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August 10, 2008
261-4779-LTR-07 R/1

Mr. Michael L. Scott
Chief, Safety Issues Resolution Branch
Office of Nuclear Reactor Regulation
United States Nuclear Regulatory Commission
Mail Stop O-11A11
Washington, DC 20555-0001

Subject: Resolution of NRC Questions Regarding ALION VUEZ 30 Day Testing Program Status of Responses

Reference:
1. Alion Letter 261-4779-LTR-01, Dated February 8, 2008 entitled Resolution of NRC Questions Regarding ALION VUEZ 30 Day Testing Program Status of Responses.
2. NRC Questions – Alion Follow Up Issues – Corrected-Bolded, sent February 13, 2008.
3. Alion Letter 261-4779-LTR-07, Dated March 28, 2008 entitled Resolution of NRC Questions Regarding ALION VUEZ 30 Day Testing Program Status of Responses.

Dear Mr. Scott:

As stated in the Reference 1 letter, the attached are our responses to Alion Problem Statement Nos. 5, 6, 11, 16 and 19. A table has been included indicating the status of each open item. The NRC comments and questions are taken from Reference 2. Alion has incorporated additional information requested by the NRC in this letter as a result of our conference call on May 14th,2008.

Alion Problem Statement No. 5

Address the adequacy of the turbulence levels in the tank to ensure adequate circulation around all coupons/materials and material in suspension.

The following response encompasses NRC comment No. 10.

10. Alion should (a) procedurally document the extent of debris settlement in the tank for each test and the justification for any observed settling being acceptable and (b) demonstrate that reduced flow rates and the addition of sample baskets and coupons does not cause non-prototypical settling in the test tank.

Response:

The VUEZ tests are a combination of leaching tests and head loss tests designed to capture the chemical interactions and their impact on debris head loss. The procedure for debris bed formation as observed by the NRC is a pouring process that ensures all of the debris is located on the debris screen. There exists the potential for particulate to arrive prior to the full fiber source is on the screen and pass through the screen and remain in circulation in the tank. The turbulence levels (TKE) in the tanks are high enough to ensure that all 10-micron particulate remains in suspension and thus arrive at the screen after a period of pool turnovers. Based on this bed formation process and tank turbulence, there is no concern relative to debris settlement in the tank that belongs on the screen.

There also exists debris and materials that represent submerged materials in containment. These materials and debris sources are "settled" debris and do not belong on the screen. For these debris sources, the pool turbulence should be such that this debris is not "transported" to the sump screen. If the turbulence levels were to transport a portion of this debris to screen, it would be have a negligible effect and be conservative.

The last concern would be the potential for any chemical precipitate to settle in the tank area and not be transported to the sump screen and impact head loss. These chemical precipitates are considerably more transportable than 10-mircon particulate (silicon carbide) which has been shown to remain in suspension by CFD.

Alion has performed a CFD of the VUEZ test tank in with a flow rate of 0.7 liter/minute which supports the above statements regarding turbulence and velocity fields. The following figures illustrate the CFD results.

