Alion Responses to NRC Staff Questions Reformatted Into Three Topical Areas

(Enclosure 4 to ML080510080 phone call summary of October 31, 2007 and November 29, 2007 phone calls with Alion)

Content of November 28, 2007 E-mail, R. Choromokos to J. Golla transmitting Alion response to NRC Staff Questions Reformatted Into Three Topical Areas:

Joe,

Attached are Alion's responses to the November 6, 2007 questions sent by John Lenning in advance of the VUEZ Trip. Perhaps tomorrow, we can keep the plant specific testing questions separate from the generic questions attached.

Talk to you tomorrow.

Rob Choromokos
Manager, Energy Services Division
Alion Science and Technology
4525 Weaver Parkway, Suite 230
Warrenville, IL 60555
www.alionscience.com

✉ *email rchoromokos@alionscience.com*
☏ *Ofc 630.393.1215 x417*
🖷 *Fax 630.393.1235*
✆ *Cell 630.846.6787*

Enclosure 4

Alion Follow-Up Issues With Responses

Head Loss and Scaling

1. It is not clear to what extent the poured debris bed formation process can generate uniform/homogeneous debris beds. Previous unexpected test results from SONGS (where no measurable head loss was recorded, in contrast with NUREG/CR-6224 correlation predictions) and TMI (where the measured head loss across the VUEZ flat plate was significantly lower than the head loss measured across a 3x3 array) suggest that the debris bed formation process may not allow the flow through the screen to orient the accumulating debris in a natural arrangement that tends to maximize head loss. Discussion during a teleconference that additional fibrous debris is sometimes added to poured debris beds to fill in visually apparent gaps or non-uniformities further underlines the staff's concern that the porosity of a poured debris bed can be significantly higher than that of a bed that is naturally formed by flow. The small size of the VUEZ loop also implies that any non-uniformity in the test debris bed would tend to have a more significant effect than on a prototype module or plant strainer. One means of resolving this issue would be to demonstrate that head loss results from integrated tank testing are approximately equal to head loss results from VUEZ testing prior to the addition of chemicals, after the results are scaled to a common temperature (as appropriate).

ALION RESPONSE: *As pointed out by the staff, it has been shown that uniform debris beds produce higher head losses than non-uniform debris beds. It is for this reason, that, <u>up to a certain point</u>, uniform beds on a flat plate yield higher measured head losses than the same quantity of debris (amount per unit surface area) collected on an "advanced geometry" strainer array. The reason for this is the tendency for real strainer hardware to collect debris in a non-uniform manner. Care must, however, be taken to ensure that the debris distribution on a flat plate is indeed as uniform as possible. Flat plate testing is typically done with a horizontal plate configuration to control the exact amount of debris collected. Because the gravitational settling velocity of the debris as it is being deposited on the strainer plate is high relative to the natural approach velocity of the flow through the strainer plate, care must be taken to ensure that random non-uniformities in debris distribution on the plate surface do not occur. The technique used by the VUEZ technicians is designed to produce to the extent possible a uniform and homogenous debris bed. One way in which this is done is by taking care to introduce debris uniformly above the plate such that even through gravitational settling, a relatively uniform debris layer would result. In addition, the rate of debris introduction is controlled. In this way, any temporary variations in bed porosity (thickness) will result in flow being redistributed to other portions of the strainer such that debris is preferentially collected there. Finally, a visual inspection of the resulting bed is performed to ensure that relative uniformity is achieved. Manual adjustments to the bed may be made for small improvements in uniformity. However, in the event the bed shows evidence of significant non-uniformity, the test is terminated. Any residual non-uniformity in the debris distribution is significantly less than the non-uniformity exhibited in the collection of debris on actual strainer hardware.*

In the beginning of the prior paragraph, it was emphasized that flat plate test results yield higher measured head losses than actual strainer hardware up to a point. There are two reasons for this limitation as will be discussed below for the examples cited by the staff. One has to do with the quantity of debris and reduction in effective strainer surface area as filling of any interstitial volume occurs, and the other is the impact of the clean strainer head loss for complex strainer geometries. Thus, the examples cited above with SONGS and TMI are not unexpected and can be explained by the following:

The TMI array head loss was higher than the flat plate head loss. This was expected as the debris bed volume (thickness) begins to fill in the interstitial volume of the prototype array and, therefore, the geometry effect causes an increase in head loss over that of a flat plate. Also, the TMI array test included a bypass mesh and clean screen head loss. The head losses should have been slightly higher than VUEZ and they were.

