Nuclear Operating Company

*South Texas Project Electric Generating Station 4000 Avenue F – Suite A Bay City, Texas 77414*

October 29, 2009
U7-C-STP-NRC-090179

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville MD 20852-2738

South Texas Project
Units 3 and 4
Docket Nos. 52-012 and 52-013
Supplemental Response to Request for Additional Information

Reference: Letter, Scott Head to Document Control Desk, "Response to Requests for Additional Information" for the South Texas Combined License Application dated September 28, 2009 U7-C-STP-NRC-0900141.

The referenced letter provided the responses to Request for Additional Information (RAI) letter numbers 260, 261, and 262 related to the STPNOC Combined Licensing Application (COLA) Part 2, Tier 2, Appendix 6C. In response to RAI 06.02.02-6, STPNOC agreed to submit to the NRC three Toshiba reports that represent the licensing basis for the STP 3 & 4 strainer sizing, the Regulatory Guide 1.82, Revision 3 compliance table, and COLA revision markups in a supplemental response to the referenced RAI by October 30, 2009. Additionally, in response to RAI 06.02.02-9, STPNOC agreed to provide the proprietary results of the Toshiba chemical effects bench-top testing by October 31, 2009. Both proprietary and non-proprietary versions of the four reports are provided in this submittal.

Attachment 1 contains the supplemental response to RAI 06.02.02-6, including the Regulatory Guide 1.82, Revision 3, compliance table and COLA markup. Attachment 2 contains the supplemental response to RAI 06.02.02-9. Attachment 3 provides an affidavit on behalf of Toshiba requesting that the proprietary information included in Attachment 4 be withheld from public disclosure in accordance with 10 CFR 2.390(a)(4). Attachment 5 includes the non-proprietary versions of the referenced reports. When separated from the proprietary attachment, the remainder of this submittal is not proprietary

The attachments include the supplemental responses to the RAI questions listed below:

RAI 06.02.02-6 RAI 06.02.02-9

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When a change to the COLA is indicated, it will be incorporated in the next routine revision of the COLA following the NRC acceptance of the RAI response.

There are no commitments in this letter

If you have any questions, please contact me at (361) 972-7136, or Bill Mookhoek at (361) 972-7274.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 10/29/09

Scott Head
Manager, Regulatory Affairs
South Texas Project Units 3 & 4

rhs

Attachments:

1. RAI 06.02.02-6 Supplemental Response
2. RAI 06.02.02-9 Supplemental Response
3. Affidavit
4. Proprietary Reports
5. Non-Proprietary Reports

cc: w/o attachment except*
(paper copy)

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## RAI 06.02.02-6 Supplemental Response

STPNOC response to RAI 06.02.02-6 committed to provide the following items in a Supplemental Response:

- The RG 1.82, Rev. 3 Compliance Table will be provided as part of a supplemental RAI response on October 30, 2009.
- The proposed revisions to the STP 3&4 COLA will be provided in a supplemental RAI response on October 30, 2009.

The RG 1.82, Rev. 3 Compliance Table is at the end of this document.

The COLA will be revised in a future revision, as shown in the markup below of COLA Revision 3. Changes from Revision 3 of the COLA are highlighted with gray shading.

Note: Add the following new section to the COLA:

### 6C.5.1 ECCS Suction Strainer Sizing Design Basis

The ECCS suction strainer design to be used on STP 3&4 is the same as the design for the Reference Japanese ABWR (see Reference 6C-10) and the STP 3&4 strainers will be at least as large as the Reference Japanese ABWR strainers. Application of the Reference Japanese ABWR ECCS suction strainer design to STP 3&4 is conservative for the following reasons:

- The sizing of the Reference Japanese ABWR strainers is based on the methodology defined in the BWROG's Utility Resolution Guideline (URG) (Reference 6C-3).
- The Reference Japanese ABWR primary containment includes fibrous and calcium silicate thermal insulation, both of which are significant contributors to strainer head loss. For STP 3&4, the only type of thermal insulation allowed inside the primary containment is all stainless steel reflective metal insulation (RMI), which results in a much lower head loss across the ECCS suction strainers.

### 6C.6 References

6C-10 The Evaluation Report for Net Positive Suction Head of Pump in Emergency Core Cooling System, Proprietary, STP Document U7-RHR-M-RPT-DESN-0001, Rev. A, May 27, 2009.