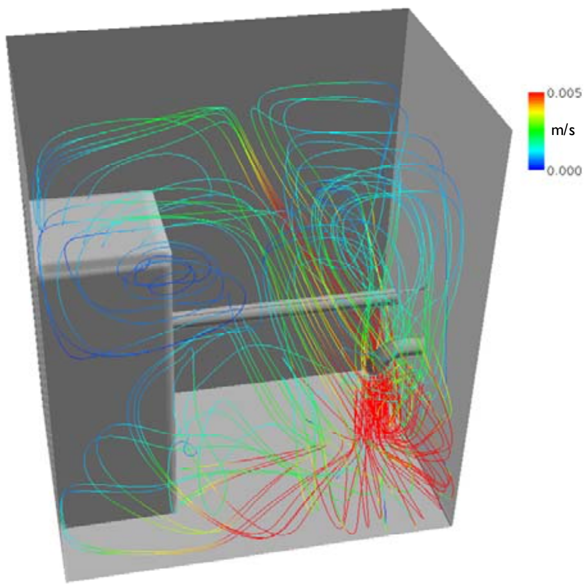

Figure 1: Velocity Streamlines in VUEZ Tank

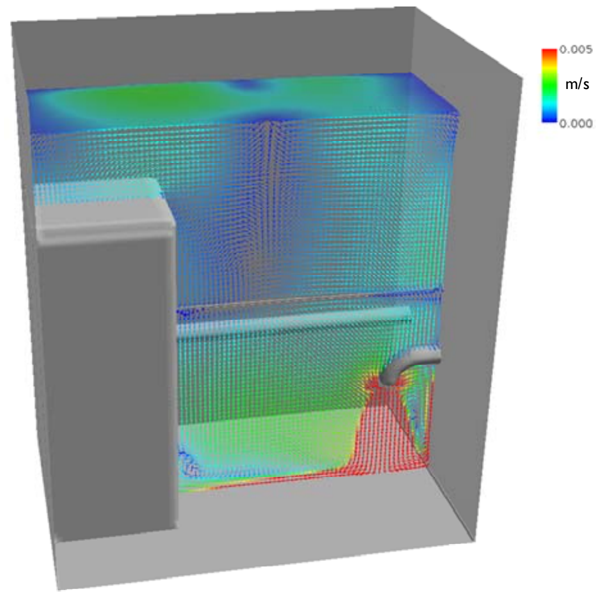

Figure 2: Velocity Vectors in VUEZ Tank

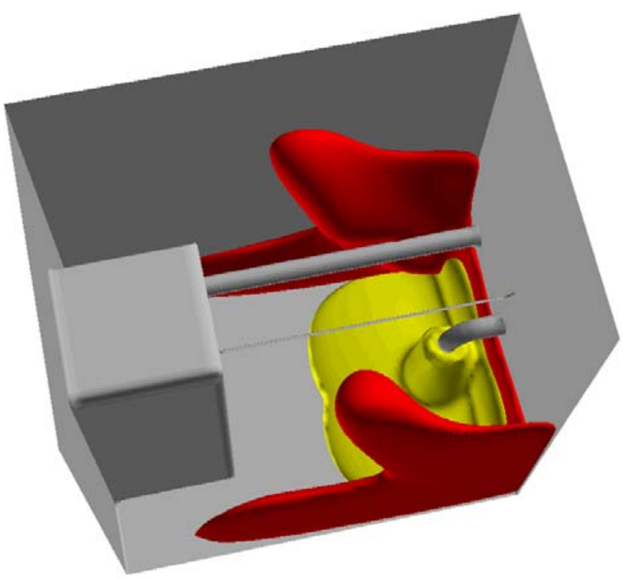

Figure 3: TKE/Velocity Sufficient to Suspend Fibers
$TKE \geq 7.6 \times 10^{-6}$ m^2/s^2 : $V_z \geq 2.25 \times 10^{-3}$ m/s

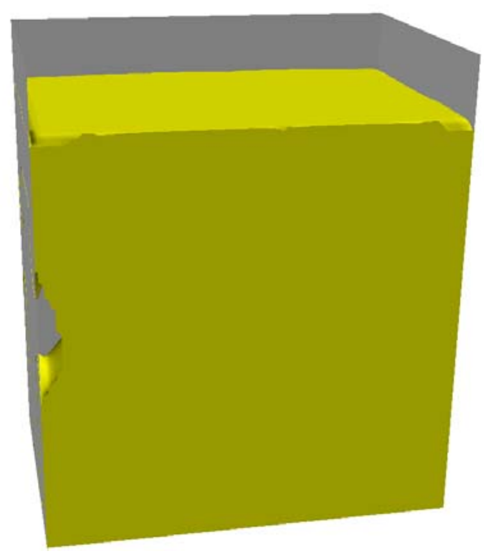

Figure 4: TKE Sufficient to Suspend 10μ Particles
$TKE \geq 3.9 \times 10^{-8}$ m^2/s^2

Alion Problem Statement No. 6

Address any material settling inside the tank and its effects on the results.

The following response encompasses NRC comment Nos. 20 and 21.

20. Alion should demonstrate that, for coupons and debris baskets that are only in the test tank for a discrete period of time, the potential for slow or non-uniform mixing of the test fluid and the potential for unevenly mixed chemical constituents does not have a non-conservative impact on the corrosion/degradation of the coupons and debris baskets, which are assumed to be in contact with well-mixed test fluid for the entire period of immersion.

21. In light of the staff observations of debris densely packed into baskets, debris baskets with only one open side, and debris baskets and samples being tightly spaced in the test tank, Alion should demonstrate that the test tank fluid at VUEZ can interact with the materials in the tank in a representative manner.

Response:

It should be pointed out that the plant pool turnover times using a typical minimum volume of 63,000 ft^3 (475,000 gallons) and a flow rate of 8,000 gpm are on the order of 1 hour which is similar to the VUEZ tank turnover time of 85 minutes.

In response to these questions, Alion has performed a CFD analysis of the VUEZ experiment at the lowest flow rate used in the experiments 0.7 liter/minute. As illustrated in figures 1 and 2, the velocities are reasonably high enough (0.016 fps) to move through the materials submerged in baskets at the bottom of the tanks. With respect to the temporary and permanent metallic coupons, the velocities need only be non-stagnant to provide for suitable leaching/corrosion and a reasonably homogenous environment.

With respect to question 21, Alion represented submerged debris settled on the containment floor and sequestered in inactive pools in the experiment. This debris was confined into small trays with a wire mesh place over the top to retain the debris from transporting around in the tank. The aspect ratio of the debris tray was to provide a large amount of surface area. Figure 5 illustrates the debris tray for SEQ#1 and the quantity of debris included in the tray.

