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April 11, 2005

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U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D. C. 20555-0001

Gentlemen:

In the Matter of) Docket No. 50-328
Tennessee Valley Authority)

SEQUOYAH NUCLEAR PLANT (SQN) - UNIT 2 - TECHNICAL SPECIFICATIONS (TS) CHANGE 03-06 - CHANGE INSPECTION SCOPE FOR STEAM GENERATOR (SG) TUBES - REVISED REQUEST

References: 1) TVA letter to NRC dated December 2, 2004, "Sequoyah Nuclear Plant (SQN) - Unit 2 - Technical Specifications (TS) Change 03-06 - Change Inspection Scope for Steam Generator (SG) Tubes"

2) TVA letter to NRC dated February 15, 2005, "Sequoyah Nuclear Plant (SQN) - Unit 2 - Technical Specifications (TS) Change 03-06 - Change Inspection Scope for Steam Generator (SG) Tubes - Revised Request"

TVA is submitting this letter in response to additional questions received from NRC staff via e-mail regarding TS Change 03-06 to License DPR-79 for Unit 2. Enclosure 1 provides clarification of the reporting requirements and clarifies the W* distance and how that distance is applied at SQN. Enclosure 2 addresses NRC staff questions on how the total number of indications is determined and the effect that severe accident temperatures and pressures will have on the leakage integrity of the joint.

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There are no commitments contained in this submittal. If you have any questions about this change, please contact me at (423) 843-7170 or Jim Smith at (423) 843-6672.

I declare under penalty of perjury that the foregoing is true and correct. Executed on this 11th day of April 2005.

Sincerely,

Original signed by

Paul Pace
Manager, Site Licensing and
Industry Affairs

Enclosures

1. Clarification of Proposed TS Changes
2. Response to NRC Technical Questions

Enclosures
cc (Enclosures):
Framatome ANP, Inc.
P. O. Box 10935
Lynchburg, Virginia 24506-0935
ATTN: Mr. Frank Masseth

Mr. Lawrence E. Nanney, Director
Division of Radiological Health
Third Floor
L&C Annex
401 Church Street
Nashville, Tennessee 37243-1532

Mr. Douglas V. Pickett, Senior Project Manager
U.S. Nuclear Regulatory Commission
Mail Stop 08G9
One White Flint North
11555 Rockville Pike
Rockville, Maryland 20852-2739

PLP:JDS:JWP:PMB
Enclosures
cc (Enclosures):
R. J. Beecken, LP 6A-C
A. S. Bhatnagar, LP 6A-C
L. S. Bryant, LP 6A-C
J. R. Douet, OPS 4A-SQN
J. C. Fornicola, LP 6A-C
D. A. Kulisek, POB 2B-SQN
F. C. Mashburn, Jr., BR 4X-C
T. J. Niessen, OPS 4A-SQN
NSRB Support, LP 5M-C
H. R. Rogers, OPS 4A-SQN
K. W. Singer, LP 6A-C
E. J. Vigluicci, ET 10A-K
WBN Site Licensing Files, ADM 1L-WBN
EDMS, WTC A-K (Re: S64 041202 800 and S64 050215 800)

I:License/TS Submittals/TSC 03-06 wstar r2

ENCLOSURE 1

TENNESSEE VALLEY AUTHORITY
SEQUOYAH NUCLEAR PLANT (SQN) UNIT 2
CLARIFICATION OF PROPOSED TS CHANGES

This enclosure addresses the following NRC questions regarding Technical Specification (TS) Change 03-06.

Question 1)

TS 4.4.5.5.d.1 only requires the licensee to notify the staff if the voltage-based alternate repair criteria leakage exceeds the "limit." The proposed second sentence has no effect on the reporting requirement. The NRC should be notified when the total accident induced leakage (from all sources) exceeds the "limit."

Response

TS 4.4.5.5.d.1 is being revised to require NRC notification if the total leakage exceeds the leakage limit. See Insert 4 on page E1-5

Question 2)

The second sentence of proposed TS 4.4.5.5.e could be misconstrued to apply to all indications in the steam generator. We believe that reporting requirements should be limited to degradation within the tubesheet region.

