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April 28, 1994 Docket No. 52-001

Chet Poslusny, Senior Project Manager
Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal
Office of the Nuclear Reactor Regulation

Subject: Submittal Supporting Accelerated ABWR Schedule - **Suppression Pool Strainers**

Reference: (1) Letter, Jack Fox to Chet Poslusny dated April 11, 1994, Same Subject

(2) Letter, Jack Fox to Chet Poslusny dated April 14, 1994, Same Subject

Dear Chet:

Enclosed is a revised SSAR markup addressing the suppression pool strainer issue. This markup incorporates References 1 and 2, and the recent interactions between GE and the NRC. It is GE's belief that this markup addresses all of the NRC concerns and should be the basis of the final resolution.

Please provide a copy of this transmittal to John Monninger.

Sincerely,

Jack Fox

Jack Fox
Advanced Reactor Programs

cc: Alan Beard (GE)
Norman Fletcher (DOE)
Joe Quirk (GE)
Craig Sawyer (GE)
Bill Taft (GE)

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6C Containment Debris Protection for ECCS Strainers

6C.1 Background

NRC Bulletin No. 93-02, "Debris Plugging of Emergency Core Cooling Suction Strainers," references NRC guidance and highlights the need to adequately accommodate debris in design by focusing on an incident at the Perry Nuclear Plant. GE reviewed the concerns addressed by NRC Bulletin 93-02 and has reviewed the design of the ABWR for potential weaknesses in coping with the bulletin's concerns. GE has determined that the ABWR design is more resistant to these problems for a number of reasons as discussed in the following.

The ultimate concern raised by the Perry incident was the deleterious effect of debris in the suppression pool and how it could impact the ability to draw water from the suppression pool during an accident. The ABWR design has committed to following the guidance provided in Regulatory Guide 1.82 and additional guidance as described below. The ~~the~~ ABWR is designed to inhibit debris generated during a LOCA from preventing operation of the Residual Heat Removal (RHR), Reactor Core Isolation Cooling (RCIC) and High Pressure Core Flooder (HPCF) systems.

6C.2 ABWR Mitigating Features

The ABWR has substantially reduced the amount of piping in the drywell relative to earlier designs and consequently the quantity of insulation required. Furthermore, there is no equipment in the wetwell spaces that requires insulation or other fibrous materials. The ABWR design conforms with the guidance provided by the NRC for maintaining the ability for long-term recirculation cooling of the reactor and containment following a LOCA.

Development work is in progress by various organizations to achieve solutions of the ECCS strainers debris plugging problem. The ABWR design is committed to apply an acceptable solution as this issue becomes resolved. Selection of insulation, strainer design, pump features, and applicable containment details will be addressed.

~~However,~~ The Perry incident was not the result of a LOCA but rather debris entering the Suppression Pool during normal operation. The arrangement of the drywell and wetwell/wetwell airspace on a Mark III containment (Perry) is significantly different from that utilized in the ABWR design. In the Mark III containment, the areas above the suppression pool water surface (wetwell airspace) are substantially covered by grating with significant quantities of equipment installed in these areas. In these areas are no real barriers to prevent small quantities of debris from falling into the suppression pool from the spaces located above the pool surface. This arrangement contributes to a much greater potential for debris to enter the suppression pool during outage activities as well as activities in the containment during power operation. ~~Furthermore,~~ Access to the wetwell airspace (containment) of a Mark III is allowed during power operations. In contrast, on the ABWR the only connections to the suppression pool are 10 drywell connecting vents (DCVs), and access to the wetwell or drywell during power operations is prohibited. The DCVs will have horizontal steel plates located above the openings that will prevent any material falling in the drywell from directly entering the vertical leg of the DCVs. This arrangement is similar to that used with the Mark II connecting vent pipes. Vertically oriented trash rack construction will be installed around the periphery of the horizontal steel plate to intercept debris. The trash rack design shall allow for adequate flow from the drywell to wetwell. In order for debris to enter the DCV it would have to travel horizontally through the trash rack prior to falling into the vertical leg of the connecting vents. Thus the ABWR is resistant to the transport of debris from the drywell to the wetwell.