**Table 1. Compliance with RG 1.82, Rev. 3 Regulatory Positions for BWRs (Section C.2)**

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.1 | **Features Needed To Minimize the Potential for Loss of NPSH**<br>The suppression pool is the source of water for such functions as ECC and containment heat removal following a LOCA, in conjunction with the vents and downcomers between the drywell and the wetwell. It should combine the following features and capabilities to ensure the availability of the suppression pool for long-term cooling. The adequacy of the combinations of the features and capabilities should be evaluated using the criteria and assumptions in Regulatory Position 2.2. | STP 3&4 will have CCI cassette type strainers on the ECCS system suctions from the suppression pool. The strainer sizing analyses for the Reference Japanese ABWR and supplemental reports to address differences in the Reference Japanese ABWR and STP 3&4 provide the bases for demonstrating that STP 3&4 ECCS strainers will comply with the requirements of this RG. | See RAI 06.02.02-6 Item A response |
| 2.1.1 | **Net Positive Suction Head of ECCS and Containment Heat Removal Pumps** | n/a—subsection heading | n/a |
| 2.1.1.1 | ECC and containment heat removal systems should be designed so that adequate available NPSH is provided to the system pumps, assuming the maximum expected temperature of the pumped fluid and no increase in containment pressure from that present prior to the postulated LOCAs. (See Regulatory Position 2.1.1.2.) | The supplemental NPSH evaluation documented in Reference 3 uses 100°C and containment at atmospheric pressure, as required by ABWR DCD Tier 1 Table 2.4.1, Item 4c. | See Reference 3, Page 8 |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.1.1.2 | For certain operating BWRs for which the design cannot be practicably altered, conformance with Regulatory Position 2.1.1.1 may not be possible. In these cases, no additional containment pressure should be included in the determination of available NPSH than is necessary to preclude pump cavitation. Calculation of available containment pressure should underestimate the expected containment pressure when determining available NPSH for this situation. Calculation of suppression pool water temperature should overestimate the expected temperature when determining available NPSH. | n/a—STP 3&4 is not an operating plant. | n/a |
| 2.1.1.3 | For certain operating BWRs for which the design cannot be practicably altered, if credit is taken for operation of an ECCS or containment heat removal pump in cavitation, prototypical pump tests should be performed along with post-test examination of the pump to demonstrate that pump performance will not be degraded and that the pump continues to meet all the performance criteria assumed in the safety analyses. The time period in the safety analyses during which the pump may be assumed to operate while cavitating should not be longer than the time for which the performance tests demonstrate the pump meets performance criteria. | n/a—STP 3&4 is not an operating plant. | n/a |
| 2.1.1.4 | The decay and residual heat produced following accident initiation should be included in the determination of the water temperature. The uncertainty in the determination of the decay heat should be included in this calculation. The residual heat should be calculated with margin. | The supplemental NPSH evaluation documented in Reference 3 uses 100°C and containment at atmospheric pressure, as required by ABWR DCD Tier 1 Table 2.4.1, Item 4c. | See Reference 3, Page 8 |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.1.1.5 | The hot channel correction factor specified in ANSI/HI 1.1-1.5-1994 should not be used in determining the margin between the available and required NPSH for ECCS and containment heat removal system pumps. | Hot channel correction factor not used—see References 1, 2 and 3. | none |
| 2.1.1.6 | The level of water in suppression pools should be the minimum value given in the technical specifications reduced by the drawdown due to suppression pool water in the drywell and the sprays. | Static head is based on the Reference Japanese ABWR suppression pool minimum water level reduced by suppression pool water in the drywell and the sprays. | See Reference 1, Page 46 (drawdown is not mentioned in Reference 1, but is addressed in system analyses) |
| 2.1.1.7 | Pipe and fitting resistance and the nominal screen resistance without blockage by debris should be calculated in a recognized, defensible method or determined from applicable experimental data. | Head loss due to clean strainer, piping and fitting resistances is calculated based on standard literature, as documented in References 1 and 2. | See Reference 1, Pages 16-26. |
| 2.1.1.8 | Suction strainer screen flow resistance caused by blockage by LOCA-generated debris or foreign material in the containment that is transported to the suction intake screens should be determined using the methods in Regulatory Position 2.3.3. | Debris generation and transport are in accordance with BWROG Utility Resolution Guidance (URG) NEDO-32686 (cited in 2.3.2.1 below). It is noted that strainer head loss for the Reference Japanese ABWR (References 1 and 2) and the supplemental NPSH evaluation for STP 3&4 (Reference 3) assume fibrous debris will adhere to the ECCS suction strainers, but STP 3&4 is prohibiting the use of non-RMI thermal insulation, so these head loss predictions are conservative for STP 3&4. | none |
| 2.1.1.9 | Calculation of available NPSH should be performed as a function of time until it is clear that the available NPSH will not decrease further. | Available NPSH is conservatively calculated In References 1, 2 and 3 for the worst case condition, i.e., all material transported from the drywell and all material assumed to pre-exist in the suppression pool is assumed to adhere to the ECCS suction strainers for the head loss calculation. | none |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
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| 2.1.2 | **Passive Strainer**<br>The inlet of pumps performing the above functions should be protected by a suction strainer placed upstream of the pumps; this is to prevent the ingestion of debris that may damage components or block restrictions in the systems served by the ECC pumps. The following items should be considered in the design and implementation of a passive strainer. | STP 3&4 will have CCI cassette type strainers on the ECCS system suctions from the suppression pool. The strainer sizing analyses for the Reference Japanese ABWR (References 1 and 2), along with supplemental information in Reference 3, provides the bases for concluding that the STP 3&4 ECCS strainers will comply with the requirements of this RG. More details are provided below. | none |
| 2.1.2.1 | The suction strainer design (i.e., size and shape) should be chosen to avoid the loss of NPSH from debris blockage during the period that the ECCS is required to operate in order to maintain long-term cooling or maximize the time before loss of NPSH caused by debris blockage when used with an active mitigation system (see Regulatory Position 2.1.5). | n/a—STP 3&4 will not use active strainers in addition to the passive strainers. | n/a |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.1.2.2 | The possibility of debris clogging flow restrictions downstream of the strainers should be assessed to ensure adequate long-term ECCS performance. The size of openings in the suppression pool suction strainers should be based on the minimum restrictions found in systems served by the suppression pool. The potential for long thin slivers passing axially through the strainer and then reorienting and clogging at any flow restriction downstream should be considered.<br>Consideration should be given to the buildup of debris at the following downstream locations: spray nozzle openings, throttle valves, coolant channel openings in the core fuel assemblies, fuel assembly inlet debris screens, ECCS pump seals, bearings, and impeller running clearances. If it is determined that a strainer with openings small enough to filter out particles of debris that are fine enough to cause damage to ECCS pump seals or bearings would be impractical, it is expected that modifications would be made to ECCS pumps or ECCS pumps would be procured that can operate long term under the probable conditions. | STP 3&4 will use state-of-the-art CCI cassette type strainers with a maximum hole size in this strainer of 1/12 inch (2.1mm). Regarding acceptance criteria for blockage of small clearances, it is noted that there will be no fiber downstream of the STP 3&4 suction strainers because the only fiber potentially inside primary containment (latent loose debris) will not be degraded during the pipe break and will not be small enough to pass through the 1/12-inch diameter holes in the CCI cassette-type suction strainers. Preliminary data from testing conducted by Westinghouse (WEC) to resolve GSI-191 has not identified any coagulation of particulate debris until after fiber is introduced to the flow stream. Therefore, blockage of small clearances in downstream components is not likely for the STP 3&4 downstream components. The analysis of the effects of debris on downstream components such as pumps, valves and heat exchangers in PWR's was documented in WCAP-16406, which was approved by the NRC. It is expected that the analysis results which showed acceptable performance of these components will apply to BWR's due to similarity in materials and clearances to the PWR components.<br>STP 3&4 design strainer bypass testing will be performed to confirm that downstream effects will not impair the functioning of critical components in the ECCS flow loop, such as pumps, valves and instrument lines, as well as ensure that adequate flow exists to cool the core. | See Response to RAI 06.02.02-2 |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.1.2.3 | ECC pump suction inlets should be designed to prevent degradation of pump performance through air ingestion and other adverse hydraulic effects (e.g., circulatory flow patterns, high intake head losses). | The CCI cassette-type strainers used in the Reference Japanese ABWR, and planned for use in STP 3&4 have been approved for use by several US PWRs during resolution of GSI-191, based on extensive testing. The suction strainers will be designed such that the actual NPSH will always be greater than the required NPSH. (See Items 2.1.1.1 and 2.1.1.9 of this table) | none |
| 2.1.2.4 | All drains from the upper regions of the containment should terminate in such a manner that direct streams of water, which may contain entrained debris, will not impinge on the suppression pool suction strainers. | The ABWR design is such that flow from the upper regions of the containment (upper drywell) passes through a circuitous route involving any one of the ten drywell connecting vents (DCVs) and then through any one of the thirty horizontal vents before reaching the suppression pool. | See Response to RAI 06.02.02-2 |
| 2.1.2.5 | The strength of the suction strainers should be adequate to protect the debris screen from missiles and other large debris. The strainers and the associated structural supports should be adequate to withstand loads imposed by missiles, debris accumulation, and hydrodynamic loads induced by suppression pool dynamics. To the extent practical, the strainers should be located outside the zone of influence of the vents, downcomers, or spargers to minimize hydrodynamic loads. The strainer design, vis-a-vis the hydrodynamic loads, should be validated analytically or experimentally. | As noted in 2.1.2.4, any large debris generated by the LOCA will have a circuitous path to reach the suppression pool, so a LOCA-generated missile from the drywell is unlikely. Additionally, the wetwell, which is the chamber in direct contact with the suppression pool, is largely empty with the only significant components/structures being an access tunnel, a grated catwalk and the SRV discharge piping, which are designed to withstand seismic and hydrodynamic loadings (if applicable). Therefore, missile loadings are unlikely.<br>The CCI cassette-type suction strainers are designed to withstand the structural loadings associated with debris accumulation and hydrodynamic loadings, including pool swell, condensation oscillation/chugging, and SRV discharge. | See Response to RAI 06.02.02-2 |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
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| 2.1.2.6 | The suction strainers should be designed to withstand the inertial and hydrodynamic effects that are due to vibratory motion of a safe shutdown earthquake (SSE) without loss of structural integrity. | The CCI cassette-type suction strainers are designed to withstand the structural loadings associated with the design basis (safe shutdown) earthquake. | none |
| 2.1.2.7 | Material for suction strainers should be selected to avoid degradation during periods of inactivity and operation and should have a low sensitivity to such adverse effects as stress-assisted corrosion that may be induced by coolant during LOCA conditions. | The CCI cassette-type suction strainers are stainless steel, as is the suppression pool liner. Periods of high stress, e.g., during hydrodynamic loads due to pool swell and condensation oscillation are relatively short duration and unlikely to produce stress-assisted corrosion cracking during the 30 day mission time for the strainers. | none |
| 2.1.3 | **Minimizing Debris**<br>The amount of potential debris (see Regulatory Position 2.3.1) that could clog the ECC suction strainers should be minimized. | Relative to the generation of debris from a postulated pipe break, the ABWR design contains a number of improvements from earlier BWR designs. The elimination of the recirculation piping removed a significant source of insulation debris from the containment and also reduced the likelihood of a large high energy pipe break which could lead to debris generation. For the STP 3&4 design, there will be no fibrous insulation or calcium silicate on piping systems, including small bore piping, inside the containment. All thermal insulation material will be a Reflective Metallic Insulation (RMI) design. | See Response to RAI 06.02.02-2 |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
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| 2.1.3.1 | Containment cleanliness programs should be instituted to clean the suppression pool on a regular basis, and plant procedures should be established for control and removal of foreign materials from the containment. | STPNOC intends to eliminate all fiber in the primary containment and will minimize other debris through an aggressive suppression pool cleanliness program. The Suppression Pool Cleanliness Program is provided in Subsection 6.2.1.7.1 and is included as an operational program in 13.4S. This program is based on industry guidance from INPO and EPRI and will be of comparable quality to the program for ECCS Sump Cleanliness used by STP Units 1 and 2. | See Response to RAI 06.02.02-5 |
| 2.1.3.2 | Debris interceptors in the drywell in the vicinity of the downcomers or vents may serve effectively in reducing debris transport to the suppression pool. In addition to meeting Regulatory Position 2.1.2, debris interceptors between the drywell and wetwell should not reduce the suppression capability of the containment. | The drywell connecting vents (DCVs) between the upper drywell and lower drywell 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. Vertically oriented trash rack construction will be installed around the periphery of the horizontal steel plate to intercept debris. 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. | See Response to RAI 06.02.02-2 |
| 2.1.3.3 | Insulation types (e.g., fibrous and calcium silicate) that can be sources of debris that is known to more readily transport to the strainer and cause higher head losses should be avoided. Insulations (e.g., reflective metallic insulation) that transport less readily and cause less severe head losses once deposited onto the strainers should be used. If insulation is replaced or otherwise removed during maintenance, abatement procedures should be established to avoid generating latent debris in the containment. | As noted above, all thermal insulation in the STP 3&4 primary containment will be stainless steel RMI, and this design restriction (no fibrous, calcium silicate or other non-RMI insulation) will continue throughout the life of the plant. | none |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.1.3.4 | To minimize potential debris caused by chemical reaction of coolant with metals in the containment, exposure of bare metal surfaces (e.g., scaffolding) to spray impingement or immersion should be minimized either by removal or by using chemical-resistant protection (e.g., coatings or jackets). | The ABWR primary containment is inerted and entered only when the plant is shutdown, so scaffold use is temporary and controlled. Permanent metal features are either stainless steel or carbon steel protected by qualified coatings. No aluminum is allowed in the STP 3&4 primary containment. | See Response to RAI 06.02.02-6 and -9 |
| 2.1.4 | **Instrumentation**<br>If relying on operator actions to mitigate the consequences of the accumulation of debris on the suction strainers, safety-related instrumentation that provides operators with an indication and audible warning of impending loss of NPSH for ECCS pumps should be available in the control room. | n/a—Operator actions are not required for the STP 3&4 passive strainers. | n/a |
| 2.1.5 | **Active Strainers** | n/a—STP 3&4 strainers are passive design. | n/a |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
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| 2.1.5 | **Active Strainers** | n/a—STP 3&4 strainers are passive design. | n/a |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.2 | **Evaluation of Alternative Water Sources**<br>To demonstrate that a combination of the features and actions listed above are adequate to ensure long-term cooling and that the five criteria of 10 CFR 50.46(b) will be met following a LOCA, an evaluation using the guidance and assumptions in Regulatory Position 2.3 should be conducted. If a licensee is relying on operator actions to prevent the accumulation of debris on suction strainers or to mitigate the consequences of the accumulation of debris on the suction strainers, an evaluation should be performed to ensure that the operator has adequate indications, training, time, and system capabilities to perform the necessary actions. If not covered by plantspecific emergency operating procedure, procedures should be established to use alternative water sources. The valves needed to align the ECCS with an alternative water source should be periodically inspected and maintained. | See below for discussion of how the STP 3&4 ECCS strainers comply with the requirements of Regulatory Position 2.3. Additionally, should all of the ECCS suction strainers 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 to maintain cooling of the fuel. The HPCF system may also be used under the condition where debris blocks the suction strainers and/or the lower core region because it delivers water from spargers located above the core. In this mode, the HPCF will need to be aligned to take continuous suction from the CST and the CST would need to be continuously re-filled. | See Response to RAI 06.02.02-2 |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.3 | **Evaluation of Long-Term Recirculation Capability**<br>During any evaluation of the susceptibility of a BWR to debris blockage, the considerations and events shown in Figures 4 and 5 should be addressed. The following techniques, assumptions, and guidance should be used in a deterministic evaluation to ensure that any implementation of a combination of the features and capabilities listed in Regulatory Position 2.1 are adequate to ensure the availability of a reliable water source for long-term recirculation after a LOCA. An assessment should be made of the susceptibility to debris blockage of the containment drainage flowpaths to the suppression pool, flow restrictions in the ECCS, and containment spray recirculation flowpaths downstream of the suction strainer to protect against degradation of long-term recirculation pumping capacity. Unless otherwise noted, the techniques, assumptions, and guidance listed below are applicable to an evaluation of passive and active strainers. The assumptions and guidance listed below can also be used to develop test conditions for suction strainers or strainer systems. | See sections below for STP 3&4 compliance with specific requirements. | n/a |
| 2.3.1 | **Debris Sources and Generation** | n/a—subsection heading | n/a |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.3.1.1 | Consistent with the requirements of 10 CFR 50.46, debris generation should be calculated for a number of postulated LOCAs of different sizes, locations, and other properties sufficient to provide assurance that the most severe postulated LOCAs are calculated. | Multiple break locations were evaluated for the Reference Japanese ABWR, and the worst-case combination of debris types and quantities was selected. Final strainer sizing evaluations for STP 3&4 will confirm that the Reference Japanese ABWR debris generation assumptions bound the actual piping configurations and potential debris types. Note that the Reference Japanese ABWR uses some fibrous and calcium silicate thermal insulation types, but STP 3&4 only allows the use of stainless steel RMI. | See Reference 2 |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.3.1.2 | An acceptable method for determining the shape of the zone of influence (ZOI) of a break is described in NUREG/CR-6224 and NEDO-32686. The volume contained within the ZOI should be used to estimate the amount of debris generated by a postulated break. The distance of the ZOI from the break should be supported by analysis or experiments for the break and potential debris. The shock wave generated during postulated pipe break and the subsequent jet should be the basis for estimating the amount of debris generated and the size or size distribution of the debris generated within the ZOI.<br>Certain types of material used in a small quantity inside the containment can, with adequate justification, be demonstrated to make a marginal contribution to the debris loading for the ECC sump. If debris generation and debris transport data have not been determined experimentally for such material, it may be grouped with another like material existing in large quantities. For example, a small quantity of fibrous filtering material may be grouped with a substantially larger quantity of fibrous insulation debris, and the debris generation and transport data for the filter material need not be determined experimentally. However, such analyses are valid only if the small quantity of material treated in this manner does not have a significant effect when combined with other materials (e.g., a small quantity of calcium silicate combined with fibrous debris). | The ZOI methodology described in the URG (NEDO-32686) was used for the Reference Japanese ABWR, and will be used for the final design calculations for STP 3&4. | See References 1 and 2 |
| 2.3.1.3 | All sources of fibrous materials in the containment such as fire protection materials, thermal insulation, or filters that are present during operation should be identified. | References 1 and 2 for the Reference Japanese ABWR include fibrous material, but STP 3&4 will prohibit fibrous materials from being used or carried into the primary containment. | See Response to RAI 06.02.02-6 |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.3.1.4 | All insulation, painted surfaces, and fibrous, cloth, plastic, or particulate materials within the ZOI should be considered debris sources. Analytical models or experiments should be used to predict the size of the postulated debris. | For the Reference Japanese ABWR, URG (NEDO-32686) guidance was used to conservatively quantify the coatings/paint chips estimated to be within the ZOI for the ABWR. Insulation within the ZOI was explicitly quantified. | See References 1 and 2, and Response to RAI 06.02.02-8 |
| 2.3.1.5 | A sufficient number of breaks in each high-pressure system that relies on recirculation should be considered to reasonably bound variations in debris generation by the size, quantity, and type of debris. As a minimum, the following postulated break locations should be considered.<br>• Breaks in the main steam, feedwater, and recirculation lines with the largest amount of potential debris within the postulated ZOI,<br>• Large breaks with two or more different types of debris, including the breaks with the most variety of debris, within the expected ZOI,<br>• Breaks in areas with the most direct path between the drywell and wetwell,<br>• Medium and large breaks with the largest potential particulate debris to insulation ratio by weight, and<br>• Breaks that generate an amount of fibrous debris that, after its transport to the suction strainer, could form a uniform thin bed that could subsequently filter sufficient particulate debris to create a relatively high head loss referred to as the 'thin-bed effect.' The minimum thickness of fibrous debris needed to form a thin bed has typically been estimated at 1/8 inch thick based on the nominal insulation density (NUREG/CR-6224). | See References 1 and 2 for break locations considered before selection of the worst-case break location. Note that the ABWR does not have Reactor Recirculation piping external to the reactor vessel, so postulated breaks in the main steam and feedwater lines result in the largest quantities of debris. Also, note that although References 1, 2 and 3 evaluate strainer head loss due to fibrous insulation, the STP 3&4 primary containment uses only stainless steel RMI for thermal insulation. | See References 1 and 2 |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.3.1.6 | The cleanliness of the suppression pool and containment during plant operation should be considered when estimating the amount and type of debris available to block the suction strainers. The potential for such material (e.g., thermal insulation other than piping insulation, ropes, fire hoses, wire ties, tape, ventilation system filters, permanent tags or stickers on plant equipment, rust flakes from unpainted steel surfaces, corrosion products, dust and dirt, latent individual fibers) to impact head loss across the suction strainer should also be considered. | URG quantities of coatings, rust, sludge and dust are all included in References 1, 2 and 3. Additionally, STP 3&4 has committed to assuming that 1 $ft^3$ of latent fiber and blockage of 2 strainer cassettes by miscellaneous latent debris (e.g., tags) in the final strainer sizing analysis. | See Responses to RAIs 06.02.02-4 and -6 |
| 2.3.1.7 | The amount of particulates estimated to be in the pool prior to a LOCA should be considered to be the maximum amount of corrosion products (i.e., sludge) expected to be generated since the last time the pool was cleaned. The size distribution and amount of particulates should be based on plant samples. | The URG values of 50 lbs (23 kg) rust and 195 lbs (89 kg) sludge were used in References 1, 2 and 3. The appropriateness of the sludge quantity will be confirmed by comparison with TEPCO data from the Japanese ABWRs K6 & 7. | See Responses to RAIs 06.02.02-5 and -6 |
| 2.3.1.8 | In addition to debris generated by jet forces from the pipe rupture, debris created by the resulting containment environment (thermal and chemical) should be considered in the analyses. Examples of this type of debris would be disbondment of coatings in the form of chips and particulates or formation of chemical debris (precipitants) caused by chemical reactions in the pool. | STP 3&4 design specifications allow only qualified coatings inside primary containment. The URG assumption that over 600 $ft^2$ of qualified coatings are within the ZOI and are removed from the base metal and all end up in the suppression pool (85 lbs of inorganic zinc and epoxy topcoat) is included in the head loss evaluations in References 1, 2 and 3. Chemical debris is not included in the head loss evaluations because potentially reactive materials (e.g., aluminum) are prohibited from the STP 3&4 containment. | See Responses to RAIs 06.02.02-8 and -9 |
| 2.3.2 | **Debris Transport** | n/a—subsection heading | n/a |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.3.2.1 | It should be assumed that all debris fragments smaller than the clearances in the gratings will be transported to the suppression pool during blowdown. Credit may be taken for filtration of larger pieces of debris by floor gratings and other interdicting structures present in a drywell (NEDO-32686 and NUREG/CR-6369). However, it should be assumed that a fraction of large fragments captured by the gratings would be eroded by the combined effects of cascading break overflow and the drywell spray flow. The fraction of the smaller debris generated and thus transported to the suppression pool during the blowdown, as well as the fraction of the larger debris that may be eroded during the washdown phase, should be determined analytically or experimentally. | As noted in 2.1.3.2 above, the ABWR contains design features which minimize the transport of accident-generated debris to the suction strainers. For the Reference Japanese ABWR, the URG factors for Mark III containments were used to predict the quantities of debris types transported to the suppression pool. The URG transport factors were based on BWROG testing and were previously accepted by NRC. | See References 1 and 2 |
| 2.3.2.2 | It should be assumed that LOCA-induced phenomena (i.e., pool swell, chugging, condensation oscillations) will suspend all the debris assumed to be in the suppression pool at the onset of the LOCA. | All debris predicted to be transported to the suppression pool was assumed to adhere to the suction strainers for the Reference Japanese ABWR. | See References 1 and 2 |
| 2.3.2.3 | The concentration of debris in the suppression pool should be calculated based on the amount of debris estimated to reach the suppression pool from the drywell and the amount of debris and foreign materials estimated to be in the suppression pool prior to a postulated break. | As stated above, all debris predicted to be transported to the suppression pool was assumed to adhere to the suction strainers for the Reference Japanese ABWR, and all materials assumed to be in the suppression pool prior to the LOCA (e.g., sludge) was assumed to adhere to the suction strainers. Additionally, the final strainer sizing analyses for STP 3&4 will assume an additional quantity of latent fiber, and that 2 cassettes in each CCI strainer are blocked due to miscellaneous latent debris like equipment tags. | See Response to RAI 06.02.02-6 |
| 2.3.2.4 | Credit should not be taken for debris settling until LOCA-induced turbulence in the suppression pool has ceased. The debris settling rate for the postulated debris should be validated analytically or experimentally. | Debris settling is not postulated. | none |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.3.2.5 | Bulk suppression pool velocity from recirculation operations, LOCA-related hydrodynamic phenomena, and other hydrodynamic forces (e.g., local turbulence effects or pool mixing) should be considered for both debris transport and suction strainer velocity computations. | Strainer head loss analyses are conservatively performed using pump runout flow rates. As noted in Item 2.3.2.3 of this table, all debris predicted to be transported to the suppression pool was assumed to adhere to the suction strainers for the reference Japanese ABWR, and all materials assumed to be in the suppression pool prior to the LOCA (e.g., sludge) were assumed to adhere to the suction strainers. | See Reference 3 |
| 2.3.3 | **Strainer Blockage and Head Loss** | n/a—subsection heading | n/a |
| 2.3.3.1 | Strainer blockage should be based on the amount of debris estimated using the assumptions and guidance described in Regulatory Position 2.3.1 and on the debris transported to the wetwell per Regulatory Position 2.3.2. This volume of debris, as well as other materials that could be present in the suppression pool prior to a LOCA, should be used to estimate the rate of accumulation of debris on the strainer surface. | See above discussions about compliance with Regulatory Positions 2.3.1 (Debris Generation) and 2.3.2 (Debris Transport). | none |
| 2.3.3.2 | The flow rate through the strainer should be used to estimate the rate of accumulation of debris on the strainer surface. | Strainer head loss is calculated for the point in time in which all debris transported to the suppression pool, along with material already in the suppression pool, has adhered to the strainers. | See References 1, 2 and 3 |