Response

TS 4.4.5.5.e is being revised to state that the report will include the number of indications within the tubesheet region and the location of the indications. See Insert 5

Question 3)

Proposed TS 4.4.5.4.a.11(b) could lead to confusion. The first sentence describes how the WCAP defines the W* distance. The second sentence describes how the licensee defines the W* distance. The third sentence indicates the inspection extent. Given the licensee's definition of the W* distance (which presumably is the "true" definition) and the requirement (4.4.5.4.a.6) that degradation within the W* distance will be plugged, it appears possible that degradation within 7.12 inches from the bottom of the WEXTEX expansion could remain in service for tubes where the bottom of the WEXTEX expansion is greater than 0.88 inch from the top of the tubesheet. We believe the "true" definition of the W* distance needs to combine the two definitions. For example, the W* distance is the larger of the following two distances as measured from the top-of-the-tubesheet (TTS): (a) 8 inches below the top-of-the-tubesheet (TTS) or (b) 7 inches below the bottom of the WEXTEX transition plus the uncertainty associated with determining the distance below the bottom of the WEXTEX transition (approximately 0.12 inches). Please provide clarification.

Response

TS 4.4.5.4.a.11(b) is being revised to state that the W* distance is the larger of the following two distances as measured from the top-of-the-tubesheet (TTS): (a) 8 inches below the TTS or (b) 7-inches below the bottom of the WEXTEX transition plus the uncertainty associated with determining the distance below the bottom of the WEXTEX transition as defined by WCAP-14797, Revision 2. See Insert 3 where:

V_{URL}	=	upper voltage repair limit
V_{LRL}	=	lower voltage repair limit
V_{MURL}	=	mid-cycle upper voltage repair limit based on time into cycle
V_{MLRL}	=	mid-cycle lower voltage repair limit based on V_{MURL} and time into cycle
Δt	=	length of time since last scheduled inspection during which V_{URL} and V_{LRL} were implemented
CL	=	cycle length (the time between two scheduled steam generator inspections)
V_{SL}	=	structural limit voltage
Gr	=	average growth rate per cycle length
NDE	=	95-percent cumulative probability allowance for nondestructive examination uncertainty (i.e., a value of 20-percent has been approved by NRC)

Implementation of these mid-cycle repair limits should follow the same approach as in TS 4.4.5.4.a.10.a, 4.4.5.4.a.10.b, and 4.4.5.4.a.10.c.

Note 1: The lower voltage repair limit is 1.0 volt for 3/4-inch diameter tubing or 2.0 volts for 7/8-inch diameter tubing.

Note 2: The upper voltage repair limit is calculated according to the methodology in GL ~~90~~ 95 -05 as supplemented. V_{URL} may differ at the TSPs and flow distribution baffle.

11. ~~Primary Water Stress Corrosion Cracking (PWSCC) Tube Support Plate Plugging Limit is used for the disposition of an Alloy 600 steam generator tube for continued service that is experiencing predominantly axially oriented PWSCC at dented tube support plate intersections as described in WCAP-15128, Revision 2, dated February 2000 as supplemented by TVA's letter to NRC dated March 2, 2000. This alternate repair criteria is applicable to Cycle 11 and 12 operation.~~

b. The steam generator shall be determined OPERABLE after completing the corresponding actions (plug all tubes exceeding the plugging limit and all tubes containing through-wall cracks) required by Table 4.4-2.

Delete and replace with Insert 3

4.4.5.5 Reports

a. Following each inservice inspection of steam generator tubes, the number of tubes plugged in each steam generator shall be reported to the Commission within 15 days.

b. The complete results of the steam generator tube inservice inspection shall be submitted to the Commission in a Special Report pursuant to Specification 6.9.2 within 12 months following the completion of the inspection. This Special Report shall include:

1. Number and extent of tubes inspected.

2. Location and percent of wall-thickness penetration for each indication of an imperfection.

3. Identification of tubes plugged.

c. Results of steam generator tube inspections which fall into Category C-3 shall be reported as a degraded condition pursuant to 10 CFR 50.73 prior to resumption of plant operation. The written followup of this report shall provide a description of investigations conducted to determine cause of the tube degradation and corrective measures taken to prevent recurrence.

d. For implementation of the voltage-based repair criteria to tube support plate intersections, notify the staff prior to returning the steam generators to service should any of the following conditions arise:

1. ~~If estimated leakage based on the projected end-of-cycle (or if not practical using the actual measured end-of-cycle) voltage distribution exceeds the leak limit (determined from the licensing basis dose calculation for the postulated main steam line break) for the next operating cycle.~~ Delete and replace with Insert 4

2. If circumferential crack-like indications are detected at the tube support plate intersections.

3. If indications are identified that extend beyond the confines of the tube support plate.

4. If indications are identified at the tube support plate elevations that are attributable to primary water stress corrosion cracking.

