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For information

South Texas Project - Nuclear Operating Company
STP Units 3 & 4

Design Report

Title: The supplementary document for the head loss evaluation report of Japanese ABWR ECCS suction strainer

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1. ABSTRACT

Toshiba replaced the ECCS Suction Strainers in the Reference Japanese ABWR plant with cassette-type strainers supplied by CCI. For this replacement work, Toshiba prepared the strainer head loss evaluation report for the Japanese regulatory authority (Construction permit, Reference Document 1), and submitted it to the customer.

This document supplements Reference Document 1 by providing additional explanation of the calculations of debris generation, debris transport, and debris adhesion to strainer, and evaluation of NPSH for the ECCS pumps.

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2. REFERENCE DOCUMENTS

1. "The Evaluation Report for Pumps' Net Positive Suction Head in Emergency Core Cooling System" (This document was made to submit to Japanese government)
2. The Guideline made by government on Japan, NISA-322c-05-4, " Capacity and structural strength evaluation on filters equipped on Emergency Core Cooling System and drywell heat removal system in boiled water reactor power plant system" , October 25. 2005 (Note 1)
3. Regulatory Guide 1.82 Revision 3, "Water Sources for Long – Term Recirculation Cooling Following a Loss of Coolant Accident", November 2003
4. Boiling Water Reactor Owners Group Topical Report, NEDO-32686, "Utility Resolution Guidance for ECCS Suction Strainer Blockage", November 1996
5. NUREG/CR-6224 "Parametric Study of the Potential for BWR ECCS Strainer Blockage Due to LOCA Generated Debris", October 1995
6. NUREG/CR-6808 "Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance", February 2003
7. Technical Report, PDR-2008-100575 Revision 0, "Application Methodology for the ECCS Suction strainer", June 3. 2008

Notes

1) The extract from this guideline is shown on Attachment G Rev.3

3. APPROACH FOR STRAINER HEAD LOSS CALCULATION AND EVALUATION OF NPSH

The steps in strainer head loss calculation and evaluation of ECCS pump NPSH are as follows.

(1) The criteria for selection of pipe break point

⇩

(2) The estimate for insulation debris in zone of influence

⇩

(3) The estimate for insulation debris transport to Suppression Pool (S/P)

⇩

(4) The estimate for other debris generation and transport to S/P

⇩

(5) The estimate for the distribution to each strainer and adhesion of debris on the strainers

⇩

(6) The estimate for the head loss of pump suction pipe, valves, tee and clean strainer (without adherence of debris)

⇩

(7) The head loss calculation for debris adhered to ECCS strainers and selection of strainer surface area.
- (7)-1 Estimate the debris characteristics for head loss
- (7)-2 Estimate the filter shape factor for CCI cassette type strainer

⇩

(8) The estimate for head of S/P water, saturated vapor pressure, inner pressure of S/P space

⇩

(9) The evaluation of NPSH for ECCS pumps

⇩

(10) The tests performed to confirm that the design of the strainers results in acceptable head losses
- (10)-1 Confirmatory small-scale test
- (10)-2 Full-scale test (for information only)

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4. SUPPLEMENTAL EXPLANATION FOR EACH STEP

(1) The criteria for selection of pipe break point

According to Section 2.3.1.5 of RG 1.82 (Reference Document 3), some numbers of breaks in each high-pressure system are selected for evaluation in Japanese BWR plants. A similar requirement is described in the Japanese guideline NISA-322c-05-4 (Reference Document 2).

In Reference Document 1, we chose the following locations as ones that we estimated had the largest amount of damage of insulation. Rev3

[ ]

The amount of debris generation was calculated for each location. (Refer to Attachment-A) From the calculated amount of debris generation, we chose Location B as the point where the head loss condition was the most severe (due to the amount of fibrous and Calcium Silicate insulation materials).