The SONGS array head loss was higher than the flat plate head loss because of the impact of clean screen which is primarily turbulent flow. The only Vuez loop that produced no head losses cited above was the Microtherm loop. This is because there is insufficient fiber to cover the screen and Microtherm (and any chemical precipitates) will pass through the screen. Similar observations were made during the associated array test. During the array testing, only a portion of the screen becomes covered with the latent fibers and the Microtherm is only filtered over that portion of the screen. It is known that Microtherm can cause significant head losses. As a result of the Microtherm/latent fiber covering the lower regions of the vertical top-hat array screen, the flow was redirected through the upper clean portions of the array (recall that the top hat are oriented vertically in a pit with the flow at the bottom). Redirecting the flow through the upper clean portions of the top-hat array forces the flow to transverse down the full length in the annular regions of the top-hats, which are filled with woven wire mesh. This is a more torturous and turbulent flow path and causes an increase in head loss. However, subsequent introduction of chemical precipitates would not increase the fraction of the screen area covered by debris.

Comparing the array non-chemical prototype debris head losses with the flat plate debris head losses without chemical effects illustrates the impact of strainer geometry and non-uniform flow fields on debris accumulation and resulting head loss. The impact of chemical effects alone is seen through a comparison of flat plate debris head losses with and without chemical effects. Alion will in all final reports applying the results of the chemical effects VUEZ experiments, address the differences noted in the array non-chemical effects head loss and the VUEZ non-chemical debris head loss.

2. The specific methodology and technical basis for using a bump-up factor to account for the head loss due to chemical effects is not clear to the staff. The bump-up approach is based on the theory that the incremental head loss from a given quantity of chemical precipitate (after scaling) will be the same for the VUEZ debris bed as for the plant condition. One of the important assumptions upon which this theory depends is that the VUEZ debris bed and the actual plant debris bed should have sufficiently similar characteristics with respect to filtering out and spatially accumulating the chemical precipitates. Based upon testing conducted to date, it is not clear to the staff that geometric differences and other factors do not influence the debris bed's properties (e.g., porosity, compression, thickness), and thus add significant uncertainty to the bump-up factor approach. It is also not clear how the bump-up approach ensures that boreholes or differential-pressure effects do not adversely affect the scaling approach One means of resolving this issue would be to document the methodology used for the bump-up approach and provide a justification with evidence that this approach is valid in light of the staff's questions.

ALION RESPONSE: *There are practical limitations associated with full scale prototype testing in a post-LOCA chemical environment. Therefore, based on previous work performed by the IRSN in support of the chemical effects investigations in France, Alion has modified a series of chemical vertical loops to evaluate the impact of chemistry on debris head loss.*

*Based on NUREG/CR-6808, Section 7.2.1, **Flat-Plate Strainers**, as with all approximations, there are advantages and disadvantages associated with flat plate testing. Page 7-14, **Important Considerations for Future Experimenters**, states that although flat-plate strainers possess several shortcomings, it has been thought that this approach would result in "conservative" head loss measurements for most debris types of interest. Furthermore, the use of the flat-plate head loss data in conjunction with the prototype strainer testing has proved to be an effective method of evaluating strainer head loss. It goes on to suggest that these (flat plate) tests are ideally suited for separate effects tests and to augment large scale test data. Within this section, Item 2, the concept of the bump-up factor is identified.*

Research done by the PWROG and USNRC on chemical effects has been related to developing a precipitate within solution that layers upon the debris bed – essentially treating this chemical debris source as an amorphous substance or nano particle that is filtered from the circulating fluid by the fiber bed.

Although experiments performed to date by Alion have not seen any visible precipitate, we can support the potential for nano size particles to contribute to head loss. These particles would contribute to head losses by filling in the voids within the debris bed and decreasing the overall bed porosity. In does not seem credible would these nano particles would redistribute the debris bed, change the shape of the debris bed or increase the compressibility of the debris bed.