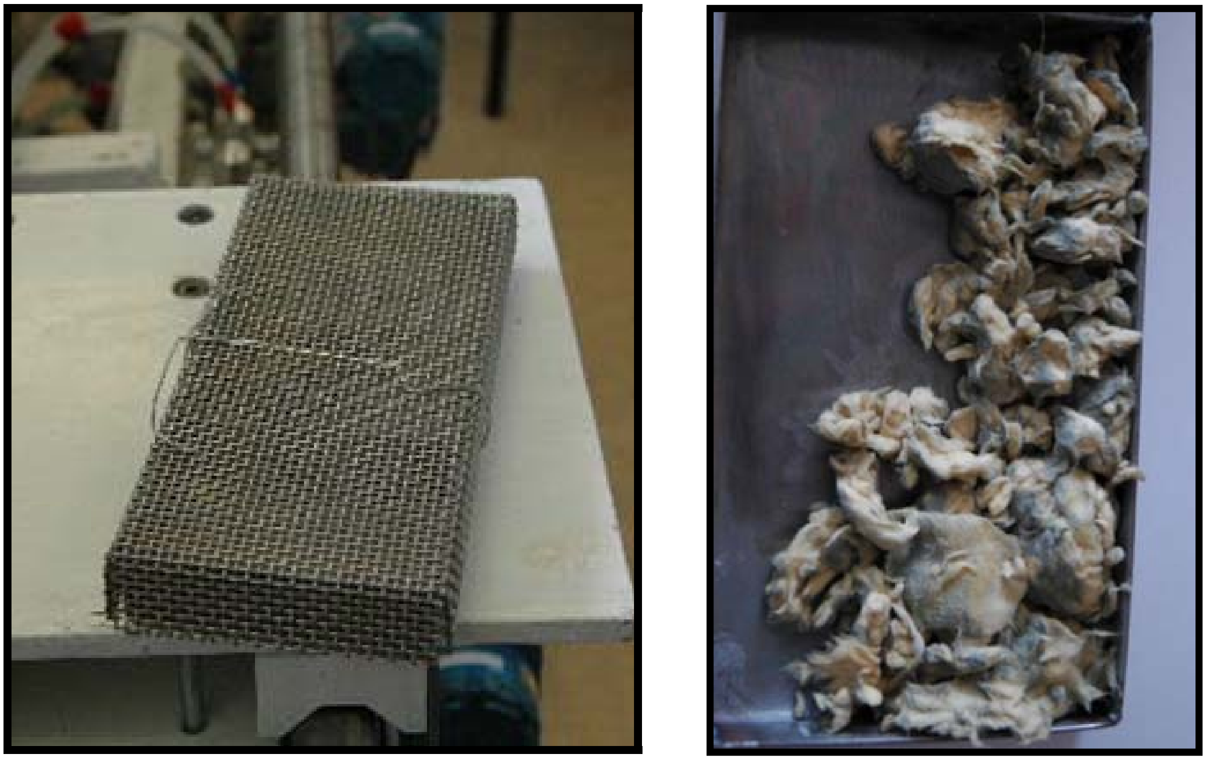

Figure 5: SEQ#1 Debris Tray and Debris (Loop 1)

The baskets were all of the same size for each of the experiments although debris quantities changed for each of the plants based on their specific debris conditions. SEQ#4 Cases 2, for example, contained a considerable amount of submerged fiberglass debris (see Figure 6). In this case, there is a concern relating to the interaction of the fluid and interior of the submerged fibrous debris. The NRC pointed out this concern when witnessing a plant specific VUEZ test and test technicians suggested a full screen tray (top and bottom) could be utilized to promote a more through mixing. Alion and VUEZ concurred that this could enhance mixing and made the change solely on a good practice judgment and not any analytical investigation.

SEQ#4 Case 1.1 was a restart of Case 1 due to a pump seal failure in Loop 1 midway through the experiment. Case 1.1 utilized the new basket type and can therefore provide a comparison on the silicon concentrations between the two basket designs (Case 1 is approximately 50% of the Case 2 fiber load). The silicon concentrations between the two loops are provided in Figures 7 and 8. As shown from the fluid ICP analysis between the two (2) loops, the difference is negligible. This is most likely due to the considerable amount surface area of the bulk fiberglass in the tray. The concentration is less than that predicted by the WCAP but is consistent with the benchtop work performed in an integrated environment and comparable to the ICET silicon levels. Table 2 provides a comparison of the quantity of fiber to the pool volume for the various experiments.