(2) The estimate for insulation debris in zone of influence

According to Section 2.3.1.2 of RG 1.82 (Reference Document 3), we estimate the amount of insulation debris in the zone of influence. An acceptable method for determining the shape of the zone of influence (ZOI) of the break locations is described in NUREG/CR-6224 (Reference Document 5) and NEDO-32686 (URG, Reference Document 4). The method used is based on Method 2 described in Section 3.2.1.2.3.2 of URG and in the document NISA-322c-05-4 (Reference Document 2):

1) ZOI for Reflective Metal Insulation (RMI), Calcium Silicate Insulation and Fiber Insulation in RMI is 7.4D.
2) ZOI for Fiber Insulation with Aluminum Jacketing is 11.4D

The details of this calculation process are shown as follows:
1) We choose the insulations resembling ones described on Table 2 of URG.
2) We determine the damage pressure of the insulation in accordance with Table 2 of URG.
3) We correct the damage pressure provided by the above with a pipe diameter as a parameter. The way of correction is to use the following correlation described in the Notes of Table 2 of URG. The pipe diameter for correction is 700A (28B), which is the maximum diameter of pipe in the drywell (D/W) of the actual plants. Rev3

$$P_{dest28"pipe} = P_{dest12"pipe} \times r_{12"pipe} / r_{28"pipe}$$

Where

$P_{dest28"pipe}$ is the destruction pressure for insulation installed on pipe of outer radius 28".
$r_{12"pipe}$ is the outer radius for insulation installed on 12" pipe.
$r_{28"pipe}$ is the outer radius for insulation installed on the 28" pipe.

4) For various types of insulation, a spherical volume of ZOI is calculated by using the following correlation in Section 3.2.1.2.3.2 of URG. Second, we find the radius of the spherical volume provided by the above calculation for each insulation type.

$$V_{ZOI(i)} = A \times D^3 \qquad \text{(Equation X)}$$

Where

$V_{ZOI(i)}$ is the volume (ft^3) of ZOI for insulation(i);
A is a constant which is function of P_{dest} and break geometry, and is provided in Table 1 of the URG. In this case, A should be determined for the value from above, assuming a double

ended break with a radial offset of >3D/2; and

D is the inside diameter (ft) of pipe where the break is postulated.

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5) The ZOI of various type insulations obtained by the above process is shown in Table(2)-1.

Table (2)-1 ZOI of insulation

Insulation	**Resembling insulation described on Table 2 of URG**	**$P_{dest12"pipe}$ (Psi)**	**A obtained by Equation X (on previous page)**	**Radius of ZOI obtained by this calculation process**	**Radius of ZOI provided by Reference Document 2 (NISA-322c-05-4)**
Calcium Silicate with Aluminum Jacketing	Calcium Silicate with Aluminum Jacketing	150	About 1686	7.4D	7.4D
Reflective metal insulation	Transco RMI	190	About 1493	7.1D	
Fiber in RMI	Jacketed NUKON with modified "Sure Hold" Bands, Camloc Strikers and Latches	150	About 1686	7.4D	
Fiber with Aluminum Jacketing	Unjacketed NUKON	10	About 6180	11.4D	11.4D

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(3) The estimate for insulation debris transport to Suppression Pool (S/P)

According to Section 2.3.2 of RG 1.82 (Reference Document 3), we estimate the amount of insulation debris transport to S/P. An acceptable method for debris transport to S/P is described in NEDO-32686 (URG, Reference document 4) and NUREG/CR-6369 on RG 1.82 Rev3. It is based on the various insulation debris generation and transport factors described in Section 3.2.3.2.5 of URG and the document NISA-322c-05-4, as shown in Table (3)-1.

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Table (3)-1 Factor for combined debris generation and transport

Insulation material		Factor for combined debris generation and transport
Fiber (in RMI)		0.15
Fiber (With Aluminum Jacketing)	Above Grating	0.28
	Below Grating	0.78
Calcium Silicate		0.1
Foil in RMI		0.5

The details of this calculation process are shown as follow,

1) We choose the insulation resembling one described in Table 5 and Table 6 of URG.
2) We determined the factor for combined debris generation and transport of the various insulation types referred to in Table 5, Table 6 and Appendix E " Air Jet Impact Testing of Fibrous and Reflective Metallic Insulation" of URG.
3) The bases for selection of the factors for combined debris generation and transport are shown in Table (3)-2.

Table (3)-2 Summary of the bases for selection of the factors for combined debris generation and transport (1/2)

Insulation	**Resembling insulation described in Table 5 and Table 6 of URG.**	**Factor for combined debris generation and transport** (Note 1)	**Summary of bases for selection of factor for combined debris generation and transport**
Calcium Silicate with Aluminum Jacketing	Calcium Silicate with Aluminum Jacketing	0.1	The damage ratio of the Air jet test was around 2%, even if large pieces are included. However, a damage ratio of 10% is used for conservatism. Regardless of having grating or not, all insulation damaged is assumed to transport to S/P.
Reflective metal insulation	Transco RMI	0.5	For the Air jet test, the greatest damage ratio was 42%. This value was conservatively rounded up to 50%. Regardless of having grating or not, all insulation damaged is assumed to transport to S/P.