In the Perry incident, the insulation material acted as a sepia to filter suspended solids from the suppression pool water. The Mark I, II, and III containments have all used carbon steel in their suppression pool liners. This results in the buildup of corrosion products in the suppression pool which settle out at the bottom of the pool until they are stirred up and resuspended in the water following some event (SRV lifting). In contrast, the ABWR liner of the suppression pool is fabricated from stainless steel which significantly lowers the amount of corrosion products which can accumulate at the bottom of the pool.

Since the debris in the Perry incident was created by roughing filters on the containment cooling units a comparison of the key design features of the ABWR is necessary. In the Mark III design more than 1/2 of the containment cooling units are effectively located in the wetwell airspace. For the ABWR there are no cooling fan units in the wetwell air space. Furthermore the design of the ABWR Drywell Cooling Systems does not utilize roughing filters on the intake of the containment cooling units.

In the event that small quantities of debris enter the suppression pool, the Suppression Pool Cleanup System (SPCU) will remove the debris during normal operation. The SPCU is described in Section 9.5.9 and shown in Figure 9.5.1~~, of the ABWR SSAR~~. The SPCU is designed to provide a continuous cleanup flow of 250 m^3/h. This flow rate is sufficiently large to effectively maintain the suppression pool water at the required purity. The SPCU system is intended for continuous operation and the suction pressure of the pump is monitored and provides an alarm on low pressure. Early indication of any deterioration of the suppression pool water quality will be provided if significant quantities of debris were to enter the suppression pool and cause the strainer to become plugged resulting in a low suction pressure alarm.

The ABWR will at a mimimum, size the ECCS suction strainers in accordance with Reg. Guide 1.82 for all breaks required to be considered. Breaks involving the Main Steam Lines are expected to determine the strainer size per Reg. Guide 1.82. To address the uncertainty regarding the potential non-conservatism associated with the head loss calculations performed for strainer sizing the following additional requirement will be met:

> For breaks other than those involving the main and RCIC steam systems, the RHR suction strainers will have a constructed area at least 3 times the basic strainer surface area obtained from Reg. Guide 1.82, as required for the specific break under consideration.

The suction strainers at Perry did not meet the current regulatory requirements. The ABWR ECCS suction strainers will utilize a "T" arrangement with conical strainers on the 2 free legs of the "T". This design separates the strainers so that it minimizes the potential for a contiguous mass to block the flow to an ECCS pump. The ABWR design also has additional features not utilized in earlier designs that could be used in the highly improbable event that all suppression pool suction strainers were to become plugged. The alternate AC (Alternating Current) independent water addition mode of RHR allows water from the Fire Protection System to be pumped to the vessel and sprayed in the wetwell and drywell from diverse water sources to maintain cooling of the fuel and containment. The wetwell can also be vented at low pressures to assist in cooling the containment.

INSERT A

6C.4 Discussion Summary

In summary, the ABWR design includes the necessary provisions to prevent debris from impairing the ability of the RCIC, HPCF, and RHR systems to perform their required post-accident functions. Specifically, the ABWR does the following:

(1) The design is resistant to the transport of debris to the suppression pool.

(~~2~~ 3) The SPCU system will provide early indication of any potential problem.

(~~3~~ 6) The ECCS suction strainers meet the current regulatory requirements unlike the strainers at the incident plants.

(~~4~~ 5) The equipment installed in the drywell and wetwell minimize the potential for generation of debris.

In addition to the ABWR design features, the control of the suppression pool cleanliness is a significant element of minimizing the potential for strainer plugging.

(2) The suppression pool liner is stainless steel, which significantly reduces corrosion products.

(4) The SPCU system operation will maintain suppression pool cleanliness.

(7) The RHR suction strainers will apply an additional factor of 3 design margin.

INSERT A

6C.3 RG 1.82 Improvement

All ECCS ~~S~~trainers will at a minimum be sized to conform with the guidance provided in Reg Guide 1.82 Rev. 1 for the most severe of all postulated breaks.