Figure 6: SEQ#4 Case Submerged Fiber Loading (Case 2)

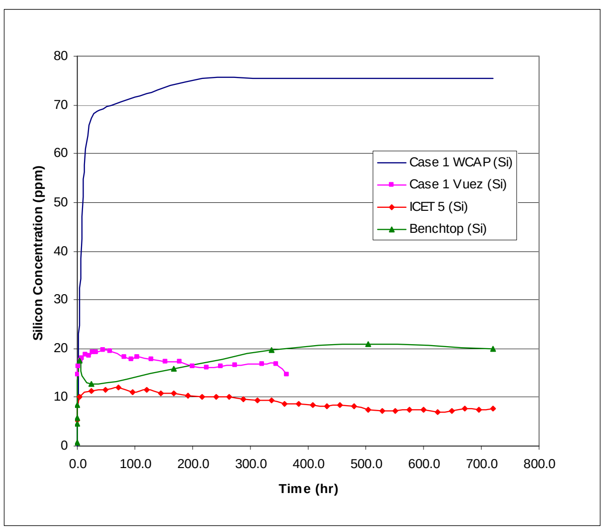

Figure 7: Silicon Concentration with Solid Bottom (Case 1)

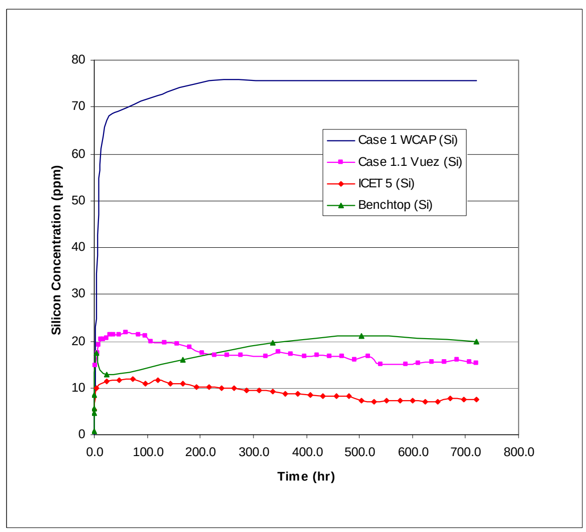

Figure 8: Silicon Concentration with Mesh Bottom (Case 1.1)

The following table 1 presents the submerged materials for each of the cases (loops) in SEQ#4. Based on this table and figure 6, this large amount of submerged fiberglass in a tray (Case 2) only occurred on one loop and is not typical.

Submerged Fiberglass Materials					
Material Type	Case 1	Case 2	Case 3	Case 4	Units
Temp-Mat	34.5	71.5	88.6	5.1	ft^3
NUKON/Fiberglass	358.9	768.3	224.9	89.3	ft^3
Thermal-Wrap	16.0	44.1	0.0	0.0	ft^2
Mineral Wool	0.0	0.0	2.4	0.0	ft^3

Table 1: SEQ#4 Submerged Fiber Loadings

Containment Materials	***Max for All IP Cases***	***Benchtop Test 10***	***ICET Test #5***	***Units***
Aluminum	0.037	0.042	3.5	ft^2/ft^3
Zinc	0.596	0.6	4.6	ft^2/ft^3
Temp-Mat	0.0024	0.003	-	ft^3/ft^3
NUKON/Thermal Wrap	0.022	0.027	.137	ft^3/ft^3
Cal-Sil	0.001	0.0015		ft^3/ft^3
Mineral Wool	5.32E-5	Note 1	-	ft^3/ft^3
Concrete Surface	0.008	0.047	0.045	ft^2/ft^3

Table 2: SEQ#4 Material to Pool Volume Ratios

Alion Problem Statement No. 11

What is the impact of a sudden temperature drop from a heat exchanger and the potential for thermal cycling?

The following response encompasses NRC comment No. 16

16. Alion should (a) describe the impact of thermal cycling of the test fluid to represent a sudden temperature drop in a heat exchanger and (b) demonstrate that neglecting this effect does not have a significant adverse impact on the VUEZ test results.

Response:

A concern was raised by the U.S. NRC relating to the potential of precipitate formation in that the existing VUEZ testing does not address the effect of a sudden temperature drop from a heat exchanger (such as RHR) and the potential for thermal cycling.

Two different heat exchanger tests were performed on supersaturated aluminum solutions at the same concentration (180 ppm Aluminum, 2800 ppm Boron, 0.7 ppm Lithium, and trisodium phosphate (TSP) with fixed pH between 8.5 and 8.6) to investigate the emulsion formation profile between two different conditions of cooling and heating treatment.

The 180 ppm Al concentration is estimated to be the solubility of Al at the high temperature conditions (158° F). When the solutions are cooled to room temperature, the solutions are in the supersaturated condition. The solubility of Al in these solutions at this temperature and pH is only a few ppm, and either amorphous or crystalline AlOOH [or $Al(OH)_3$] is expected to precipitate (or to form an emulsion).

For the first test, the solution stayed at 158° F for about five minutes, and then the solution was cooled at room temperature. Visual observations were conducted for the next 11 days. A slight cloudiness or cloudiness (that is basis on emulsion) was first observed on day 3. The cloudiness continued to develop, and at 11 days the solution was very cloudy. Because of the development of emulsion, a second test with heating and cooling cycles was conducted.