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Notes

1) This factor is shown in Table 5 and Table 6 of URG.

Table (3)-2 Summary of the bases for selection of the factors for combined debris generation and transport (2/2)

Insulation	**Resembling insulation described in Table 5 and Table 6 of URG.**	**Factor for combined debris generation and transport (Note 1)**	**Summary of bases for selection of factor for combined debris generation and transport**
Fiber with Aluminum Jacketing	Unjacketed NUKON	0.28(Above Grating), 0.78(Below Grating)	In the Air jet test, the damage ratio of the debris which became tiny was about 23%. For conservatism, a ratio of damage and transport for insulation above grating was assumed to be 28%, considering that it could become smaller due to spray and pass through the grating. For insulation below grating, 70% is assumed to transport to S/P.
Fiber in RMI	Jacketed NUKON with modified "Sure Hold" Bands, Camloc Strikers and Latches	0.15	In the Air jet test, the damage ratio for generation of small debris was about 15%, Regardless of having grating or not, all insulation damaged is assumed to transport to S/P.

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Notes

1) This factor is shown in Table 5 and Table 6 of URG.

(4) The estimate for other debris generation and transport to S/P

According to Section 2.3.1.6, 2.3.1.7 and 2.3.1.8 of RG 1.82 (Reference Document 3), we estimate the amount of generation and transport for additional debris, such as Sludge, Paint Chips, Rust Flakes and Dust. A similar requirement is described in the Japanese guideline NISA-322c-05-4. These are based on URG (Reference Document 4) and are prescribed as follows. Rev3

Sludge: 195 lb
Paint Chips: 85 lb
Rust Flakes: 50 lb
Dust: 150 lb

(5) The estimate for the distribution to each strainer and adhesion of debris on the strainers

According to URG (Reference Document 4), we estimate the distribution and adhesion of debris on the strainers. A similar requirement is described in the Japanese guideline NISA-322c-05-4 (Reference Document 2). Rev3

We assume that all debris that transported to the S/P is not settled and adheres to the strainers, based on Section 3.2.5 of URG. As shown in Section 3.2.6.2.2 of URG, the debris in the S/P is distributed and adheres to the strainers according to the ratio of ECCS pump flow rates.

(6) The estimate for the head loss of pump suction pipe, valves, tee and clean strainer (without adherence of debris)

We estimate the head loss of pump suction pipe, valve, tee and clean strainer (without adherence of debris) according to standard technical documents. These calculation processes are described in Section 4.5 and 4.6 of the evaluation report (Reference Document 1).

The head loss for the clean strainer is considered for the following:

1. The losses due to the flow constriction at the outlet of the strainer
2. The losses through the holes in the perforated plate filter elements

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The losses due to the first case (the flow constriction at the outlet of the strainer) cannot be replicated by the small-scale strainer testing used to determine head loss due to the debris adhering to the strainer. Therefore, the loss is calculated for an orifice between the strainer outlet and inlet to the piping tee using the appropriate flow conditions.

The losses due to the second case (through holes in the perforated plate filter elements) are not significant because the area of the holes is approximately 1/3 the total area of each strainer, which are approximately 47 m^2 and 37 m^2. Therefore, the opening through the filter element holes is more than 10 times the area of the strainer outlet and the losses are considered insignificant. (Note that any localized losses through the holes in the filter elements would be part of the total head loss measured during the small-scale strainer debris tests.)

(7) The head loss calculation for debris adhered to ECCS strainers and selection of strainer surface area (first type of small-scale testing).

[Specific surface area]

The head loss calculation for flow passing through debris adhered to the ECCS strainers is calculated by the formula in NUREG/CR-6224 (Reference Document 5). (See Equation 1 in Reference Document 1.) The specific surface area for each type of debris is necessary to calculate this head loss. The specific surface area (Sv) of the debris type with the highest head loss, Calcium Silicate insulation is obtained as follows,

1) Calcium Silicate insulation

   We obtain Svp of Calcium Silicate insulation by the head loss test for the fiber insulation and Calcium Silicate insulation mixed. The testing used to determine the Svp for Calcium Silicate is shown in Attachment B.