Most all of Alion's experiments performed to date comport well with International studies on the effects of chemistry on fiberglass. In the presence of aluminum, the fiberglass will become a nucleation site for sodium aluminum silicate. The sodium aluminum silicate will increase the surface roughness of the fibers and decrease the overall porosity of the debris bed. Again, the chemical effects do not alter shape or distribution of the debris bed as these impacts are slow to occur and take place later in time during the accident and at cooler temperatures. Alion has presented these results numerous times to the Staff for TSP and NUKON/Mineral Wool environments

Therefore, based on Alion and International studies, chemical effects occur within the debris bed and do not cause the debris bed to change shape or redistribute when compared to non-chemical debris bed geometry. Therefore the changes to the debris bed are within the debris bed morphology itself. These changes can be compared in vertical loop testing and applied. Since the chemical reaction products have the effect of modifying the characteristics of the debris bed and thereby increasing the measured head loss by some multiplicative factor, it is reasonable to conclude that this multiplicative factor increase in head loss would be observed for a prototypic strainer. Another way of characterizing this is that the shape factor (ratio of head loss on a prototype strainer versus flat plate strainer for otherwise identical flows and debris quantities) applies with or without the impact of chemical reaction products.

3. Maximum load versus thin bed testing. During the previous call, Alion made the statement that maximum debris cases are chosen for chemical testing based on their causing higher head loss than the thin bed tests during earlier non-chemical testing. Presuming that the bump-up approach is justified, once chemicals are considered, the maximum debris case would continue to be bounding only as long as the thin-bed bump-up factor is not so severe as to overcome the lower thin-bed head loss without chemicals, or

$$\frac{Thin\,Bed\,Bump-up\,Factor}{Maximum\,Load\,Bump-up\,Factor} \leq \frac{Maximum\,Load\,HL}{Thin\,Bed\,HL}$$

Why is there confidence that this must be the case?

ALION RESPONSE: *Our position remains to determine the maximum total head loss (chemical effects included). If the impact of chemical effects on the thinner bed produces a higher head loss than the thicker bed, then this is the case. Alion considers the full range of debris loads on the screen for chemical effects. To date, the data would suggest that thicker debris loads incur more chemical effects due to more surfaces on which to deposit aluminum. Additional testing and data would be presented to support such statements.*

4. During the most recent phone call, Alion stated that larger bump-up factors were calculated for maximum load cases as opposed to thin-bed cases based on previous VUEZ testing. Provided that these tests were not unduly influenced by issues such as debris coarseness and bed pouring, and that general principles can be deduced from these results that are applicable to other plants' test conditions, then it may be appropriate to use these tests as a basis to rule out the conduct of future thin bed tests. At present, sufficient information is not available to the staff to determine that not performing thin bed tests in the future is justified. In addition, the procedure and technical basis for determining the appropriate thickness of the thin beds in the VUEZ tests was not fully clear to the staff during the phone call, and additional discussion of this issue would be beneficial. If a future decision is made that performing thin bed tests is unnecessary, further discussion of the technical basis underlying this decision could help to resolve the staff's questions in this area.

ALION RESPONSE: *Alion statements to when thin-bed VUEZ chemical effects testing is not required is when there is insufficient fiber to cover the screen and this been substantiated by the prototype testing. Flat plate VUEZ thin-bed testing is non-representative of the prototype testing as it would assess a condition that does not exist. The definition of the "thin-bed" load is vendor specific and would constitute that fiber load sufficient to cover the screen with the full particulate loading. The fiber load in this case can often exceed an average bed thickness of one-half inch.*

5. While the large VUEZ loop offers a means of accounting for circumscribed and partially circumscribed (transitioning) debris beds, it is not clear whether the flat plate in the small loop can be scaled for these conditions (e.g., modeling effective bed thicknesses, circumscribed / partially circumscribed flow areas and approach velocities). As discussed in a previous teleconference, these geometric effects may be partially responsible for reduced head loss seen for TMI test conditions in the VUEZ loop as compared to the large tank with the 3x3 array.