| RG 1.82 Subsection No. | RG Requirement | STP 3&4 Compliance (Note 1) | Comment |
|---|---|---|---|
| 2.3.3.3 | The suppression pool suction strainer area used in determining the approach velocity should conservatively account for blockage that may result. Unless otherwise shown analytically or experimentally, debris should be assumed to be uniformly distributed over the available suction strainer surface. Debris mass should be calculated based on the amount of debris estimated to reach or to be in the suppression pool. (See Revision 1 of NUREG-0897, NUREG/CR-3616, and NUREG/CR-6224.) | Uniform adhesion of all material in the suppression pool to the suction strainers is assumed in the strainer head loss analyses. Debris mass is calculated consistent with URG guidance. | See References 1, 2 and 3 |
| 2.3.3.4 | The NPSH available to the ECC pumps should be determined using the conditions specified in the plant's licensing basis. | Reference 3 was prepared to adjust the analyses in References 1 and 2 to use pump runout flow (instead of pump design flow), in accordance with the U.S. ABWR DCD statement that the NPSH evaluation is performed under pump runout conditions. | See Reference 3 |
| 2.3.3.5 | Estimates of head loss caused by debris blockage should be developed from empirical data based on the strainer design (e.g., surface area and geometry), postulated debris (i.e., amount, size distribution, type), and velocity. Any head loss correlation should conservatively account for filtration of particulates by the debris bed. | Head loss correlations from NUREG/CR-6224 were confirmed to conservatively predict strainer head loss based on testing of the CCI cassette-type strainers. Filtration by the debris bed was considered. | See References 1 and 2 |
| 2.3.3.6 | The performance characteristics of a passive or an active strainer should be supported by appropriate test data that addresses, at a minimum, (1) suppression pool hydrodynamic loads and (2) head loss performance. | Testing was performed for the Reference Japanese ABWR as documented in References 1 and 2. Confirmatory testing will be performed for STP 3&4 after final strainer sizing calculations are completed. | See References 1 and 2 |

Note 1: References used in this table include:

- Reference 1—"The Evaluation Report for Net Positive Suction Head of Pump in Emergency Core Cooling System," Proprietary, STP Doc. U7-RHR-M-RPT-DESN-0001, Rev. A, May 27, 2009.

- Reference 2—"The Supplementary Documentation for the Head Loss Evaluation Report of Japanese ABWR ECCS Suction Strainer," Proprietary, STP Doc. U7-RHR-M-RPT-DESN-0002, Rev. B, October 20, 2009.
- Reference 3—"The Evaluation Example of the Head Loss of the ECCS Suction Strainer and Pipe in the ECCS Pump Run-out Flow Condition," Proprietary, STP Doc. U7-RHR-M-RPT-DESN-0003, Rev. A, May 27, 2009.

**RAI 06.02.02-9 Supplemental Response**

STPNOC response to RAI 06.02.02-9 committed to provide the proprietary results of the Toshiba "Chemical Effects Bench-Top Test" by October 31, 2009.

The proprietary version of this report is included in Attachment 4 of this submittal. The non-proprietary version is included in Attachment 5.

Affidavit for Withholding Confidential and Proprietary Information from Public Disclosure under 10 CFR § 2.390

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of

STP Nuclear Operating Company

Docket Nos.52-012
52-013

South Texas Project
Units 3 and 4

AFFIDAVIT

I, Keisuke Kitsukawa, being duly sworn, hereby depose and state that I am Senior Manager, Plant Design & Engineering Department, Nuclear Energy Systems & Services Division, Power Systems Company, Toshiba Corporation; that I am duly authorized by Toshiba Corporation to sign and file with the Nuclear Regulatory Commission the following application for withholding Toshiba Corporation's confidential and proprietary information from public disclosure; that I am familiar with the content thereof; and that the matters set forth therein are true and correct to the best of my knowledge and belief.

In accordance with 10 CFR § 2.390(b)(ii), I hereby state, depose, and apply as follows on behalf of Toshiba Corporation:

(A) Toshiba Corporation seeks to withhold from public disclosure the documents listed in Attachment 1 of this affidavit, and all information identified as "Proprietary Class 2" therein (collectively, "Confidential Information").

(B) The Confidential Information is owned by Toshiba Corporation. In my position as Senior Manager, Plant Design & Engineering Department, Nuclear Energy Systems & Services Division, Power System Company, Toshiba Corporation, I have been specifically delegated the function of reviewing the Confidential Information and have been authorized to apply for its withholding on behalf of Toshiba Corporation.

(C) The report listed in Attachment 1 as Item (1) provides the analyses and test data used to evaluate chemical debris effects for STP 3&4, which supports the response to Request for Additional Information (RAI) 06.02.02-9. The reports listed in Attachment 1 as Items (2) through (4) provide the licensing basis for STP 3 & 4 strainer sizing, which support the response to Request for Additional Information (RAI) 06.02.02-6. The confidential Information which is entirely confidential and proprietary to Toshiba Corporation is indicated in the document using brackets, or the statement "The remaining pages in this document contain proprietary information, and are therefore omitted from this Non-Proprietary version of the report."

(D) Consistent with the provisions of 10 CFR § 2.390(a)(4), the basis for proposing that the Confidential Information be withheld is that it constitutes Toshiba Corporation's trade secrets and confidential and proprietary commercial information.

Toshiba Corporation has a rational basis for determining the types of information customarily held in confidence by it, and utilizes a system to determine when and whether to hold certain types of information in confidence.

The basis for claiming the information so designated as proprietary is as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Toshiba Corporation's competitors without license from Toshiba Corporation constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Toshiba Corporation, its customers or suppliers.

(e) It reveals aspects of past, present, or future Toshiba Corporation or customer funded development plans and programs of potential commercial value to Toshiba Corporation.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Toshiba Corporation system which include the following:

(a) The use of such information by Toshiba Corporation gives Toshiba Corporation a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Toshiba Corporation competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Toshiba Corporation ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Toshiba Corporation at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Toshiba Corporation of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Toshiba Corporation in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Toshiba Corporation capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

Further, on behalf of Toshiba Corporation, I affirm that:

(i) The Confidential Information is confidential and proprietary information of Toshiba Corporation.

(ii) The Confidential Information is information of a type customarily held in confidence by Toshiba Corporation, and there is a rational basis for doing so given the sensitive and valuable nature of the Confidential Information as discussed above in paragraphs (D).

(iii) The Confidential Information is being transmitted to the NRC in confidence.

(iv) The Confidential Information is not available in public sources.

(v) Public disclosure of the Confidential Document is likely to cause substantial harm to the competitive position of Toshiba Corporation, taking into account the value of the Confidential Information to Toshiba Corporation, the amount of money and effort expended by Toshiba Corporation in developing the Confidential Information, and the ease or difficulty with which the Confidential Information could be properly acquired or duplicated by others.