[Empirical shape factor, fg factor] Rev3

The analytical correlation of head loss due to debris given in NUREG/CR-6224 (Reference Document 5) is based on a one-dimensional strainer and would therefore under-predict the head loss for a cassette-type strainer that has the same surface area. Small-scale head loss testing is used to determine the difference (shape factor) between head loss predicted by the NUREG formula and actual head loss from testing for a range of debris bed thicknesses, as shown in Figures 4-4 and 4-5 of Reference Document 1. Figures 4-4 and 4-5 in Reference Document 1 are used to select an appropriate shape factor for each ECCS strainer. Note that the shape factor is a function of debris bed thickness (which is a function of the size of the strainers), so a best estimate must be made of the expected final debris bed thickness so that the strainer can be sized to result in an acceptable head loss.

Section 10 of this report describes the small-scale test loop set-up which was used both for this shape factor testing and the confirmatory final design testing.

(8) The estimate for head of S/P water, saturated vapor pressure, inner pressure of S/P space

According to Section 2.1.1.6 of RG 1.82 (Reference Document 3), the level of water in S/P is assumed to be the minimum level in the S/P. That value is used to estimate the head of S/P water.

According to Section 2.1.1.2 of RG 1.82 (Reference Document 3), the temperature of S/P water is maximum value obtained from the accident analysis, and it is used to estimate the saturated vapor pressure. Rev3

According to Section 2.1.1.1 of RG 1.82 (Reference Document 3), the containment pressure prior to the postulated LOCA is used to estimate the pressure of the S/P gas space. That is, no credit is taken for an increase in pressure due to the postulated LOCA. A similar requirement is described in the Japanese guideline NISA-322c-05-4 (Reference Document 2).

(9) The evaluation of NPSH for ECCS pumps

According to Section 2.1.1.9 in RG 1.82 (Reference Document 3), we evaluate NPSH of ECCS pumps for the severest condition for debris adhesion, which is the pump rated, or design flow rate for the Reference Japanese ABWR. Rev3

(10) The tests performed to confirm that the design of the strainers results in acceptable head losses (second type of small-scale tests)

We validated the design calculation of head loss for the condition with debris adhered on strainer surface by means of a confirmatory small-scale test. We performed the small scale test using cassette type strainers which are the same as for the actual plant. The small scale test uses four (4) filter elements, as shown in Figure (10)-1. The test filter dimensions are the same as the actual strainer's filter dimension. Surface area of strainer's filter is shown on Attachment-F. Rev3

Test filter

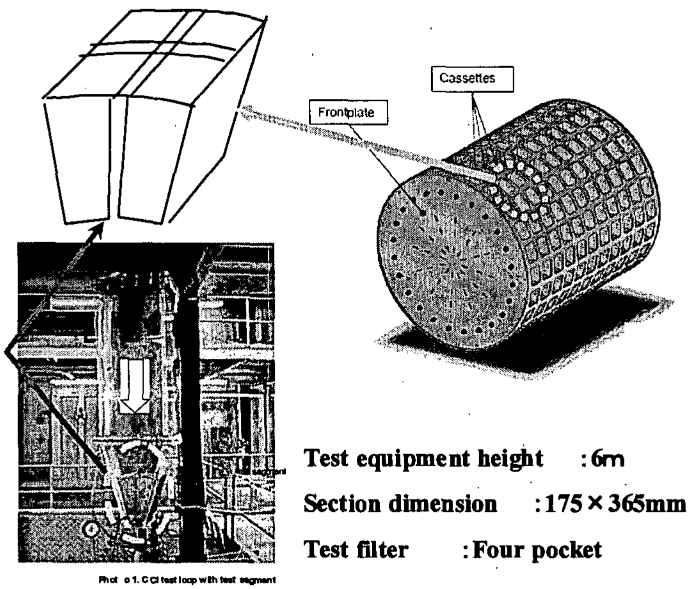

Figure (10)-1 Small scale test set-up

The confirmatory small scale test results are shown in Attachment C. The testing confirmed that our design calculations are conservative, and therefore the strainer designs are acceptable.

We also carried out a full scale test with a representative strainer to confirm the influence of the true scale, as documented in Reference Document 7. A test strainer that simulated the actual ABWR HPCF strainer was used on this test. Note that the full-scale test is provided for information only because it can not be confirmed that all the debris used in the full-scale testing adhered to the strainer. That is, it is possible that some of the debris settled out in the tank used for this horizontal test. Therefore, only the small-scale testing is considered to prove that Rev3 the ECCS strainer designs are conservative (because there is no way for any of the debris used in the testing to not adhere to the filter elements in the vertical test loop used for the small-scale tests. Rev3

Attachments D and E are excerpts from Reference Document 7, and are for information only.

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