ALION RESPONSE: *As pointed out by the staff, a "transitioning bed" exhibits higher head losses than what would be predicted if the debris volume were distributed over a simple surface with the full area of the strainer. The filling of interstitial volume results in an increase in debris bed thickness and an increase in fluid velocity through at least portions of the bed. For very large debris quantities, this can be approximated by considering the debris quantity (less that which filled the interstitial volume) to be deposited on the outside of a "circumscribed" strainer surface, an area typically much less than the full strainer surface area. This results in a simple model for the higher effective bed thickness and larger effective approach velocity. This type of modeling approach was used successfully with BWR stacked disk strainers where it was* *demonstrated that such predictions with the NUREG-6224 correlation were in good (but conservative) agreement with measured results for sufficiently large debris quantities.*

The Vuez tests in either the small or large loops are not intended to determine the actual head losses associated with the prototype hardware. Rather, the goal is to replicate flow conditions and debris loadings to approximate those which would be seen on the actual screen. The Vuez results only provide the relative impact of chemical effects. Thus, there is no need to try to replicate exactly the effective debris bed thickness and effective flow rate. These quantities are simply estimated with the goal of achieving a non-chemical effects head loss that approximates that observed in the array test. Only the relative head loss increase due to chemical effects is obtained from Vuez.

6. During the initial teleconference, Alion stated that a generic fiber size distribution was used for the VUEZ testing. The staff expectation is that an appropriate procedure for preparing fine fiber be implemented (which is particularly important for the thin bed test, since for many strainer designs, fines may be the only debris size that actually reaches the strainer), and that the surrogate debris used matches the plant-specific size distributions from the debris transport calculation. Observing test practices at VUEZ may provide a basis to resolve this issue.

ALION RESPONSE: *Alion concurs with this statement and has ensured that all latent fibrous debris loads are "fines."*

7. It is important to ensure gas release and boreholes do not disrupt debris bed structure. Alion has stated that improvements have been made to address this issue for the small VUEZ loops, and that the limited experience to date has not shown there is a gas issue with the large VUEZ loop. Staff review of additional test results demonstrating these points could provide a basis to resolve the issue.

ALION RESPONSE: *Alion has modified the VUEZ vertical loop suction piping to preclude the impact of void formation under the debris bed. The last round of testing has shown no evidence of void formation as with testing earlier in the summer. Bore holes however, may exist with calcium silicate debris beds within insufficient fiber to cover the screen. Every vendor has seen this phenomenon to date and although there is no way to predict the quantity of bore holes, the formation of bore holes would clearly be prototypical and expected under realistic conditions. Alion does not preclude or prevent the formation of bore holes. The preparation of the calcium silicate is in "fine," however, Alion does not add fibrous debris beyond the design loading developed by the Licensee. In reality there are some calcium silicate plants that do not have sufficient fiber to cover the screen and bore holes are going to occur.*

<u>Chemical Effects</u>

8. The NRC staff is interested in how a given licensee determines that the test parameters selected for the VUEZ loops provide test results that are conservative with respect to chemical effects. This is particularly important since test results may show that certain dissolved species remain in solution instead of forming precipitate in the time frame of interest. For example, as was described by Alion in a previous phone call, the early part of the test may be conducted with temperatures representative of the upper range of post-LOCA temperature profiles for a plant to favor dissolution of materials. The latter part of the test may be conducted at temperatures representative of the plant's lower temperature profile to favor precipitation of dissolved materials. With respect to test pH, higher pH

conditions may favor greater dissolution of important materials, such as aluminum, while near neutral pH values would provide conditions that favor precipitation of aluminum hydroxide type species. Additional information that describes how licensees determine that a given set of tests provides for a conservative chemical effects evaluation could provide a basis to resolve this question.

ALION RESPONSE: *The basis for the test parameters are developed in detail in the supporting calculations. To our knowledge, only one (1) plant has provided these to the Staff although several more have been developed. Additionally, only one (1) plant has finished the chemical effects evaluation report which provides much of the information requested in this question.*

9. Tests are initially conducted for an extended period at low pH to account for the test equipment's inability to test at the short-term, peak post-accident temperatures. Alion considers the extended period at low temperature to be conservative. What is the basis for considering that this is conservative with respect to material degradation (e.g., corrosion of aluminum)?

ALION RESPONSE: *The basis for the test parameters are developed in detail in the supporting calculations. This issue specifically addressed in the supporting calculations.*

10. The existing VUEZ testing does not address the effect of a sudden temperature drop from a heat exchanger and the potential for thermal cycling. During the teleconference, Alion stated that equipment was being procured to analyze this effect. Additional detail on how these tests will be conducted and their results could provide a basis to resolve the issue.