The following clarifying assumptions will also be applied and will take precedence:

(1) The debris generation model will utilize right angle cones acting in both directions;
(2) The amount of insulation debris generated will be assumed to be 100% of the insulation in a distance of 3 L/D of the postulated break within the right angle cones including targeted insulation;
(3) All of the insulation debris generated will be assumed to be transported to the suppression pool;
(4) The debris in the suppression pool will be assumed to remain suspended until it is captured on the surface of a strainer.

The sizing of the RHR suction strainers will assume that the insulation debris in the suppression pool is evenly distributed to the 3 pump suctions. The strainer size will be determined based on this amount of insulation debris and then increased by a factor of 3. The flow rate used for calculating the strainer size will be the runout system flow rate.

The sizing of the RCIC and HPCF suction strainers will conform to the guidance of Reg Guide 1.82 and will assume that the insulation debris in the suppression pool is proportionally distributed to the pump suctions based on the flow rates of the systems at runout conditions. The strainers assumed available for capturing insulation debris will include 2 RHR suction strainers and a single HPCF or RCIC suction strainer.

6C.5 Strainer Sizing Analysis Summary

A preliminary analysis was performed to assure that the above requirements could be satisfied using strainers compatible with the suppression pool design as shown by Figure 1.2-13i. The following summarizes the results, which indicate strainer sizes that are acceptable within the suppression pool design constraints.

Each loop of an ECCS system has a single suppression pool suction strainer configured in a T shape with a screen region at the two ends of the T cross member. Analysis determined the area of each screen region. Thus, RHR with three loops has six screen regions. The HPCF with two loops has four screen regions, and the RCIC has two screen regions. The characteristic dimension given for the screens in the results below indicates a surface area consisting of a circle with a diameter of the dimension plus a cylinder with a diameter and length of the dimension.

By the requirements above, all of the debris deposits on the strainers. The distribution of debris volume to the strainer regions was determined as a fraction of the loop flow splits based on runout flow. Debris on the screen creates a pressure drop as predicted by NUREG-0897, which is referenced by R.G. 1.82. The equation for NUKON™ insulation on page 3-59 of NUREG-0897 was used for this analysis. The NUKON™ debris created pressure drop equation is a function of the thickness of debris on the screen (which is a function of debris volume), the velocity of fluid passing through the screen (runout flow used), and the screen area. The debris created pressure drop was applied in an equation as follows; the static head at the pump inlet is equal to the hydraulic losses through the pipe and fittings, plus the pressure drop through the debris on the strainers, plus the hydraulic loss through the unplugged strainer, plus a margin equal to approximately 10% of the static head at the pump inlet, and plus the required NPSH. The static head takes into account the suppression pool water level determined by the draw down calculated as applicable for a main steam line break scenario. A summary of the applicable quantitative information input is provided in Table 6C-1, and a summary of the analysis results is provided in Table 6C-2.

6C.5 Strainer Sizing Analysis Summary (continued)

By making realistic assumptions, the following additional conservatisms are likely to occur, but they were not applied in the analysis. No credit in water inventory was taken for water additions from feedwater flow or flow from the condensate storage tank as injected by RCIC or HPCF. Also, for the long term cooling condition, when suppression pool cooling is used instead of the low pressure flooder mode (LPFL), the RHR flow rate decreases from runout (1130 m^3/h) to rated flow (954 m^3/h), which reduces the pressure drop across the debris.