5. If the calculated conditional burst probability based on the projected end-of-cycle (or if not practical, using the actual measured end-of-cycle) voltage distribution exceeds 1 X 10^{-2}, notify the NRC and provide an assessment of the safety significance of the occurrence.

e. ~~For implementation of the depth-based repair criteria for axial PWSCC at dented TSPs, the results of the condition monitoring and operational assessments will be reported to the NRC within 120 days following completion of the inspection. The report will include tabulations of indications found in the inspection, tabulations of tubes repaired and left in service under the ARC, and growth rate distributions for indications found in the inspection as well as the growth distributions used to establish the tube repair limits. Any corrective actions found necessary in the event that condition monitoring requirements are not met will be identified in the report.~~

Insert 5

Insert 3

11. a) Bottom of WEXTEX Transition (BWT) is the highest point of contact between the tube and tubesheet at, or below the top-of-tubesheet, as determined by eddy current testing.
    b) The W* distance is the larger of the following two distances as measured from the top-of-the-tubesheet (TTS): (a) 8 inches below the TTS or (b) 7 inches below the bottom of the WEXTEX transition plus the uncertainty associated with determining the distance below the bottom of the WEXTEX transition as defined by WCAP-14797, Revision 2.
    c) W* Length is the length of tubing below the bottom of the WEXTEX transition (BWT), which must be demonstrated to be non-degraded in order for the tube to maintain structural and leakage integrity. For the hot leg, the W* length is 7.0 inches which represents the most conservative hot-leg length defined in WCAP-14797, Revision 2.

Insert 4

Leakage is estimated based on the projected end-of-cycle (or if not practical using the actual measured end-of-cycle) voltage distribution. This leakage shall be combined with the postulated leakage resulting from the implementation of the W* criteria to tubesheet inspection depth. If the total projected end-of-cycle accident induced leakage from all sources exceeds the leakage limit (determined from the licensing basis dose calculation for the postulated main steam line break) for the next operating cycle, the staff shall be notified.

Insert 5

e. The calculated steam line break leakage from the application of tube support plate alternate repair criteria and W* inspection methodology shall be submitted in a Special Report in accordance with 10 CFR 50.4 within 90 days following return of the steam generators to service (MODE 4). The report will include the number of indications within the tubesheet region, the location of the indications (relative to the bottom of the WEXTEX transition (BWT) and TTS), the orientation (axial, circumferential, skewed, volumetric), the severity of each indication (e.g., near through-wall or not through-wall), the side of the tube from which the indication initiated (inside or outside diameter), and an assessment of whether the results were consistent with expectations with respect to the number of flaws and flaw severity (and if not consistent, a description of the proposed corrective action).

ENCLOSURE 2

TENNESSEE VALLEY AUTHORITY
SEQUOYAH NUCLEAR PLANT (SQN) UNIT 2
RESPONSE TO NRC TECHNICAL QUESTIONS

This enclosure addresses two technical questions from the NRC staff review of Technical Specification (TS) Change 03-06.

NRC question 4:

Please confirm that when determining the number of indications in the 8- to 12-inch region that the number of indications detected in all four steam generators (SGs) will be used to determine the number of indications in each SG. Thus, the total historical count (from all four SGs) plus the number of projected indications (for all four SGs) will be combined and that 25 percent of this total will be applied to each of the four SGs. This is in contrast to determining the total historical count (for one SG) plus the number of projected indications (in one SG) and taking 25 percent of this total and applying it to this specific SG (and then repeating the process for the other three SGs).

TVA Response:

The total historical count (from all four SGs) plus the number of projected indications (for all four SGs) will be combined and 25 percent of this total will be applied to each of the four SGs.

