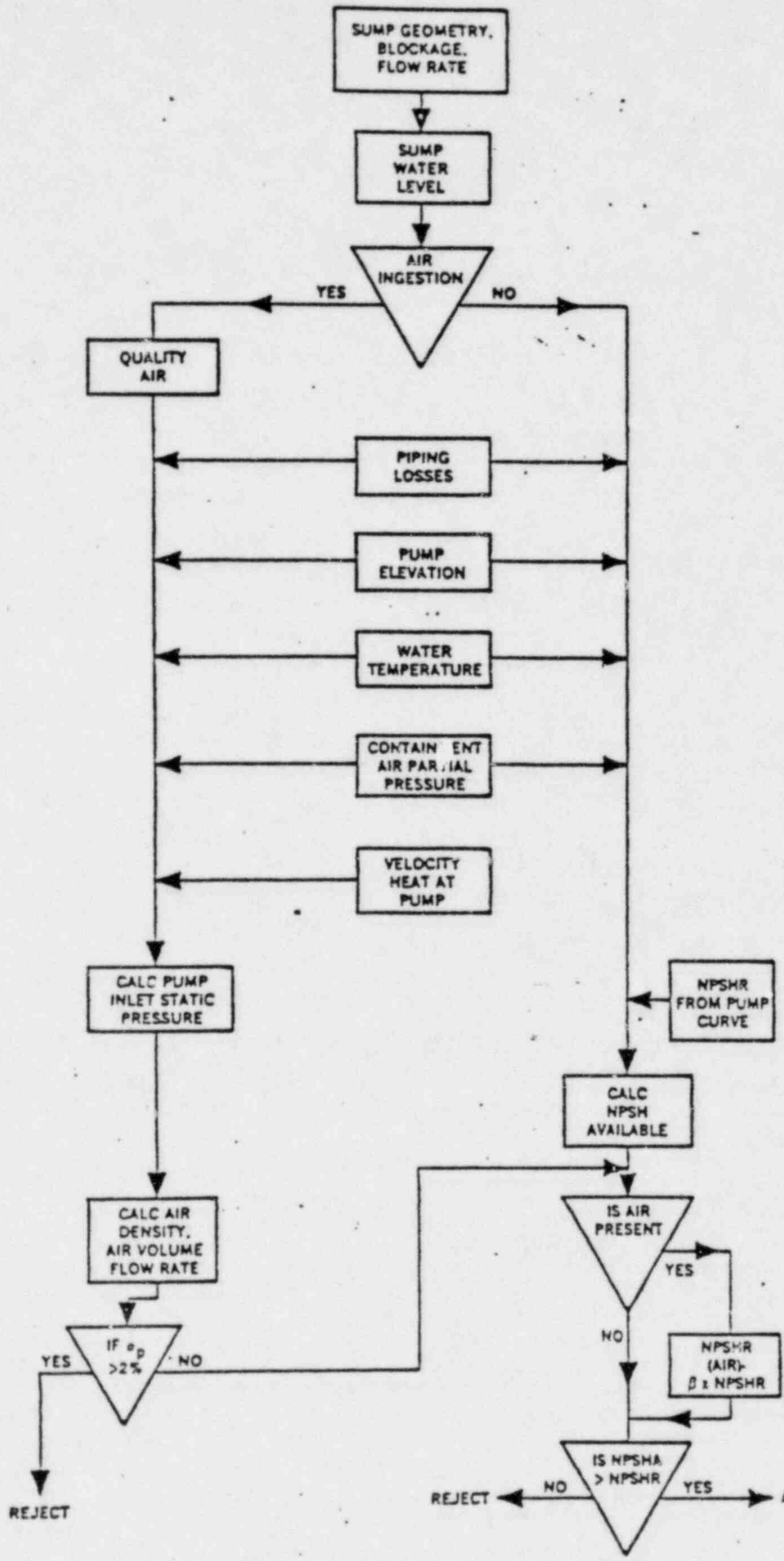
Figure A-1 Performance Considerations Relevant to Containment Emergency Sump Performance



V_{PW} - VOLUME OF SHREDDED FIBROUS INSULATION REMOVED BY PIPE WHIP. (FT^3)
V_{PI} - VOLUME OF SHREDDED FIBROUS INSULATION REMOVED BY PIPE IMPACT. (FT^3)
V_{JI} - VOLUME OF SHREDDED FIBROUS INSULATION REMOVED BY JET IMPINGEMENT. (FT^3)
α_{PW} - FRACTION OF VOLUME OF SHREDDED INSULATION CAUSED BY PIPE WHIP PROMPTLY TRANSPORTED TO SUMP.
α_{PI} - FRACTION OF VOLUME OF SHREDDED INSULATION CAUSED BY PIPE IMPACT PROMPTLY TRANSPORTED TO SUMP.
α_{JI} - FRACTION OF VOLUME OF SHREDDED INSULATION CAUSED BY JET IMPINGEMENT PROMPTLY TRANSPORTED TO SUMP.
L/D - RATIO OF PIPE LENGTH TO PIPE DIAMETER.
V - TOTAL VOLUME OF SHREDDED DEBRIS TRANSPORTED TO SUMP SCREEN. (FT^3)
A_f - AREA OF AS-FABRICATED FIBROUS INSULATION DISLODGED BY JET. (FT^3)
A_m - AREA OF AS-FABRICATED REFLECTIVE METALLIC INSULATION DISLODGED BY JET. (FT^2)
A - EFFECTIVE AREA OF SUMP SCREEN. (FT^2)
H - MAXIMUM LINEAR DIMENSION OF AS-FABRICATED INSULATION. (FT)
P - PERIMETER OF EFFECTIVE SUMP SCREEN. (FT)
t - CALCULATED THICKNESS OF SHREDDED DEBRIS MAT ON SUMP SCREEN. (IN)