The second test was performed with the solution initially at 158° F, followed by ice-water quenching to room temperature (70° F), and heated back up to the 158° F. The solution was heated and quenched four (4) times in ten minute intervals. The ice-water quenching <u>did not accelerate the process for the development of emulsion</u> nor does the precipitate instantly form during the cooling process. The exposure of the solution to the decreased temperature in the RHR heat exchanger would be for a relatively short period of time and as illustrated in this experiment would not result in precipitation in the heat exchanger or affect the process of precipitation.

Alion Problem Statement No. 16

How are measurement uncertainties accounted for in the development of the test parameters and application of the experimental results?

The following response encompasses NRC comment No. 25

25. Alion should demonstrate that neglecting measurement uncertainties associated with the VUEZ testing does not have a significant adverse impact on the validity of the test results.

Response:

The Vuez Facility testing was intended to determine the change in head loss associated with a specified condition (precipitate, temperature, etc). The intent of the testing was not to determine the absolute head loss associated with a given debris mix and chemical interaction. The use of accurate instruments, calibrated to accepted standards, to monitor test parameters is reasonable and appropriate.

Alion did not neglect measurement uncertainties in the development of the test facility or protocols. Critical test parameters were measured with instrumentation calibrated to accepted standards. No uncertainty analysis was performed or deemed necessary. We fully understand the concepts involving variances of independent random variables being additive, but applying them to this test protocol was not necessary or reasonable.

The test protocols were generally developed or based on conservatively bounding inputs from each of the plants. It is noted that each parameter measured or controlled is not entirely or necessarily dependent on one or all of the other parameters. The result of quality, calibrated instruments with conservative inputs is a test that produces reasonably conservative or nominal results. This was the stated intent. The nominal instrument uncertainty is more than offset by the conservatisms in the debris mix. The result of artificial addition of test uncertainty on top of conservative inputs is an unreasonable test with no basis or connection to plant conditions. Therefore, it was concluded that an uncertainty analysis was not necessary and that the use of instruments calibrated to accepted standards is reasonable and would not have a significant impact on the validity of the test results.

Alion Problem Statement No. 19

Provide a summary of the quality assurance issues noted and their impact on results or corrective actions taken?

The following response encompasses NRC comment No. 28

28. Alion should demonstrate that the quality assurance associated with the VUEZ testing is adequate.

Response:

Alion takes very seriously the quality aspects of the experiment as well as all aspects of our work. Alion maintains a 10CFR50 Appendix B Program. The Vuez work was performed in accord with ALION-PLN-ALION-1002-01. When, errors or non-conformances occur they are identified and appropriate corrective actions taken. The Alion program is available for staff review upon request.

During the staff visit to the Vuez Facility, they noted that a procedure required that boiled Temp-Mat be added to the tank; however, the Temp-Mat that was added to the tank did not appear to the staff to have been boiled. After significant parts of 2 of the 4 formed debris beds floated away, the vendor then stated that it was not clear that the Temp-Mat had been boiled and attributed the partial floatation of the two debris beds to the Temp-Mat not having been boiled. Further investigation by Alion staff showed that the Temp-mat was indeed boiled. However, to eliminate any questions as to the validity of the test, the test was re-performed with new material prepared as required. This observation was noted in the project notes.

Also, during one of the tests that was nearly completed the staff observed a sample material basket that had been resting screen-side down (presumably for the duration of the test), such that no basket surfaces were open for fluid interaction with the test fluid. As a result, no leached material from the debris samples in this sample basket could have participated in the test. As a result of this event Alion implemented a wire mesh container for the submerged materials to preclude any inadvertent orientation changes and to promote better circulation of the fluid through the materials. A discussion of this observation and resulting corrective actions are detailed in the Vuez Project notes.

As stated, Alion takes very seriously the quality aspects of the experiment as well as all aspects of our work. Alion maintains a 10CFR50 Appendix B Program. The Vuez work was performed in accord with it and it's project plan. When, errors or non-conformances occur they are identified and appropriate corrective actions taken. The Alion program is available for staff review upon request. Alion, VUEZ and licensee oversight has ensured that test startups have gone according to both the technical and quality requirements. Non-conformances are identified, documented, dispositioned, corrective actions taken and communicated to Alion and their clients for acceptance. Based upon these actions, the testing at the Vuez Facility is adequate and in accord with 10CFR50 Appendix B.

If you have any questions or require additional information please contact me at (630) 846-6787 or Steven Unikewicz at (703) 439-7133.

Sincerely,

Robert Choromokos
Manager, Energy Services Division

Enclosure

cc: P. Mast
S. Unikewicz
Owner's Group Distribution

THERMAL CYCLING OF RECIRCULATION SUMP FLUID

HEAT EXCHANGER TESTS ON 180-PPM-ALUMINUM IN TSP SOLUTION

June 6, 20089

Abstract

A concern was raised by the U.S. NRC relating to the potential of precipitate formation in that the existing VUEZ testing does not address the effect of a sudden temperature drop from a heat exchanger and the potential for thermal cycling. This paper will address the potential for precipitate formation due to sudden temperature drops.