Table 6C-1

Debris Analysis Input Parameters

Estimated debris created by a main steam line break	2.6 m^3.
RHR runout flow (Figure 5.4-11, note 13)	1130 m^3/h
HPCF runout flow (Table 6.3-8)	890 m^3/h
RCIC controlled constant flow (Table 5.4-2)	182 m^3/h
Debris on RHR screen region, 3 RHR loops operating	0.434 m^3.
Debris on HPCF screen region	0.369 m^3.
Debris on RCIC screen region	0.097 m^3.
RHR required NPSH (Table 6.3-9)	2.4 m
HPCF required NPSH (Table 6.3-8)	2.2 m
RCIC required NPSH (Table 5.4-2)	7.3 m
RHR pipe, fittings and unplugged strainer losses*	0.60 m
HPCF pipe, fittings and unplugged strainer losses*	0.51 m
RCIC pipe, fittings and unplugged strainer losses*	0.39 m
Suppression pool static head above pump suction	5.05 m

* Calculated hydraulic losses

Table 6C-2

Results of Analysis

RHR screen region area / characteristic dimension	5.66 m^2 / 1.20 m
HPCF screen region area / characteristic dimension	1.46 m^2 / 0.61 m
RCIC screen region area / characteristic dimension	0.27 m^2 / 0.26 m
Total ECCS screen region area	40.0 m^2

Table 6.2-2b Net Positive Suction Head (NPSH) Available to RHR Pumps

A. Suppression pool is at its minimum depth, El. –3740 mm.

B. Centerline of pump suction is at El. –7200 mm.

C. Suppression pool water is at its maximum temperature for the given operating mode, 100°C.

D. Pressure is atmospheric above the suppression pool.

E. Minimum ~~Maximum~~ suction strainer ~~losses are 0.21m.~~ area as committed to by Appendix C methods

$NPSH_{available} = H_{ATM} + H_S - H_{VAP} - H_F$

where:

H_{ATM} = Atmospheric head

H_S = Static head

H_{VAP} = Vapor pressure head

H_F = Maximum Frictional head including strainer allowed

Minimum Expected NPSH

RHR Pump Runout is 1130 m^3/h.

Maximum suppression pool temperature is 100°C.

H_{ATM} = 10.78m

H_S = 3.46m

H_{VAP} = 10.78m

H_F = ~~0.80m~~ 0.71m

NPSH available = 10.78 + 3.46 – 10.78 – ~~0.80~~ 0.71 = ~~2.66m~~ 2.75 m

NPSH required = 2.4m

Margin = 0.35m = $NPSH_{available} - NPSH_{required}$

Table 6.3-9 Design Parameters for RHR System Components (Continued)

(4) Type water	Reactor Building Cooling Water
(5) Fouling factor	0.0005
(3) Strainer (D008)	
Location	Suppression Pool
Size	~~Meet pump NPSH requirements when 50% plugged~~ As required for insulation debris per Appendix 6C
(4) Restricting Orifices	
Location (D003)	Vessel return line
Size	Limit flow to vessel to 954 m^3/h
Location (D002)	Suppression pool return line
Size	Limit flow during suppression pool cooling to 954 m^3/h
Location (D004)	Fuel pool return line
Size	Limit flow during fuel pool cooling to 350 m^3/h
Location (D00l)	Pump minimum flow line
Size	Limit pump flow through the bypass line to 148 m^3/h
Location (D005)	Discharge line to wetwell spray
Size	Limit wetwell spray sparger flow to 114 m^3/h
Location (D006)	Discharge line to drywell sparger
Size	Limit drywell spray sparger flow to 840 m^3/h
(5) Flow Elements (FE009)	
Location	Pump discharge line, downstream of heat exchanger bypass return
Rated Flow	954 m^3/h
Head Loss	6.1m w.g. maximum @ 954 m^3/h
Accuracy	±2.5% combined element, transmitter and indicator at rated flow
(6) Vessel Flooder Sparger	
Flow Rate	954 m^3/h
Minimum Exit Velocity	11 m/s @ 954 m^3/h
(7) Wetwell Spray Sparger	
Flow Rate	114 m^3/h
(8) Drywell Spray Sparger	
Flow Rate	840 m^3/h

Table 6.2-2c Net Positive Suction Head (NPSH) Available to HPCF Pumps

A. Suppression pool is at its minimum depth, El. –3740 mm.

B. Centerline of pump suction is at El. –7200 mm.

C. Suppression pool water is at its maximum temperature for the given operating mode, 100°C.

D. Pressure is atmospheric above the suppression pool.

E. ~~Maximum~~ Minimum suction strainer ~~losses are 0.5m.~~ area as committed to by Appendix 6C methods.

$NPSH_{available} = H_{ATM} + H_S - H_{VAP} - H_F$

where:

H_{ATM} = Atmospheric head

H_S = Static head

H_{VAP} = vapor pressure head

H_F = Maximum Frictional head including strainer allowed

Minimum Expected NPSH

HPCF Pump Runout is 890 m^3/h.