*CALCULATIONAL METHODS ARE AS GIVEN IN REFERENCE 2

Figure A-2 Debris Generation, Transport and Sump Blockage Potential



FLOW CHART FOR CALCULATION OF PUMP INLET CONDITION

Figure A-3

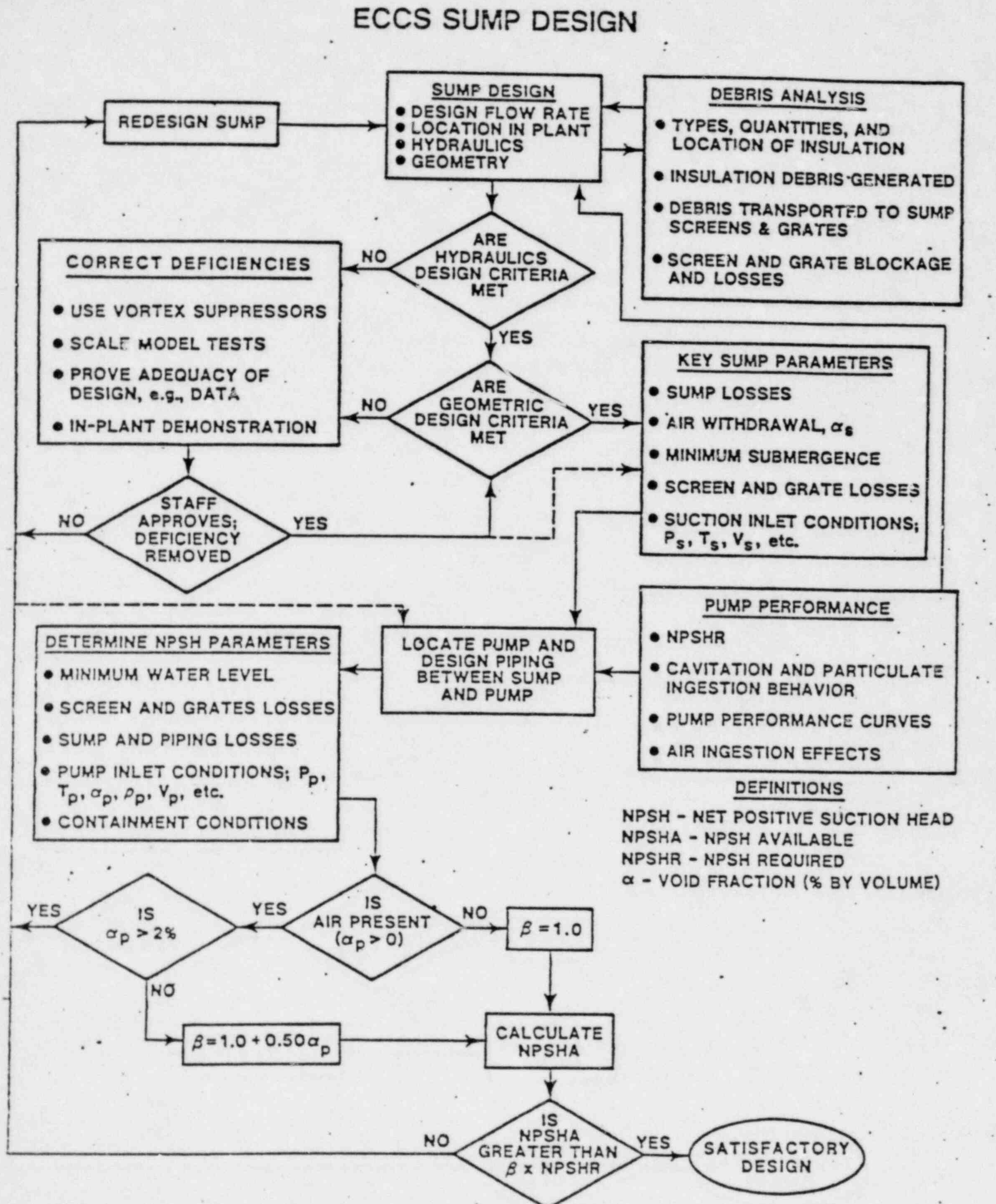


Figure A-4 Combined Technical Considerations for Sump Performance