Two different heat exchanger tests were performed on supersaturated aluminum solutions at the same concentration (180 ppm Al, 2800 ppm Boron, 0.7 ppm Lithium, and trisodium phosphate (TSP) with fixed pH between 8.5 and 8.6) to investigate the emulsion formation profile between two different conditions of cooling and heating treatment.

The 180 ppm Al concentration is estimated to be the solubility of Al at the high temperature conditions (158° F). When the solutions are cooled to room temperature, the solutions are in the supersaturated condition. The solubility of Al in these solutions at this temperature and pH is only a few ppm, and either amorphous or crystalline AlOOH [or $Al(OH)_3$] is expected to precipitate (or to form an emulsion).

For the first test, the solution stayed at 158° F for about five minutes, and then the solution was cooled at room temperature. Visual observations were conducted for the next 11 days. A slight cloudiness (that is basis on emulsion) was first observed on day 3. The cloudiness continued to develop, and at 11 days the solution was very cloudy. Because of the development of emulsion, a second test with heating and cooling cycles was conducted.

The second test was performed with the solution initially at 158° F, followed by ice-water quenching to room temperature (70° F), and heated back up to the 158° F. The solution was heated and quenched four (4) times in ten minute intervals. The ice-water quenching <u>did not accelerate the process for the development of emulsion</u>.

Since the solubility difference between amorphous and crystalline AlOOH (or $Al(OH)_3$)
[note that $Al(OH)_3 \leftrightharpoons AlOOH + H_2O$] is known, the solution was heated to 200° F and held at the high temperature overnight. The solution was cooled to room temperature again to look for any cloudiness development and none was observed. Five days later, a thin film of precipitate was present at bottom of the test flask, and a slight cloudiness was present in the solution.

The history of heat on the solution varies the precipitation behavior of the Al supersaturated solution: The cloudiness of amorphous emulsion is observed when the supersaturated solution stays at low temperature (RT), but at high temperature, it forms crystalline AlOOH. The ice quenching does not accelerate the precipitation kinetics.

Experimental Method

<u>Test 1</u>: The first heat exchanger test used 175 to180 ppm Al in 2800 ppm B (boric acid) with 0.7 ppm Li adjusted to pH 8.6 with TSP in a round bottom flask. The solution started at 158° F and then cooled to room temperature. The solution started to turn cloudy between day 3 and day 4 and was very cloudy by day 11 as seen in Figure-1.

Figure-1: 175-180-ppm-Al in 2800 ppm B (boric acid) adjusted to pH 8.6 with TSP: Heated to 158°F and then cooled to room temperature at Day 4 and Day 11

<u>Test 2:</u> For the second test, a solution of 2800 ppm B (boric acid) and 0.7 ppm Li (LiOH) was placed in an Erlenmeyer flask and heated to 158° F. Next, an Al solution in TSP was added to the boric acid solution. The resulting solution contained 180 ppm Al in 2800 ppm B (boric acid with 0.7 ppm Li) and TSP at pH 8.5, Figure 2 shows that the solution of 2800 ppm B (boric acid) with 0.7 ppm Li (LiOH) is clear before and after the aluminum dissolved in TSP (180-ppm-Al and TSP to pH 8.5) is added.

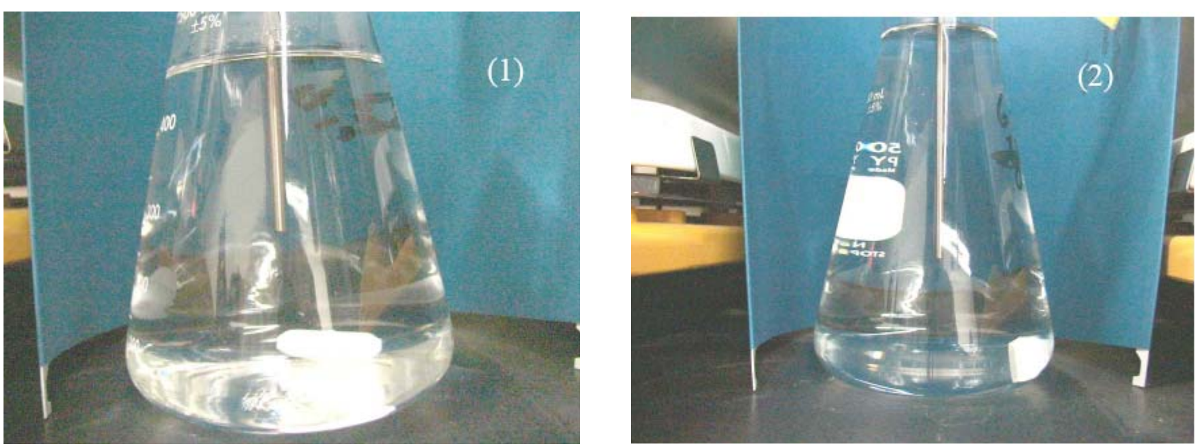

Figure-2: 2800 ppm B (boric acid) with 0.7 ppm Li (LiOH) (1) and with 180 ppm Al and TSP to pH 8.5 (2) (Solution remains clear)

The solution was then heated to about 160° F and cooled rapidly to room temperature. Figure 3(1) shows that the solution is still clear when cooled. The heating and cooling cycle was repeated three more times. The solution remained clear and figure 3(2) shows the clear solution at the end of the fourth cooling cycle.