NRC question 5:

The proposed W* inspection criteria relies on residual stresses and differential thermal expansion to achieve structural and leakage integrity of the tube-to-tubesheet joint. As documented in NUREG-1570, "Risk Assessment of Severe Accident-Induced Steam Generator Tube Rupture," the primary system temperature may reach 1200 to 1500°F. Given Commission Policy that the staff should be risk informed and that severe accident conditions may cause relaxation of the tube-to-tubesheet joint contact pressure associated with the WEXTEX expansion process, your insights into the following would be appreciated.

Please describe the effect that severe accident temperatures and pressures (e.g., station blackout, "high - dry" severe accident scenario as described in NUREG-1570) will have on the leakage integrity of the joint. Although the tubes would seek to expand further relative to the tubesheet, could the substantially lower yield strength of material at elevated temperatures reduce the contact pressure associated with the WEXTEX expansion process such that there is significantly less resistance to leakage than exists under design basis accident conditions?

TVA Response

SQN's nuclear steam supply system vendor has indicated the effect of severe accident temperatures and pressures on the leak rate would be expected to result in minimal differences relative to predictions made for faulted conditions, such as a steam line break (SLB). This is based on qualitative considerations of the behavior of the tube and tubesheet material with regard to the crevice leak path. The temperatures are so high that the water becomes steam at the pressure of the relief valve set points, so the reactor coolant is vented until only steam remains. In addition, the subsequent primary side gas is an aerosol with solid particulates.

The rationale for estimating the effect on the crevice is based on consideration of both differential pressure and the significant rise in the temperature of the tube material, or the tube and tubesheet material in the long term. Severe accident descriptions are based on the results of probability and risk assessment (PRA) analyses associated with postulated failure sequences. A general concern regarding severe accident considerations is the potential for temperature induced tube failure because of a loss of strength or creep. Thus, information is sought here regarding the likelihood of temperature induced failure of the joint to retain effective sealing of the primary pressure boundary. Finally, it is considered that valves have remained open and that the SG in addition to being dry, i.e., no liquid present, is at atmospheric pressure. Hence, the differential pressure between the primary and secondary sides of the SG is taken to be similar to that during a postulated SLB event, about 2300 to 2500 pounds per square inch (psi).

There are two effects associated with the change in the temperature, a diminution of the material properties such as the modulus of elasticity and the yield strength, and the potential for creep relaxation of the tube-to-tubesheet joint. Moreover, there are five contributing effects to the final interface or contact pressure between the tube and the tubesheet, which governs the section area present for fluid flow,

1) The residual interference fit from the installation of the tube in the tubesheet,
2) Transmission of pressure in the tube to the tube-to-tubesheet interface,

3) An increase due to the higher coefficient of thermal expansion of the tube material,
4) A potential reduction due to pressure in the crevice between the tube and the tubesheet, and,
5) Loosening due to dilation of the holes in the tubesheet associated with bowing of the tubesheet from the primary-to-secondary pressure difference.

It is strongly stressed that there is no real crevice between the tube and the tubesheet because there is always an interference fit between the outside diameter (OD) of the tube and inside diameter (ID) features of the tubesheet hole. The leak path arises because the mating surfaces are not perfectly smooth, the tubesheet hole being significantly rougher than the surface of the tube. This means that the flow has to follow a rather torturous path from the point where it enters the interface to the point where it exits the top of the tubesheet. If the surfaces were perfectly smooth there could never be any flow because the leak path would have zero area. Thus, when the term crevice is used it is with regard to an effective crevice corresponding to the fact that flow occurs. The flow that does occur would usually be characterized as weeping because it takes place at such a slow rate.

The effect of the postulated severe accident conditions on each factor is discussed in the following paragraphs. Qualitative considerations of potential creep and aerosol effects are discussed last.

Residual Contact Pressure

The extreme conditions associated with severe accident conditions have no bearing on the residual contact pressure from the installation of the tube. There is an indirect effect related to the impact of the thermal conditions on the overall contact pressure that is discussed later with regard to the effect on material properties.