Keisuke Kitsukawa (signature) — Oct. 21, '09

Keisuke Kitsukawa — Date

Senior Manager
Plant Design & Engineering Department
Nuclear Energy Systems & Services Division
POWER SYSTEMS COMPANY
TOSHIBA CORPORATION

**Attachment 1 to the Toshiba Affidavit to the NRC**

**(Proprietary Information)**

DOCUMENTS ENCLOSED (TO BE WITHELD FROM PUBLIC DISCLOSURE PER 2.390)

| Item | Document Description | Document Number | Rev |
|---|---|---|---|
| 1. | Bench top test of Chemical effect for ECCS suction strainers (Proprietary Version) | U7-RHR-M-RPT-DESN-0005 | A |
| 2. | The Evaluation Report for Net Positive Suction Head of Pump in Emergency Core Cooling System (Proprietary Version) | U7-RHR-M-RPT-DESN-0001 | A |
| 3. | The supplementary document for the head loss evaluation report of Japanese ABWR ECCS suction strainer (Proprietary Version) | U7-RHR-M-RPT-DESN-0002 | B |
| 4. | The evaluation example of the head loss of the ECCS suction strainer and pipe in the ECCS pump run-out flow condition (Proprietary Version) | U7-RHR-M-RPT-DESN-0003 | A |

Affidavit

平成２１年登簿第　100　号

# 認　証

嘱託人株式会社東芝部長橘川敬介は、公証人の面前で、添付書面に署名した。

よって、これを認証する。

平成２１年　10　月　21　日、本公証人役場において

横浜市中区羽衣町2丁目7番10号

横浜地方法務局所属

公　証　人

Notary

KENJI　TERANISHI

# 証　明

上記署名は、横浜地方法務局所属公証人の署名に相違ないものであり、かつ、その押印は、真実のものであることを証明する。

平成２１年　10　月　21　日

横浜地方法務局長　紺野清幸

## APOSTILLE

(Convention de La Haye du 5 octobre 1961)

1. Country : JAPAN
   This public document
2. has been signed by KENJI TERANISHI
3. acting in the capacity of Notary of the Yokohama District Legal Affairs Bureau
4. bears the seal/stamp of KENJI TERANISHI , Notary

Certified

5. at Tokyo
6. OCT. 21, 2009
7. by the Ministry of Foreign Affairs
8. 09-№ 300569
9. Seal/stamp :
10. Signature :

Kazutoyo OYABE

For the Minister for Foreign Affairs

Affidavit

Registered No. 166 of 2009.

## Certificate of Acknowledgment of Notary

On this 21st day of October, 2009, before me, KENJI TERANISHI, a notary in and for YOKOHAMA District Legal Affairs Bureau, personally appeared Keisuke KITSUKAWA, Senior Manager of TOSHIBA Corporation, with satisfactory evidence of his identification, affixed his signature to the attached document.

Witness, I set my hand and seal.

Notary | Notary's seal (Official)

KENJI TERANISHI

Kannai-odori Notary office

2-7-10, Hagoromocho, Naka-ku, Yokohama-city, Japan.

Attached to the Yokohama District Legal Affairs Bureau.

# Non-Proprietary Reports

- The supplementary document for the head loss evaluation report of the Japanese ABWR ECCS suction strainer
- The evaluation example of the head loss of the ECCS suction strainer and pipe in the ECCS pump run-out flow condition
- The Evaluation Report for Net Positive Suction Head of Pump in Emergency Core Cooling System
- Bench top test of Chemical effect for ECCS suction strainers

| Toshiba Project Document No. | Rev. No. |
|---|---|
| 7A31-0903-0002 | 2 |

STP Units 3 & 4

| DESIGN REPORT | |
|---|---|
| STPNOC Doc./Dwg. No. | Rev. |
| U7-RHR-M-RPT-DESN-0002 | B |

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

| 2 | Oct.20,2009 | Disposition of CAR-09-170 | M. Murakami Oct 20, 2009 | K. Iwata Oct 20, 2009 | T. Sone Oct 20, 2009 |
|---|---|---|---|---|---|
| Rev. No. | Issue Date | Description | Approved by | Reviewed by | Prepared by |

| Initial Issue Date | Issued by | Approved by | Reviewed by | Prepared by | Document filing No. |
|---|---|---|---|---|---|
| May.27,2009 | Piping Design Group | M.Murakmi May. 27, 2009 | K.Iwata May. 27, 2009 | T.Sone May. 27, 2009 | PDR-2009-100048 |

**TOSHIBA CORPORATION**
**Nuclear Energy Systems & Services Division**

# Record of Revisions

| Rev No. | Date | Description | Approved by | Reviewed by | Prepared by |
|---|---|---|---|---|---|
| 0 | May.27,2009 | First issue | M.Murakmi May. 27, 2009 | K.Iwata May. 27, 2009 | T.Sone May. 27, 2009 |
| 1 | June.24,2009 | Addition of the Attachment E "The results of the head loss test with full scale strainer for Japanese reference BWR plant" | M.Murakmi June. 24, 2009 | K.Iwata June. 23, 2009 | T.Sone June. 23, 2009 |
| 2 | See Cover Page | Disposition of CAR-09-170 | See Cover Page | See Cover Page | See Cover Page |
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# Contents

# 1. ABSTRACT

Rev2

Toshiba replaced the ECCS Suction Strainers made by CCI on Japanese ABWR plant. On this replacement work, Toshiba made the strainer head loss evaluation report for Japanese authority (Construction permit, Reference Documents 1), and submitted to the customer. This document is made for the purpose of explaining the view of the way to calculate the amount of debris generation, debris transport, debris adhesion to strainer, and to evaluate NPSH for ECCS pump.

# 2. Reference Documents

Rev2

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 [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 Appendix

## 3. Process of strainer head loss calculation and evaluation for NPSH

Rev2

Process of strainer head loss calculation and evaluation for ECCS pump NPSH is shown as follows.

(1) The criterion for selection of pipe break point

⇩

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

⇩

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

⇩

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

⇩

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

⇩

(6) The estimate for the head loss of pump suction pipe, valves, tee and strainer itself

⇩

(7) The head loss calculation for flow pass of debris adhered on ECCS strainers and definition of strainer's surface area.

(7)-1 Estimate the debris characteristic for head loss

(7)-2 Estimate the filter form factor of 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 for NPSH of ECCS pump

⇩

(10) The test performance to validate for the design of strainer head loss

(10)-1 Small scale test

(10)-2 Full scale test (for representation)

## 4. Supplemental explanation for each process items

Rev2

### (1) The criterion for selection of pipe break point

According to Section 2.3.1.5 on RG1.82 (Reference document 3), some numbers of breaks in each high-pressure system are selected for all evaluation in Japanese BWR plants. A similar demand is described in the Japanese guideline NISA-322c-05-4 (Reference document 2).

On Reference document 1, we chose the following location as one that we estimated the amount of damage of insulation. These were assumed with much amount of damage of the insulation.

[ ]

The amount of debris generation was calculated for each location. (Refer to Attachment-A ) From the calculated result of the amount of debris generation, I chose location B as the point where the condition was the severest.

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

According to Section 2.3.1.2 on RG1.82 (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 spots is described in NUREG/CR-6224 (Reference document 5) and NEDO-32686 (URG, Reference document 4) on RG1.82 Rev3. It is based on Method 2 described at Section 3.2.1.2.3.2 of URG and prescribes it as the follows, 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 follow,

1) We choose the insulations resembling ones described on Table 2 of URG.

2) We determine the damage pressure of the insulation to be applicable to 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 as the Notes of Table 2 on URG. The pipe diameter for correction is 700A (28B), which is the maximum diameter of pipe in D/W of the actual plants.

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

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 type insulation, a spherical volume of ZOI is calculated to use the following correlation on Section 3.2.1.2.3.2 of URG. Secondary, we find the radius of a ball becoming the spherical volume provided by the above calculation. This radius is a radius of ZOI for one.

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

Where

$V_{ZOI(i)}$ is the volume (ft3) of ZOI for insulation(i);
A is a constant which is function of $P_{dest}$ and break geometry, and is provided in Table 1. In this case, A should be determined for the value of 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.

5) ZOI of various type insulations obtained by the above process is shown as 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 expression (X) | Radius of ZOI obtained by this calculate process | Radius of ZOI provided by the document 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 |

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

According to Section 2.3.2 on RG1.82 (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 RG1.82 Rev3. It is based on the various insulation debris generation and transport factor described at Section 3.2.3.2.5 of URG and the document NISA-322c-05-4 and prescribes it by table (3)-1.

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

| Insulation 's 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 on Table 5 and Table 6 of URG.
2) We determined the factor for combined debris generation and transport of the various insulation to refer to Table 5, Table 6 and Appendix E " Air Jet Impact Testing of Fibrous and Reflective Metallic Insulation" of URG.
3) The view point for the factor for combined debris generation and transport of the various type insulations to be determined by the above process is shown as Table (3)-2.

Table (3)-2 the summary of view point for the factor for combined debris generation and transport (1/2)

| Insulation | Resembling insulation described on Table 5 and Table 6 of URG. | Factor for combined debris generation and transport [1)] | Summary of view point |
|---|---|---|---|
| Calcium Silicate with Aluminum Jacketing | Calcium Silicate with Aluminum Jacketing | 0.1 | Even if the piece of some size included the damage ratio of the Air jet test result, it was around 2%.<br>We suppose a damage ratio with 10% by furthermore, it extends to become tiny depending on PCV spray or ECCS injection, and keep conservatism.<br>Regardless of having grating or not, we suppose all insulation damaged is transport to S/C. |
| Reflective metal insulation | Transco RMI | 0.5 | By the air jet test, the greatest damage ratio was 42%. In addition, the damage shape became tiny in less than 6inch$^2$. We round this value and assumed it 50%.<br>Regardless of having grating or not, we suppose all insulation damaged is transport to S/C. |

Notes

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

Table (3)-2 the summary of view point for the factor for combined debris generation and transport (2/2)

| Insulation | Resembling insulation described on Table 5 and Table 6 of URG. | Factor for combined debris generation and transport [1)] | Summary of view point |
|---|---|---|---|
| Fiber with Aluminum Jacketing | Unjacketed NUKON | 0.28(Above Grating), 0.78(Below Grating) | By the air jet test, a ratio to occur of the debris which became tiny was about 23%. In addition, the possibility that remaining most fell to as a piece very much was predicted by a test result.<br>We suppose a ratio of damage and transport insulation above grating with 28%, considering that it is become tiny with spray and so on. For insulation below grating, we suppose that the insulation which became tiny, and 70% of the remaining insulation transport to S/P. |
| Fiber in RMI | Jacketed NUKON with modified “Sure Hold” Bands, Camloc Strikers and Latches | 0.15 | By the air jet test, a ratio to occur of the debris which became tiny was about 15%, and a piece very much did not occur.<br>We suppose a damage ratio with 15%.<br>Regardless of having grating or not, we suppose all insulation damaged is transport to S/C. |

Notes

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

### (4) The estimate for the another debris generation and transport to S/P

According to Section 2.3.1.6, 2.3.1.7 and 2.3.1.8 on RG1.82 (Reference document 3), we estimate the amount of generation and transport for the debris except insulation debris, such as Sludge, Paint Chips, Rust Flakes and Dust. A similar demand is described in the Japanese guideline NISA-322c-05-4. These are based on URG (Reference document 4) and are prescribed as follows.

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

### (5) The estimate for the distribution to the strainers and adhesion debris on the strainers

According to URG (Reference document 4) , we estimate the amount of the distribution and adhesion debris on the strainers. A similar demand is described in the Japanese guideline NISA-322c-05-4 (Reference document 2).
We suppose that all debris to flow in S/P is not settled, based on Section 3.2.5 of URG. It is shown in Section 3.2.6.2.2 of URG that the debris to flow in S/P is distributed to the strainers according to ratio of ECCS pump flow rate and is adhered on strainer.

## (6) The estimate for the head loss of pump suction pipe, valves, tee and strainer itself

We estimate the head loss of pump suction pipe, valve, tee and strainer itself according to the general technical documents. These calculation processes are refer to Section 4.5 and 4.6 of the evaluation report (Reference document 1)

The flow in strainer and the head loss of strainer itself are different by the condition, such as No debris adhesion and max debris adhesion. (Refer to Figure (6)-1 and Figure (6)-2)
On Japanese NPT, the head loss of strainer itself is calculated by simplified method namely an orifice. In addition, there is the method to evaluate as other methods in detail, such as CFD and so on.