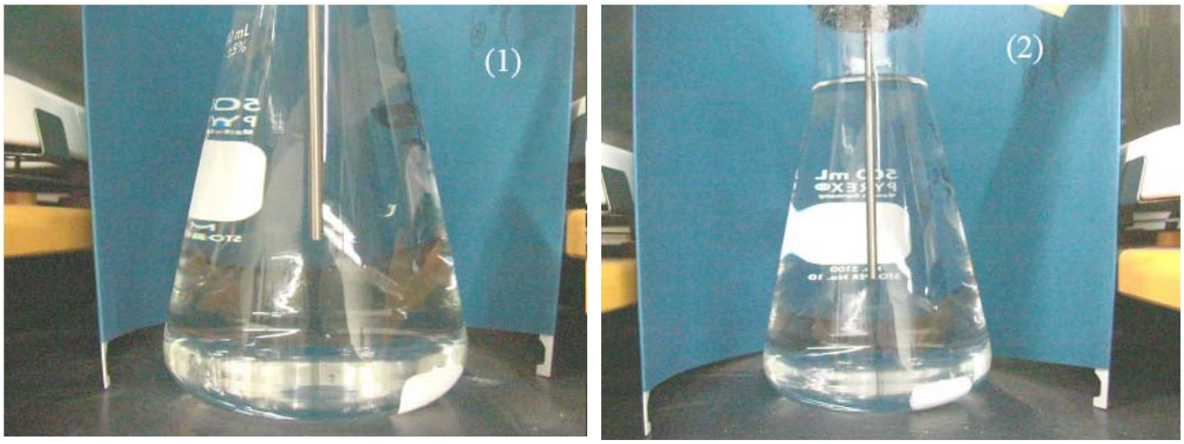

Figure 3: 2800 ppm B (boric acid) with 0.7 ppm Li, 180 ppm Al and TSP to pH 8.5 (1) First cool down to 25° C, (2) fourth cool down to 25° C (Solution remains clear.)

After the fifth heating to 158° F, the solution was stirred and heated to about 200° F. The test solution was held at about 200° F for 24 hours. Figure 4 shows the heating and cooling cycles.

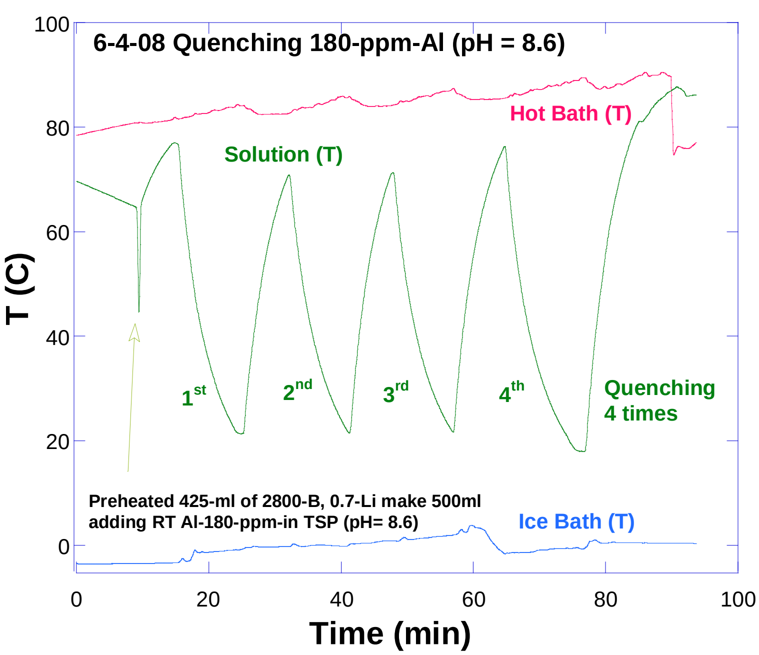

Figure 4:

Test 2 quenching cycles of 180 ppm Al in 2800 ppm B (boric acid) with TSP (pH = 8.5) solution cycles between the hot bath and ice bath. (Solution was subsequently heated to 200° F for 24 hours.)

The four quenching tests indicated that no cloudiness was observed from the 180 ppm Al solution during the test period shown in Figures 2 through 4. The solution remained very clear. As shown in Figure 5, the T and derivative (dT/dt) vs. time for the quenching test, there was no physical changes observed. The estimated solubility of Al is as shown in Figure 6 for the T and pH (20 (68 °F) < T (F) < 70 (158° F), pH = 8.5) is 5 ppm. With Al < X (T, pH) <180 ppm Al, the Al concentration exceeded the estimated solubility, but no cloudiness was observed. This could indicate that the precipitate does not develop under these test conditions. The previous test (test #1) showed that the cloudiness took a few days to become visible.