Internal Pressure Tightening

The inherent strength of the tube-to-tubesheet joint is controlled by the modulus of elasticity, i.e., a measure of the stiffness in a uniaxial tensile test of the material, of each of the materials and not the yield strength per se. If the tube material yields, which would occur prior to yielding of the tubesheet material, the effective stiffness of the tube would decrease significantly, on the order of a factor of 100. Normally the contact pressure between the tube and the tubesheet is increased by the internal pressure in the tube. Since the tube and the tubesheet are both elastic members, only about 75 percent of the internal pressure is transmitted to the interface. The amount of pressure transmitted to the interface is a function of the moduli of both the tube and the tubesheet. If the tube yields and the tubesheet does not, the amount of pressure transmitted would increase to about 92 percent and the joint would get tighter. For SLB and severe accident conditions, the increase of 17 percent would amount to about 435 psi relative to a total differential pressure of about 2500 psi. This means that the reduction in contact pressure that could be postulated as occurring because of yielding of the tube material would be offset by the increase in contact pressure.

Thermal Expansion Tightening

In addition to the potential for an increase in the pressure tightening component of the interface load, there is a thermal component due to the difference in thermal expansion coefficients between the tube and the tubesheet. The net effect is that the interface pressure increases by a little more that 1 psi for each degree increase in temperature above ambient conditions. Thus, an increase in the temperature from 600 to 1400 degrees Fahrenheit (°F) would increase the contact pressure by about 800 psi. The combination of tightening and elevated temperature would be expected to further deform the mating asperities and increase the area of contact between the tube and the tubesheet. The initial effect would be a reduction in the crevice area available for flow from the primary to secondary side of the SG. The decreased radial stiffness of the tube at greater than 1000°F may result in increased conformance of the tube OD surface with surface irregularities in the tubesheet hole, and could further reduce leakage potential (and pullout resistance) due to increased contact area between the tube and tubesheet hole. Thus, it is possible that high and dry scenarios could create a joint condition that has a greater leakage resistance than a tube at 600°F during postulated SLB conditions.

There are competing factors to consider associated with the yield strength of the material. The as-installed yield strength of the tubes in the tubesheet is likely on the order of 25 percent greater than for a tube that has not been expanded. Information in the Nuclear Systems Materials Handbook indicates that a reduction in the yield strength of the tube material on the order of 25 percent could be expected at temperatures on the order of 1300 to 1400°F. At higher temperatures the yield strength could diminish to about 23,000 or 24,000 psi. The stress intensity that is associated with pressure acting on the tube can be calculated as the pressure times the ratio of the mean radius to the thickness of the tube. For Sequoyah the value is 8.25. The contact pressure that would result in a stress intensity corresponding to yield would be about 2900 psi. Per Table 4.4-7 of WCAP-14797, Revision 1, for example, a contact pressure of about 1500 psi at the depth of 6 inches in Zone B and 4 inches in Zone A results in sufficient axial load to resist the faulted end cap load of 1600 pounds. For the computation of W* this load is multiplied by a factor of 1.43, a factor that is not required for severe accident considerations. The contact pressure corresponding to yielding at 30,000 psi is about 3600 psi.

Pressure in the Crevice

The leak rate during postulated SLB events is based on the results from tests performed to simulate the pressures and temperatures of interest, including whatever pressure was associated with the flow between the primary and secondary regions of the specimen, thus simulating the effective crevice between the tube and the tubesheet. There is no true crevice or gap between the tube and the tubesheet. A limiting model of the mating of the asperities indicates that a lower bound effective area of contact if the surfaces are in a yielded state is about one-third of the projected area. Thus, an upper bound for the potential area of contact by fluid leaking from the primary to the secondary side of the SG is about two-thirds of projected outside surface. The calculation of the effective contact area is based on the contact pressure and assumes plastic deformation of the mating asperities. However, it is the maximum contact pressure achieved during the installation of the tube into the tubesheet that would likely control the surface deformation. The installation pressure is sufficient to bring about gross yielding of the tube, and could very well result in yielding of the surface asperities in the tubesheet holes. Thus, it can be judged that the effective contact area is significantly greater than the lower bound value of an analysis based on the compressive yield strength of the material. This means that the effective surface area for internal pressure to reduce the contact pressure is expected to be significantly less than the upper bound value of two-thirds of the projected surface area.