ALION RESPONSE: *This issue can be addressed experimentally and plans are being looked into to develop this capability. We doubt very much this will produce much and a recent test has taken the temperatures down to 16°C without any impacts. However, we would carry this item forward at this time until further information is developed.*

11. Zinc and aluminum coatings are being represented by increasing the surface area of zinc and aluminum coupons. Is the dissolution of large pieces of these metals representative of the dissolution of significantly smaller chips or particles of failed coatings debris (e.g., in terms of surface-area-to-volume ratio)? Could the corrosion rate be different for different sizes of materials?

ALION RESPONSE: *If we consider that the metallic particles like Zn or Al in the coatings are electronically connected each other, therefore, it is reasonable to assume that would be behave similar to metallic plates. This is because when the metallic particles are well connected to each other, the local charge distribution is homogenized by the electrons flow under any heterogeneous charge developed during the corrosion progress. Therefore, the metallic coatings corrosion can be treated the same as metallic sheet corrosion.*

12. As discussed during the recent phone call, the rapid addition of buffer to the VUEZ test loop has been shown to cause a temporary increase in head loss. What is the cause of this observed increase in head loss?

ALION RESPONSE: *We cannot explain the temporary increase in head loss associated with rapid buffer addition (pH shock). However, after the increase the decrease appears to be triggered by a temperature decrease. We have since controlled the introduction of buffer to be consistent with the expected dissolution times in containment.*

13. Removal of materials from the test tank: (1) By the end of the test, based on the procedures provided, approximately five percent of the loop volume could be removed through the process of sampling the test volume (including any dissolved and suspended species). (2) Small quantities of particulate that are considered non-transportable are not included in the test for their chemical impacts (e.g., ALION-CAL-SONGS-4194-03, Rev. 2, Pg 29 of 35). How much of these materials may be removed without significantly affecting the test results?

ALION RESPONSE: *The test protocol requires the removal of solution to so that we can analyze the corrosion products in solution. In most instances, we are looking for calcium, aluminum, silicon, zinc levels. Based on the ICP results to date, a five percent change would have no significant impact on the experiment as the levels are sufficiently high. A statement can be added to the test report noting this effect.*

Test Procedure / Miscellaneous

14. Confidence should exist that the VUEZ tests are repeatable. Alion discussed TMI testing that is currently underway that has shown some evidence of repeatability thus far. Data for slightly varied test conditions can also show evidence of repeatability if it correlates with expected behavior. Staff review of additional VUEZ data could help resolve this issue.

ALION RESPONSE: *The retesting of TMI has provided evidence of repeatability. The repeatability is certainly a function of establishing a consistent debris bed. After our discussions with the Staff in September, Alion has focused more attention on debris bed preparation and introduced a first step of testing the debris bed in demineralized water at temperature without chemicals to ensure a consistent and definable base head loss. This additional first step has not come without charge as the fiberglass leaches even in demin water and causes the demin water to become slightly alkaline and affect the early pH readings during the acid phase. We are currently addressing this issue.*

15. How are measurement uncertainties accounted for / propagated through the analysis? Between the flow rate measurement, flow control, head loss measurement, and temperature measurement, there could be a relatively high uncertainty associated with the head loss results. (Variances of independent random variables are additive.) In addition, uncertainties associated with temperature could affect the timing of the corrosion process – for example, Alion approximated in its test procedure that corrosion rates double about every 18°F – and thus the timing of precipitate induced head loss.

ALION RESPONSE: *While this is true, adding up the uncertainties associated with all the processes in this experiment would provide an overly conservative assessment of chemical effects and inconsistent with the other parts of the analysis. Alion suggests that all uncertainties associated with the GSI-191 analyses be addressed in a holistic approach.*

16. The staff requests a copy of the test procedure for the large VUEZ loop and is interested in any experience from this loop with regard to debris bed formation and other issues discussed above regarding the small loops, such as a comparison of head loss results to prototype testing, settling, and circumscribed scaling.

ALION RESPONSE: *Alion can either provide a "generic" test procedure for the VUEZ loop, or we can request that D.C. Cook provide an actual test procedure. It is our understanding that D.C. Cook could make this available to the Staff for their review.*

17. What is the schedule for providing a copy of the report on the deterioration of alkyd coatings in post-LOCA containment pool to the NRC?

ALION RESPONSE: *It is suggested that Alion submit this report as a response to an audit item from a Licensee. We will contact a Licensee to provide this report.*