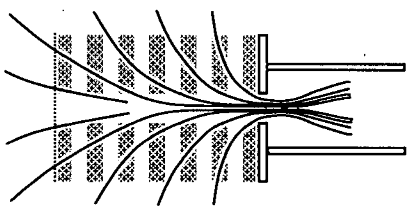

Figure.(6)-1 No debris adhesion

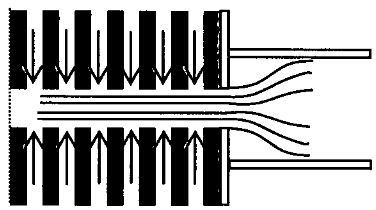

Figure.(6)-2 max debris adhesion

## (7) The head loss calculation for flow pass between debris adhered on ECCS strainers and definition of strainer's surface area.

[Specific surface area ]
The head loss calculation for flow pass between debris adhered on ECCS strainers is calculated by the formula on NUREG/CR-6224 (Reference document 2). The specific surface area of the domestic insulation is necessary to calculate this head loss. It is based on a special property of various debris. The specific surface areas (Sv) of the domestic insulation (Calcium Silicate insulation) are 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. This test result is shown on Attachment - B.

[Empirical shape factor, fg factor]

When we evaluate it with NUREG/CR-6224 evaluation formula, it is necessary to revise it for influence of the shape of the cassette filter. We obtain this factor (fg factor) from head loss test. (Refer to Section 4.3 of Reference document 1 for the detail)

### (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 on RG1.82 (Reference document 3), we suppose the level of water in S/P is the minimum value and estimate the head of S/P water.

According to Section 2.1.1.2 on RG1.82 (Reference document 3), we suppose the temperature of S/P water is maximum value to obtain from accident analysis and estimate the saturated vapor pressure.

According to Section 2.1.1.1 on RG1.82 (Reference document 3), we estimate the inner pressure without increase in containment pressure from the present prior to the postulated LOCAs. A similar demand is described in the Japanese guideline NISA-322c-05-4 (Reference document 2).

### (9) The evaluation for NPSH of ECCS pump

According to Section 2.1.1.9 on RG1.82 (Reference document 3), we evaluate NPSH of ECCS pump in the severest condition for debris adhesion. This evaluation for NPSH is usually carried out on condition that the flow rate is adjusted to rating flow rate on Japan.

## (10) The test performance to validate for the design of strainer head loss

We validate the design calculation of head loss on the condition which the debris is adhered on strainer surface by the means of small scale test. We perform the small scale test for all cassette type strainers purveyed to actual plant. The small scale test means the head loss test to use with a part of strainer, (Refer to Figure (10)-1) Test filter dimension is as same as actual strainer's filter dimension.

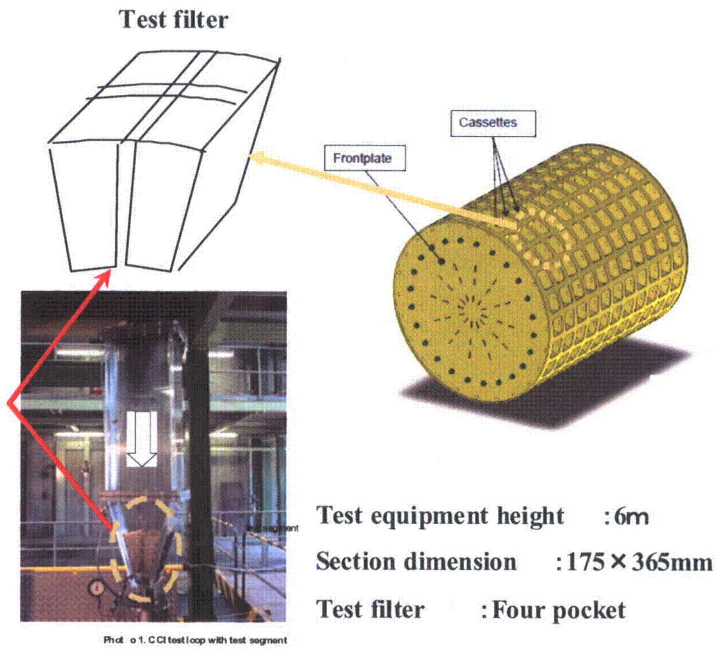


Figure (10)-1 Small scale test outline

The small scale test result, which we performed for the strainers evaluated its NPSH on the evaluation report of Reference document 1, is shown on Attachment –C. We confirmed our design calculation was conservative by this test.

We carried out a full scale test with a representative strainer to confirm the influence of the true scale, shown by Appendix A of Reference document 7. The test strainer simulated actual ABWR HPCF strainer was used on this test. (Refer to Attachment D) We confirmed our design calculation was conservative by this test too, like what it was provided by a small scale test result.(Refer to Attachment E)

Note
"The remaining pages in this document contain proprietary information, and are therefore omitted from this Non-Proprietary version of report"

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**FOR INFORMATION**

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

# Design Report

Title: The evaluation example of the head loss of the ECCS suction strainer and pipe in the ECCS pump run-out flow condition

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| May.27, 2009 | Piping Design Group | M. Murakami May 27, 2009 | K. Iwata May 27, 2009 | T. Sone May 27, 2009 | PDR-2009-100833 |

**TOSHIBA CORPORATION**
**Nuclear Energy Systems & Services Division**

Contents

## 1. Introduction

This document provides the evaluation example of the head loss of the ECCS suction strainers and piping in the ECCS pump run-out flow condition. In this evaluation, the design of the Japanese reference ABWR without insulation layout is used as precondition. (i.e. system and equipment performance, layout of piping, and the ECCS suction strainer design) And it is assumed that the layout of insulations in this evaluation is changed from the Japanese reference ABWR, in consideration of fibrous and calcium silicate insulation being reduced in next ABWR. Therefore, this evaluation is an example, and the practical evaluation will be based on a detailed design in next ABWR.

2. Amount of debris to a strainer

2.1 Amount of insulation debris

In this evaluation, it is assumed that the layout of insulations is changed from the Japanese reference ABWR, in consideration of fibrous and calcium silicate insulation being reduced in next ABWR. Contents for change are as follows.

- Calcium Silicate insulations are changed to RMI or fibrous insulations, and are excluded from the insulation layout. (i.e. Calcium Silicate insulation is not used.)
- The fibrous insulation installed on pipe (> 3in) is changed to RMI.
- The Japanese fibrous insulation (mineral wool) is changed to US fibrous insulation (NUKON).

(1) Amount of insulations in Zone Of Influence in the containment

The amount of insulations for evaluation is defined by selecting Zone of Influence (ZOI) contains a large amount of damaged insulations.

In this evaluation, the inlet part of MSIV F002(B) (28in-MS-2-1) is selected as containing a large amount of fibrous insulations. (Attachement-1)

The amount of insulations in ZOI is shown in the Table 2-1.

Table 2-1. The amount of insulations in ZOI

<table>
<tr><th>Pipe break location</th><th>Insulation Type</th><th>Radius of ZOI</th><th colspan="2">The amount of insulations in the ZOI</th></tr>
<tr><td rowspan="5">Inlet part of MSIV F002(B) (28in-MS-2-1)</td><td>Fibrous insulation with metal jacketing<br>(Same as "Jacketed NUKON with modified "Sure-Hold" Bands, Calmoc Strikers and Latches )</td><td>7.4 D</td><td colspan="2">0 ($m^3$)</td></tr>
<tr><td rowspan="2">Fibrous insulation without jacketing<br>(Same as "Unjacketed NUKON".<br>And include covered by metal plate.)</td><td rowspan="2">11.4 D</td><td>Above grating</td><td>0.14 ($m^3$)</td></tr>
<tr><td>Below grating</td><td>0.88 ($m^3$)</td></tr>
<tr><td>Calcium Silicate with Aluminum jacketing</td><td>7.4 D</td><td colspan="2">0 ($m^3$)</td></tr>
<tr><td>RMI<br>(Reflective Metal Insulation)</td><td>7.4 D</td><td colspan="2">734.93 ($m^2$)</td></tr>
</table>

(2) Insulation debris generation and transport

The amount of insulation debris in the Table 2-2 shows debris generation in the containment, and transport to Suppression Pool (S/P). It is assumed that all of insulation debris in the Table 2-2 adheres to the filter of the ECCS suction strainers.

Table 2-2. The amount of insulation debris generation and transport

<table>
<tr><th colspan="2">Insulation Type</th><th>Factors for debris generation and transport</th><th>The amount of insulation debris</th></tr>
<tr><td colspan="2">Fibrous insulation with metal jacketing<br>(Same as "Jacketed NUKON with modified "Sure-Hold" Bands, Calmoc Strikers and Latches )</td><td>0.15</td><td>0 (m<sup>3</sup>)</td></tr>
<tr><td rowspan="2">Fibrous insulation without jacketing<br>(Same as "Unjacketed NUKON".<br>And include covered by metal plate.)</td><td>Above grating</td><td>0.28</td><td rowspan="2">0.73 (m<sup>3</sup>)</td></tr>
<tr><td>Below grating</td><td>0.78</td></tr>
<tr><td colspan="2">Calcium Silicate with Aluminum jacketing</td><td>0.1</td><td>0 (m<sup>3</sup>)</td></tr>
<tr><td colspan="2">RMI</td><td>0.5</td><td>367.47 (m<sup>2</sup>)</td></tr>
</table>

(3) Other debris

The amounts of other debris are as follows.

This is same as the Japanese reference ABWR's.

- Paint chips: 85lb (39kg)
- Rust Flakes: 50lb (23kg)
- Dust /Dirt: 150lb (68kg)
- Sludge: 195lb (89kg)

2.2 Evaluation for the amount of debris adhesion to a strainer

(1) Assumption of single failure

With assumption of a single failure of an Emergency Diesel Generator (D/G) which is equivalent of the hardest single failure to ECCS, the system number are shown in Table 2-3.

Table 2-3. System number

| System | System number | | | |
|---|---|---|---|---|
| | D/G(A) | D/G(B) | D/G(C) | D/G(C) accident (total) |
| Residual Heat Removal (RHR) | 1 | 1 | 1 | 2 |
| High Pressure Core Flooder (HPCF) | - | 1 | 1 | 1 |

(2) Flow rate and Debris distribution

The run-out Flow rates of the ECCS pumps are shown in the Table 2-4

Table 2-4. Flow rate (Run-out Flow)

| System | Flow Rate ($m^3/h$) |
|---|---|
| RHR | 1130 |
| HPCF | 890 |

It is assumed that insulation debris transported to S/P and other sludge evenly adheres to a strainer in proportion with the flow rate of each system number.

The amounts of debris adhering to each strainer are shown in Table 2-5.

Table 2-5. The amount of debris on the ECCS suction strainers

| system | Fibrous insulation ($m^3$) | Calcium Silicate ($m^3$) | RMI ($m^2$) | Sludge (kg) | Paint Chips (kg) | Rust Flakes (kg) | Dust /Dirt (kg) |
|---|---|---|---|---|---|---|---|
| RHR | 0.261 | 0 | 131.821 | 31.927 | 13.990 | 8.251 | 24.394 |
| HPCF | 0.206 | 0 | 103.823 | 25.140 | 11.019 | 6.498 | 19.213 |

## 3. Head loss caused by debris blockage

### 3.1 Calculation of head loss caused by debris blockage

A calculation of head loss caused by debris blockage is same as the Japanese reference ABWR's.

- Increase of head loss caused by fibrous and particle debris blocakge

  NUREG/CR-6224 is applied, and is corrected by the fg-factor.

- Increase of head loss caused by RMI debris blockage

  The equation of head loss calculation for RMI debris shown in NUREG/CR-6808 is applied.

### 3.2 Evaluation conditions

(1) Filtering surface of the ECCS suction strainers

Filtering surface of each ECCS suction strainers is as follows.

- RHR (2 strainers per 1 system): 47.00 $m^2$
- HPCF (2 strainers per 1 system): 36.76 $m^2$

(2) Property value of debris for head loss calculation

The values used for head loss calculation is shown in the Table 3-1.

(3) Suppression Pool water temperature

The S/P water temperature for calculation of head loss caused by debris blockage is 47 degrees Celsius same as the Japanese reference ABWR.

3.3 Head loss caused by debris blockage

Increase of head loss on the ECCS suction strainer caused by debris is shown in the Table 3-3. The head loss shown in the Table 3-3 is value of peak of "Thin-Bed-Effect".