Maximum suppression pool temperature is 100°C

H_{ATM} = 10.78m

H_S = 3.46m

H_{VAP} = 10.78m

H_F = ~~1.02m~~ 0.91 m

NPSH available = 10.78 + 3.46 – 10.78 – ~~1.02~~ 0.91 = ~~2.44m~~ 2.55 m

NPSH required = 2.2m

Margin = 0.35 = NPSHavailable – NPSHrequired

Table 6.3-8 Design Parameters for HPCF System Components

(1) Main Pumps (C001)	
Number of Pumps	2
Pump Type	Centrifugal
Drive Unit	Constant speed induction motor
Flow Rate	182 m^3/h @ 8.22 MPaA reactor pressure*
	727 m^3/h @ 0.79 MPaA reactor pressure*
Developed Head	890m @ 8.22 MPaA reactor pressure
	190m @ 0.79 MPaA reactor pressure
Maximum Runout Flow	890 m^3/h @ 0.10 MPaA reactor pressure
Minimum Bypass Flow	73 m^3/h
Water Temperature Range	10° to 100°C*
NPSH Required	2.2m
(2) Strainer (D001)	
Location	Suppression Pool
Size	~~50% plugged shall meet pump NPSH requirements~~ As required for insulation debris per Appendix 6C.
(3) Restricting Orifice (D002)	
Location	Pump discharge line
Size	Limit pump flow to values specified
(4) Condensate Storage Tank	570 m^3 reserve storage for HPCF and RCIC Systems combined
(5) Flow Elements (FE008)	
Location	Pump discharge—downstream of minimum flow bypass line
Head Loss	6.1m w.g. maximum @ 727 m^3/h
Accuracy	±2.5% combined element, transmitter and indicator at maximum rated
(6) Core Flooder Sparger	
Flow Rate	727 m^3/h minimum @ 0.79 MPaA reactor pressure
Pressure Drop	50m w.g. maximum @ 727 m^3/h
(7) Piping and Valves	
Design Pressures	0.31 MPaG—suction and discharge connected to suppression pool
	2.82 MPaG—pump suction
	10.79 MPaG—pump discharge

Table 5.4-1a Net Positive Suction Head (NPSH) Available to RCIC Pumps

A Suppression pool is at its minimum depth, El. –3740 mm.

B. Centerline of pump suction* is at El. –7200 mm.

C. Suppression pool water is at its maximum temperature for the given operating mode, 77°C.

D. Pressure is atmospheric above the suppression pool.

E. Minimum ~~Maximum~~ suction strainer ~~losses are 1.46m (50% plugged)~~ area as committed to by Appendix C methods.

$N_{PSH} = H_{ATM} + H_S - H_{VAP} - H_F$ available

where:

H_{ATM}	=	Atmospheric head
H_S	=	Static head
H_{VAP}	=	Vapor pressure head
H_F	=	Maximum Frictional head including strainer allowed

Minimum Expected NPSH
RCIC pump flow is $182\ m^3/h$
Maximum suppression pool temperature is 77°C

H_{ATM}	=	~~10.73m~~ 10.62 m
H_S	=	3.46m
H_{VAP}	=	~~4.22m~~ 4,33 m
H_F	=	~~1.82m~~ 2.10

~~Strainer head loss = 1.46m~~ e

NPSH available = ~~10.73~~ 10.62 + 3.46 – ~~4.22~~ 4.33 – ~~1.82~~ 2.10 = ~~8.15m~~ 7.65 m

NPSH required = 7.3m

~~* NPSH Reference Point~~

Margin= 0.35m = $NPSH_{available} - NPSH_{required}$

* NPSH Reference Point