There is some experimental evidence that the crevice region of the tube and tubesheet does not become as wetted as might be expected from the above analytical considerations. Two tubes were removed from the Surry power plant and the surfaces examined for evidence of exposure to secondary side water. For both it was found that there was very little penetration of the secondary side water into the crevice. Although the secondary side pressure is significantly less than the primary side pressure under faulted conditions, the secondary side interface is at the location along the tube where dilation of the tubesheet holes would be a maximum. The implication is that if a tube crack is leaking through the crevice, it is unlikely that the entire circumferential area of the outside of the tube would be involved. This phenomenon further reduces the effective surface area for fluid in the crevice to reduce the contact pressure.

A reasonable assumption for flow through porous media is that the pressure drop is linear through the crevice, thus the average pressure in the crevice would be about 1250 psi. Taking the effective surface area as one-half of the total surface area leads to consideration of an effective pressure in the crevice of about 600 psi, or about 25 percent of the differential pressure drop. This is really no different than the situation that could be expected during a postulated SLB event.

Since the predicted leak rates are based on test data, the pressure in the crevice during the tests would be the same as that between the tube and the tubesheet in the SG.

Saturation pressure is about 1500 psi, so the average pressure in the crevice during a postulated SLB event could be as high as 2000 psi. This is normally omitted from consideration in the mathematical flow model so that the pressure drop for the flow is maximized, more than doubled, and the fluid is considered to consist of a steam and water mixture with a significantly reduced viscosity. The model calculations treat the flow as directly proportional to the differential pressure and inversely proportional to the viscosity.

Tubesheet Bow

For a "high and dry" condition the applied pressure differential, which induces tubesheet bowing and thus reduces joint tightness, would not be expected to exceed 2500 psi. For high and dry scenarios that involve temperatures greater than 600°F the joint tightness would be increased above the current analyzed condition due to an increased thermal expansion contribution. The pressure tightening contribution would be unaffected for equal primary-to-secondary pressure differentials for the SLB and high and dry conditions. Therefore, considering only the physically applied loading conditions, the high and dry scenario would involve a tighter tube to tubesheet joint.

Creep Effects

The preceding discussion was aimed at consideration of deformations that did not involve creep of the materials.

However, at the elevated temperatures associated with postulated severe accident conditions, creep of the tube and tubesheet material could be likely to occur. The question is whether or not creep relaxation of the tube-to-tubesheet joint could occur to the extent that the potential leak rate would be expected to increase significantly. While some relaxation of the contact pressure could occur, no gap could ever open between the tube and the tubesheet. The load acting to relax the joint is mostly deformation controlled except for the portion resulting from the internal pressure in the tube.

Under creep conditions the material undergoes constant volume deformation, i.e., Poisson's ratio is 0.5. Thus, for there to be compressive relaxation of deformation and load in the radial direction, there must be attendant extensions of the material in the hoop and axial directions. Since the geometry is closed in the hoop direction, i.e., the cylinder surface is complete, compression in the hoop direction would require axial extension and radially inward deformation of the material (radially outward deformation is suppressed by the tubesheet). The latter is countered by the internal pressure in the tube. The axial extension of the tube material is countered by the friction between the tube and the tubesheet, i.e., strain in the axial direction is suppressed, tending to affect a state of plane strain. Without a detailed finite element analysis of the creep interactions, the relative effects cannot be accurately quantified. However, it is not difficult to see that there are competing deformations that tend to lead to no meaningful change in the contact pressure relative to that during postulated faulted conditions.

Aerosol Effects

Given the scale of the leak path between the tube and the tubesheet, it is judged to be likely that the torturous path between the tube and the tubesheet would become clogged with the aerosol particles in the vaporized materials from the damaged core. This would significantly restrict leakage from the tube-to-tubesheet interface to the secondary side of the SG, thus preventing the natural circulation inhibiting effects of primary-to-secondary leakage.

Summary

Consideration of the potential effects leads to the conclusion that it is likely that there is no change in the effective flow area for weeping fluid between the tube and the tubesheet. Although the contact pressure may decrease as a consequence of creep relaxation on a macroscopic scale, an attendant decrease in the flow area would be expected because a creep relaxation of the tubesheet asperities on a microscopic scale. Hence, no meaningful change in the predicted leak rates relative to that during postulated accident conditions would be expected. In addition, it is likely that the leak path would eventually become clogged with particles in the primary fluid aerosol and there would be no long-term meaningful effect on natural circulation cooling of the fluid.