Table 3-3. Head loss caused by debris blockage

| | RHR | HPCF |
|---|---|---|
| Increase of head loss caused by fibrous and particle debris blockage (i.e. fibrous insulation, sludge, paint chips, rust flakes, and dust/dirt) | 0.48 m | 0.49 m |
| Increase of head loss caused by RMI debris blockage | 0.01 m | 0.01 m |
| Total | 0.49 m | 0.50 m |

NOTES: The value of table 3-3 rounded off decimal the third place and displayed a hundredth.

3.4 Strainer head loss without debris and Pipe head loss

In this evaluation, the run-out flow is applied as flow rate.

A calculation method of head loss for strainer without debris, Tee connected to strainer and pipe of the down stream from the Tee is similar to the Japanese reference ABWR's.

The ECCS suction strainer without debris and pipe head loss is shown in the Table 3-4.

Table 3-4. The ECCS suction strainer without debris and pipe head loss

| | Head Loss (m) | | | |
|---|---|---|---|---|
| System | The ECCS suction strainer (without debris) | Pipe | | |
| | | Tee connected to strainer | pipe of the down stream from the Tee | Total |
| RHR | 0.11 | 0.34 | 0.36 | 0.49 |
| HPCF | 0.02 | 0.28 | 0.81 | 0.73 |

4. Evaluation for NPSH in ECCS

4.1 Result of evaluation for NPSH in ECCS

We adopt comparison evaluation with Required NPSH by ECCS pump and NPSH after the debris adhesion such as the damaged insulation and so on which shown in Clause 3.

(1) The evaluation for NPSH no adhesion of debris

The results of the evaluation for NPSH of the ECCS pump at no adhesion of debris are shown in the Table 4-1 and 4-2.

Table 4-1. The evaluation for NPSH of the RHR pump at no adhesion of debris

| | Evaluation for NPSH |
|---|---|
| He: Water head | 3.46m |
| H0: Space pressure of S/P | 10.77m |
| Hv: Saturated Vapor pressure | 10.77m |
| H1: Pipe head loss | 0.70m |
| H2: Strainer head loss (without debris) | 0.11m |
| NPSH (He+H0-Hv-H1-H2) | 2.65m |
| NPSH required by pump | 2.0m |

Table 4-2. The evaluation for NPSH of the HPCF pump at no adhesion of debris

| | Evaluation for NPSH |
|---|---|
| He: Water head | 3.46m |
| H0: Space pressure of S/P | 10.77m |
| Hv: Saturated Vapor pressure | 10.77m |
| H1: Pipe head loss | 1.09m |
| H2: Strainer head loss (without debris) | 0.02m |
| NPSH (He+H0-Hv-H1-H2) | 2.35m |
| NPSH required by pump | 1.7m |

NOTES:

Based on ITAAC of DCD/Tire1, "H0" is atmospheric pressure, and "Hv" is saturated vapor pressure at 100 degrees Celsius of water temperature. (Attachment-2)

(2) The evaluation for NPSH at adhesion of debris

The results of the evaluation for NPSH of the ECCS pump at adhesion of debris are shown in the Table 4-3 and 4-4.

Table 4-3. The evaluation for NPSH of the RHR pump at adhesion of debris

| | Evaluation for NPSH |
|---|---|
| He: Water head | 3.46m |
| H0: Space pressure of S/P | 10.77m |
| Hv: Saturated Vapor pressure | 10.77m |
| H1: Pipe head loss | 0.70m |
| H2: Strainer head loss (without debris) | 0.11m |
| Hd: Head loss caused by debris blockage | 0.49m |
| NPSH (He+H0-Hv-H1-H2-Hd) | 2.16m |
| NPSH required by pump | 2.0m |

Table 4-4. The evaluation for NPSH of the HPCF pump at no adhesion of debris

| | Evaluation for NPSH |
|---|---|
| He: Water head | 3.46m |
| H0: Space pressure of S/P | 10.77m |
| Hv: Saturated Vapor pressure | 10.77m |
| H1: Pipe head loss | 1.09m |
| H2: Strainer head loss (without debris) | 0.02m |
| Hd: Head loss caused by debris blockage | 0.50m |
| NPSH (He+H0-Hv-H1-H2-Hd) | 1.85m |
| NPSH required by pump | 1.7m |

(3) The result of evaluation for NPSH at adhesion of debris

The result of the evaluation for ECCS pump NPSH is shown in the Table 4-5.

Table 4-5. Evaluation for ECCS pumps NPSH

| System | NPSH required (m) | NPSH (at no adhesion of debris) (m) | NPSH at adhesion of debris (NPSH - Head loss for adhesion of debris) (m) |
|---|---|---|---|
| RHR | 2.0 | 2.65 | 2.16 |
| HPCF | 1.7 | 2.35 | 1.85 |

As shown in the Table 4-5, ECCS pump NPSH after the debris adhesion based on nominal dimensions exceeds Required ECCS pump NPSH. Therefore Required NPSH is secured in the operational condition of the ECCS pump.

Attachment-2

## Table 2.4.1 Residual Heat Removal System (Continued)

| Inspections, Tests, Analyses and Acceptance Criteria | | |
|---|---|---|
| **Design Commitment** | **Inspections, Tests, Analyses** | **Acceptance Criteria** |
| 4. continued<br>c. The RHR pumps have sufficient NPSH. | 4. continued<br>c. Inspections, tests and analyses will be performed upon the as -built RHR System. NPSH tests of the pumps will be performed in a test facility. The analyses will consider the effects of:<br>– Pressure losses for pump inlet piping and components.<br>– Suction from the suppression pool with water level at the minimum value.<br>– 50% blockage of pump suction strainers.<br>– Design basis fluid temperature (100°C).<br>– Containment at atmospheric pressure. | 4. continued<br>c. The available NPSH exceeds the NPSH required by the pumps. |

## Table 2.4.2 High Pressure Core Flooder System (Continued)

| Inspections, Tests, Analyses and Acceptance Criteria | | |
|---|---|---|
| **Design Commitment** | **Inspections, Tests, Analyses** | **Acceptance Criteria** |
| d. The HPCF System flow in each division is not less than a value corresponding to a straight line between a flow of 182 $m^3$/h at a differential pressure of 8.12 MPa and a flow of 727 $m^3$/h at a differential pressure of 0.69 MPa. | d. Tests will be conducted on each division of the as-built HPCF System in the HPCF high pressure flooder mode. Analyses will be performed to convert the test results to the conditions of the Design Commitment. | d. The converted HPCF flow satisfies the following:<br>The HPCF System flow in each division is not less than a value corresponding to a straight line between a flow of 182 $m^3$/h at a differential pressure of 8.12 MPa and a flow of 727 $m^3$/h at a differential pressure of 0.69 MPa. |
| e. The HPCF System has the capability to deliver at least 50% of the flow rates in item 3d with 171°C water at the pump suction. | e. Analyses will be performed of the as-built HPCF System to assess the system flow capability with 171°C water at the pump suction. | e. The HPCF System has the capability to deliver at least 50% of the flow rates in item 3d with 171°C water at the pump suction. |
| f. System flow into the reactor vessel is achieved within 16 seconds of receipt of an initiation signal and power available at the emergency busses. | f. Tests will be conducted on each HPCF division using simulated initiation signals. | f. The HPCF System flow is achieved within 16 seconds of receipt of a simulated initiation signal. |
| g. The HPCF pumps have sufficient NPSH available at the pumps. | g. Inspections, tests and analyses will be performed upon the as-built system. NPSH tests of the pumps will be performed in a test facility. The analyses will consider the effects of:<br>- Pressure losses for pump inlet piping and components.<br>- Suction from the suppression pool with water level at the minimum value.<br>- 50% minimum blockage of the pump suction strainers. | g. The available NPSH exceeds the NPSH required by the pumps. |

## Table 2.4.2 High Pressure Core Flooder System (Continued)

| Inspections, Tests, Analyses and Acceptance Criteria | | |
|---|---|---|
| **Design Commitment** | **Inspections, Tests, Analyses** | **Acceptance Criteria** |
| g. (continued) | g. (continued)<br>- Design basis fluid temperature (100°C).<br>- Containment at atmospheric pressure. | g. (continued) |
| h. Automatic transfer of pump suction from the CST to the suppression pool occurs when a low CST water level or high suppression pool water level signal exists. | h. Tests will be conducted on each HPCF division using simulated input signals for each process variable to cause trip conditions in two, three, and four instrument channels of the same process variable. | h. HPCF System receives suction transfer initiation signal. |
| i. Following receipt of a suction transfer initiation signal, the HPCF System automatically switches pump suction. | i. Test will be conducted on each HPCF division using simulated suction transfer initiation signals. | i. Upon receipt of a simulated suction transfer initiation signal, the following occurs:<br>- Suppression pool suction valve opens.<br>- CST suction valve closes. |
| j. When a high water level signal in the reactor pressure vessel exists, the reactor vessel injection valve is automatically closed. | j. Tests will be conducted on each HPCF division using simulated high reactor water level signals to cause trip conditions in two, three, and four instrument channels of water level variable. | j. The HPCF System receives a signal to close the reactor vessel injection valve. |
| k. Following receipt of an injection valve closure signal, the HPCF System automatically closes the vessel injection valve. | k. Tests will be conducted on each HPCF division using a simulated injection valve closure signal. | k. Upon receipt of a simulated injection valve closure signal, the reactor vessel injection valve closes. |

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For information

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

# Design Report

Title: The Evaluation Report for Net Positive Suction Head of Pump in Emergency Core Cooling System

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**TOSHIBA CORPORATION**
**Nuclear Energy Systems & Services Division**

[ ] The Evaluation Report for Net Positive Suction Head of Pump in Emergency Core Cooling System

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Note

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**FOR INFORMATION**

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

# Design Report

Title: Bench top test of Chemical effect for ECCS suction strainers

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**TOSHIBA CORPORATION**
Nuclear Energy Systems & Services Division

# Contents

## 1. Summary

NRC have required to address 12 issues for US BWR Plants, that was obtained from knowledge of GSI-191 issue on US PWR
This document is shown as the result of bench- top test, carried out for purpose of addressing Chemical effect of these issues for ECCS Suction Strainers.

## 2. Chemical effect bench-top test

Chemical effect test have two tests, such as dissolution test and precipitation test. These are similar to the tests in WCAP-16530-NP. The detail of this test is shown on Attachment A.

### 2.1 Test pieces and condition

**(1) Test pieces**

Test pieces are shown on Table 2-1.

Table 2-1 test pieces of chemical effect test

| Test pieces | | Equipments with the possibility to be installed in primary containment vessel |
|---|---|---|
| Insulation | Glass wool [1] | The insulation of piping |
| | Mineral wool (Rock wool) [1] | |
| | Calcium Silicate [1] | |
| Metal | Carbon steel (uncoated) | The steel for support and so on.<br>Pipe<br>Equipments<br>etc |
| | Aluminum | The jacket for insulation<br>The foil in RMI<br>The accessories of valve<br>etc |
| Galvanized iron | Zinc plating iron | The duct of HVAC<br>etc |

Note

1) Japanese insulation

**(2) The water condition**

The water condition at post LOCA to be assumed on these tests is shown as follows,

1) The water in S/P is pure water. Its temperature raise by 97 degree and falls afterwards.
2) The SLC action is assumed. [1] In this case, the water in S/P is more than PH7.

   Note

   1) There is possibility that SLC system is acted after LOCA on US BWR Plants.

(3) **Scenario to make the chemical product**

According to the scenario to make the chemical product shown on the Table 2-2., the combination of dissolution test and precipitation test is carried out.

Table 2-2 the combination of Dissolution test and Precipitation test

| Case | Dissolution test | Precipitation test |
|---|---|---|
| Case A | The material is dissolved in high temperature water(97℃) | The temperature drop of this water is conducted to create the chemical product. |
| Case B | | The water is more than PH 7 by SLC action, the chemical product is created. |
| Case C | The insulation is dissolved in high temperature water(97℃), thereby this water is more than PH7. Aluminum is dissolved in this water. | The temperature drop of this water is conducted to create the chemical product. |
| Case D | | PH of the water is increased by SLC action, the chemical product is created. |

## 2.2 Test method

The method of dissolution test and precipitation test is shown on Figure 2-1.Test device is shown on Figure 2-2.

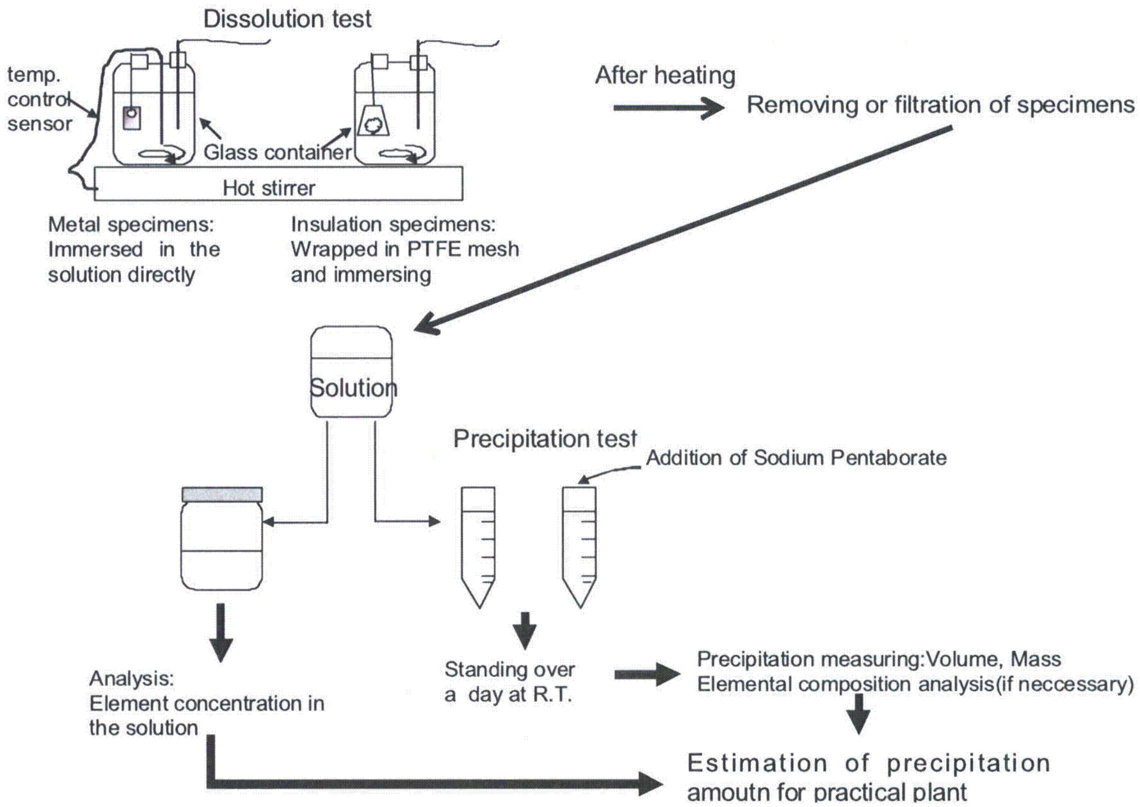



Figure 2-1 Test method

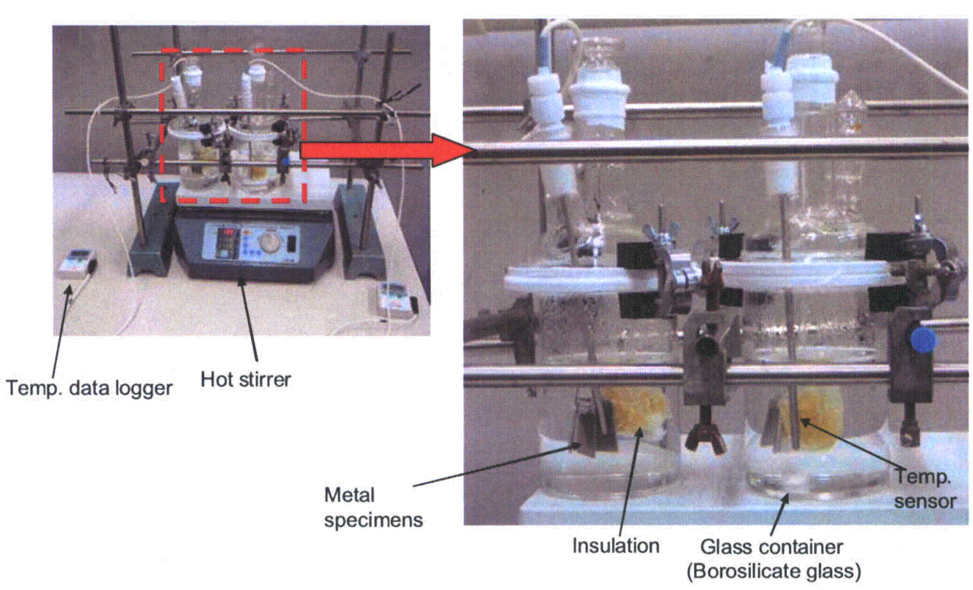



Figure 2-2 Test device

### 2.3 Test matrix

Test matrix for this dissolution test and precipitation test is shown on Table 2-3.

Table 2-3 Test Matrix

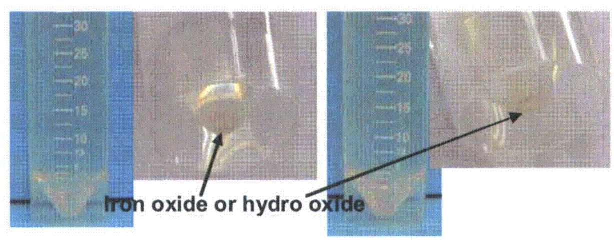
| Material | | Dissolution test | | | | Precipitation test | Combination Case |
|---|---|---|---|---|---|---|---|
| | | Solution | Time/ h | | Temperature/℃ | Method of precipitation | |
| Insulation | Glass wool | Pure water | (24) | 100 | 97 | Cooling samples to R.T. | Case A |
| | | | | | | Addition of sodium pentaborate | Case B |
| | Mineral wool (Rock wool) | Pure water | (24) | 100 | 97 | Cooling samples to R.T. | Case A |
| | | | | | | Addition of sodium pentaborate | Case B |
| | Calcium Silicate | Pure water | (24) | 100 | 97 | Cooling samples to R.T. | Case A |
| | | | | | | Addition of sodium pentaborate | Case B |
| Metal | Carbon steel without coating | Pure water | (24) | 100 | 97 | Cooling samples to R.T. | Case A |
| | | | | | | Addition of sodium pentaborate | Case B |
| | Zinc plating iron | Pure water | (24) | 100 | 97 | Cooling samples to R.T. | Case A |
| | | | | | | Addition of sodium pentaborate | Case B |
| Galvanized iron | Aluminum | Pure water | (24) | 100 | 97 | Cooling samples to R.T. | Case A |
| | | | | | | Addition of sodium pentaborate | Case B |
| Mix | Aluminum+ Grass wool | Pure water | (24) | 100 | 97 | Cooling samples to R.T. | Case C |
| | | | | | | Addition of sodium pentaborate | Case D |

## 2.4 Result of Bench-top test

The results of dissolution test are that dissolution concentration of insulations and metals in BWR condition were basically low, as shown below.

1) For insulation, solution composition is almost consistent with original composition.
2) For carbon steel, small amount of iron was in the solution.
3) Al in solution was not detected. Specimens gained mass by 0xidation
4) For zinc plating iron, zinc dissolved slight. Iron (base metal) was not detected.
5) For mixing test of glass wool and aluminum, mass of aluminum metal is dissolved by PH rising. But it is slight.

Also, the results of precipitation test are that except with carbon steel, precipitation was not observed in visual, meanwhile the precipitation of carbon steel was observed in small amount. (Shown on Figure 2-3)




(a) Cooling (b) Borate add

Figure2-3 Precipitation test result for carbon steel

## 3. Conclusion

The fiber insulation, Calcium Silicate insulation and Aluminum metal will be not installed in RCCV of STP-3/4. In addition to that, there is very little chemical product that was generated on this bench- top test. Therefore, we suppose that the impact of chemical effect is very small on STP-3/4.

# Study of chemical effects for ABWR ECCS Suction Strainer

## -Bench top test-

# Chemical Effects Bench-Top Test

Test materials choice
(representative materials in PCV)

↓

Dissolution test under S/P condition at LOCA

↓

Precipitation test under
post-LOCA condition

↓

Estimation of precipitation possibility

# Test Materials and Composition

## [Insulation]

(%)

| | $SiO_2$ | CaO | $Al_2O3$ | MgO | $Na_2O$ | $Fe_2O_3$ | $ZrO_2$ | $SO_3$ | $K_2O$ | SrO | $P_2O_5$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Glass wool | 63.5 | 6.5 | 4 | 3.5 | 15 | | | | | | |
| Rock wool | 43.7 | 34.2 | 16.6 | 4.4 | – | | | | | | |
| Calsium silicate | 50.2 | 44.7 | 0.8 | 0.5 | – | 0.23 | 0.48 | 0.32 | 0.1 | 0.09 | 0.04 |

## [Metal]

| | JIS* Code | Fe | Al | Si | C | Mn | P | S | Mg | Cr | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Carbon steel | SPCC | 99.7 | – | 0.01 | 0.049 | 0.22 | 0.013 | 0.014 | – | – | – |
| Aluminum | A5052 | 0.27 | 96.8 | 0.08 | – | – | – | – | 2.63 | 0.18 | 0.01 |

* : Japan Industrial Standard

## [Galvanized iron]

| | JIS* Code | Fe | Al | Si | C | Mn | P | S | Mg | Cr | Cu |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Zinc plating iron | Base : SPCC, Zinc plating 5 $\mu$ m | | | | | | | | | | |

* : Japan Industrial Standard

# Test Matrix -Dissolution test-

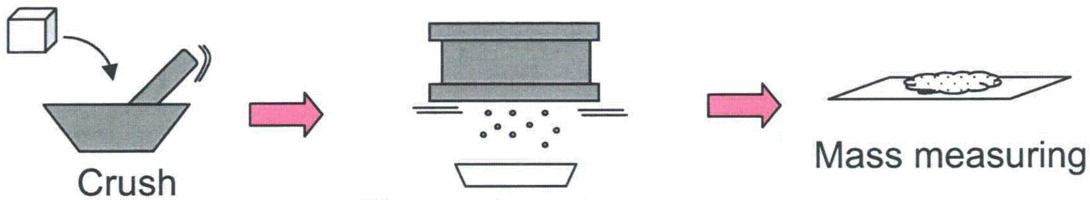
| | Material | Solution | Temp./ ℃ | Time / h | |
|---|---|---|---|---|---|
| Insulation | Glass wool | Pure water | 97 | 24 | 100 |
| | Rock wool | Pure water | 97 | 24 | 100 |
| | Calcium silicate | Pure water | 97 | 24 | 100 |
| Metal | Carbon steel | Pure water | 97 | 24 | 100 |
| | Aluminum | Pure water | 97 | 24 | 100 |
| Galvanized iron | Zinc plating iron | Pure water | 97 | 24 | 100 |
| Mix | Glass wool + Aluminum | Pure water | 97 | 24 | 100 |

Pure water : BWR condition

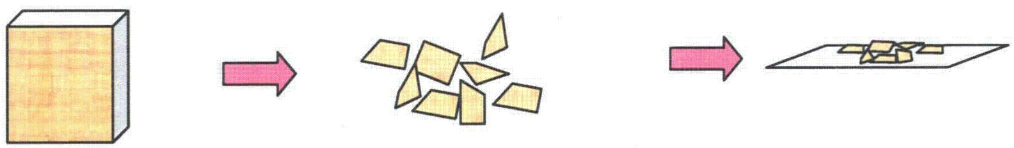
Material / Solution ratio
Insulation : 0.3 g/ 300mL, Metal 38 $cm^2$surface/ 300mL

# Specimens Preparation

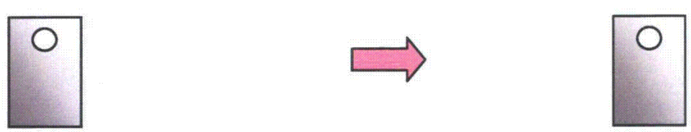
## 1.Calcium silicate



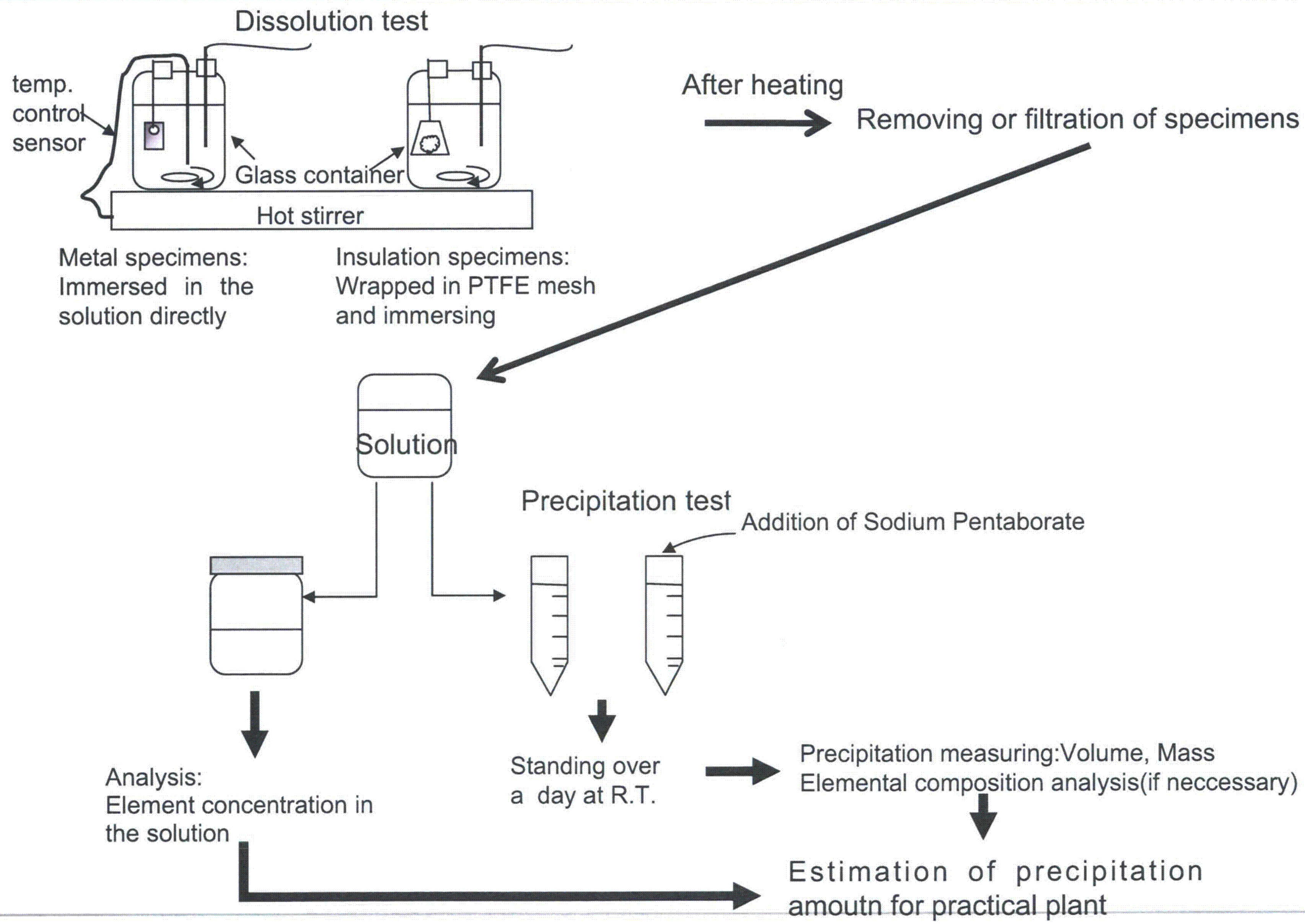

## 2. Glass wool and Rock wool



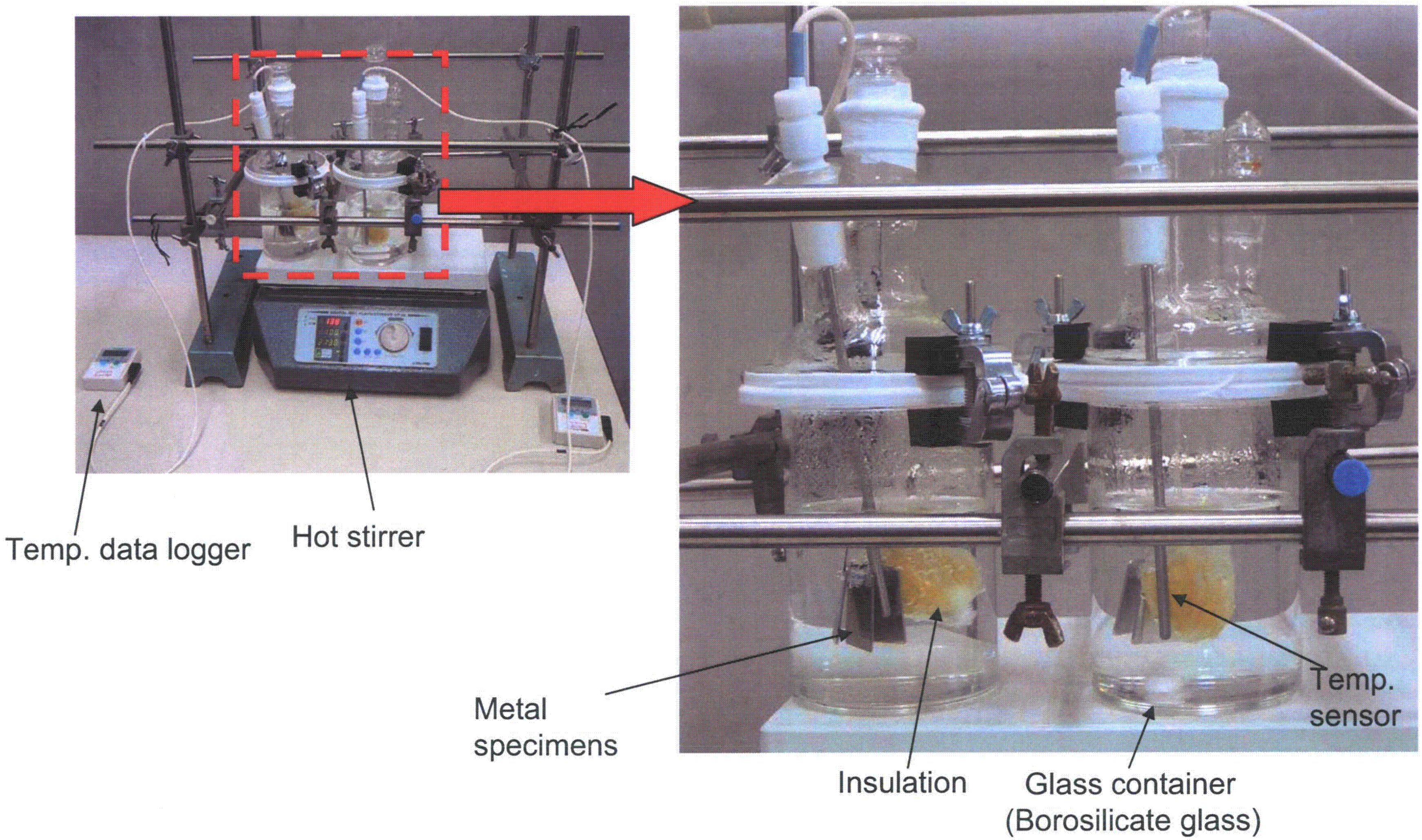

## 3. Metals



# Test Procedure



# Experimental instrument



# Test Results -Dissolution test-

[Pure water]

Insulation: Solution composition is almost consistent with original composition.
Solution's pH rose by dissolution of mineral oxide.

Carbon steel: Small amount of iron was in the solution. Mass loss of specimens were due to fall of rust (adhere to magnet)

Aluminum: Al in solution was not detected. Specimens gained mass by oxidation.

Zinc plating iron : Zinc dissolved slightly. Iron (base metal) was not detected.

Glass wool + Aluminum: Mass of Al metal specimens gained but slightly dissolved (by pH rising).

# Photos of specimens -Dissolution test-

# Photos of specimens-Dissolution test-

# Photos of specimens-Dissolution test-

# Photos of specimens-Dissolution test-

# Test Results -Precipitation test-

Carbon steel in pure water : Very small amount of precipitation (rust and/or iron hydro oxide) was observed.

In another test of pure water, precipitation was not observed.

# Photos of solutions-Precipitation test-

# Photos of solutions-Precipitation test-

# Estimation of precipitation

Insulation (Dissolved composition)

Solubility data of Oxide (around 25℃)

$SiO_2$ : 0.012 g/100 mL
CaO : $CaO + H_2O \rightarrow Ca(OH)_2$ ・・・0.17g/100 mL
$Na_2O$ : $Na_2O + H_2O \rightarrow 2NaOH$ ・・・Soluble
MgO : 0.0086 g/100 mL

Dissolved composition of insulations in 97℃ solution can dissolve at R. T..
➡ Not precipitate by cooling

*Aluminum oxide and aluminum hydro oxide are insoluble in neutral solution. Aluminum existed in the solution was another chemical form or was suspended. In visual, suspension material was not observed.

Even if suspended, its influence against strainer is regarded as negligible because the ratio of material / solution of actual plant is lower than that of this experiment (1/10 ~ 1/100).

# Estimation of precipitation

## Insulation （Reaction product）

Prediction of reaction product by chemical equilibrium calculation code [1)]

Note

1) Code name is “ Gem”. It is belonging to calculation code “ MALT2”.

[System 1] $SiO_2$,CaO,$Na_2O$,$Al_2O_3$(or $Al(OH)_3$), $H_2O$ at 97 ℃

- $NaAlSiO_4$ : Solubility data not available. In this experiment, suspended material was not observed. Its influence against strainer is regarded as negligible because the ratio of material / solution of actual plant is lower than that of this experiment (1/10 ～ 1/100).
- $Ca(OH)_2$ : Product amount estimated was lower than solubility
- $NaAlO_2$ : Soluble
- $NaSiO_3$ : Soluble

[System 2] $SiO_2$,CaO,$Na_2O$,$Al_2O_3$(or $Al(OH)_3$), $H_2O$,$H_3BO_3$(or $Na_2B_4O_7$) at 25 ℃

- $NaSiO_3$ : Soluble
- $Ca(OH)_2$ : Product amount estimated was lower than solubility

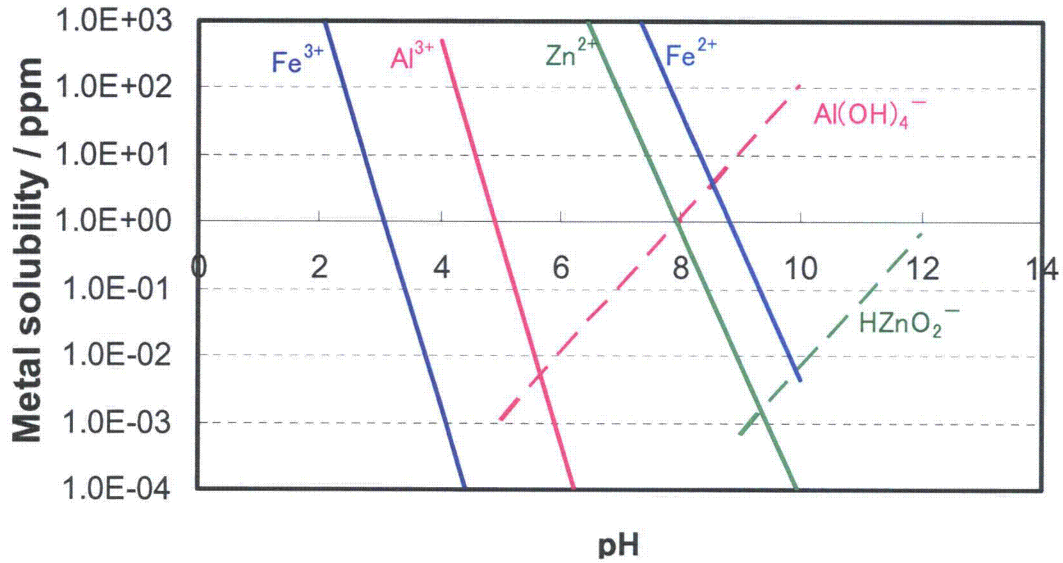
➡ Remarkable precipitation did not occure from insulation

# Estimation of precipitation

Metal

Solubility calculation of metal

(According to solubility products of metal hydro oxide around 25℃)




Iron : $Fe^{3+}$ is insoluble at neutral pH. In the experiment, precipitation was very small amount and could not be analyzed. Large volume experiment is required to confirm the precise amount of iron precipitation. $Fe^{2+}$ is soluble at neutral pH.

Aluminum : In the pure water experiments, metal aluminum didn't dissolve or dissolved less than solubility. → not precipitate

Zinc plating iron : In the experiment, zinc dissolved less than solubility.→ not precipitate

# Summary

- Dissolution concentration of insulations and metals in ABWR condition were basically low.
- Except with (Uncoated) Carbon steel, precipitation was not observed in visual.
- About carbon steel, very small amount of iron precipitation was observed.