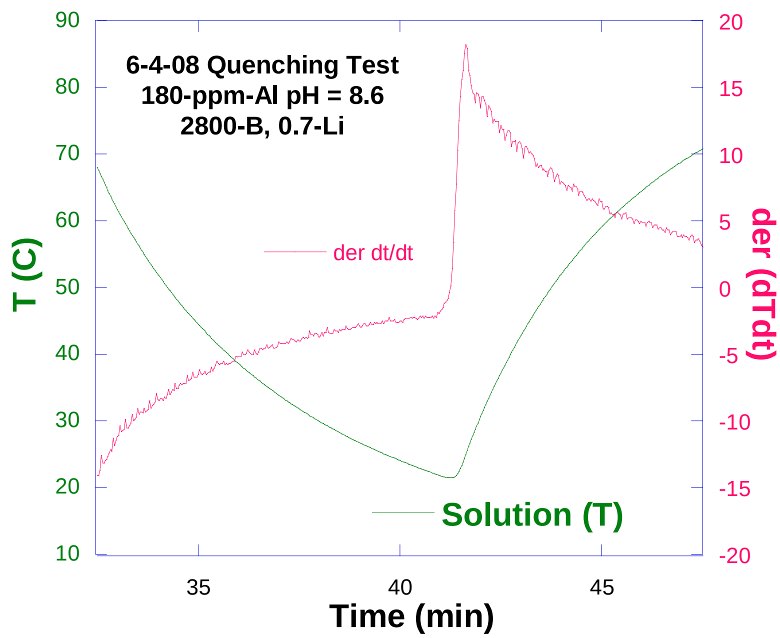

Figure-5:

T and der (dT/dt) vs. time for the quenching test of 180 ppm Al in 2800 ppm B (boric acid) with TSP (pH = 8.5) solution cycles 2 (cooling) to 3 (heating) between the hot bath and ice bath.

The nucleation and growth of crystalline AlOOH is a thermally activated process. That is the main reason test#2 was performed at a high temperature and under the solubility limit, i.e., ensure an all dissolved condition. At temperature approximately 140°F and below the amorphous phase is stable as illustrated in Test#1. At temperatures near 200 °F

At T > 140° F the crystalline AlOOH (or $Al(OH)_3$) is more stable. It would appear that at high temperature T = 95° C (≈200° F), the amorphous form readily dissolves, however, the stable crystalline phase stable condition, and the crystalline AlOOH precipitation is expected.

<u>Solubility of Crystalline Aluminum Oxyhydroxide:</u> After 4 quenching/heating cycles, the solution was held at high temperature ≈200° F for the purpose of observing the crystalline phase that has a much lower solubility. Also at high temperature, the crystalline phase is more thermodynamically stable.

Test 1 had the same concentrations of Al, B, TSP, and Li and the same pH as test 2, but the test 1 solution remained cool (room temperature). The test 2 solution was held at high temperature (200° F), to enhance the formation of crystalline aluminum oxyhydroxide.

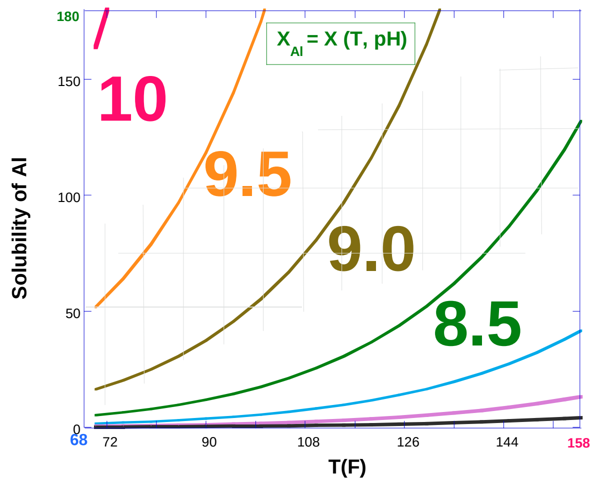

Figure 6: Solubility of Al as a function T and pH for Amorphous AlOOH (or Amorphous $Al(OH)_3$).

The test 2 solution is cloudier 96 hours later. There is a film on the bottom of the flask, and the solution is slightly cloudy. The photograph in figure 7 shows the cloudy test 2 solution and the clear reverse osmosis water. A few milliliters of the test 2 solution (and some of the film) from the bottom of the flask was transferred to a glass centrifuge tube.

After one day, the solution in the tube is clear and there is a precipitate at the bottom of the tube. There also appears to be more precipitate film on the bottom of the flask. Because the test 2 condition was for a stable crystalline form, the deposit on the bottom is expected to be crystalline AlOOH.

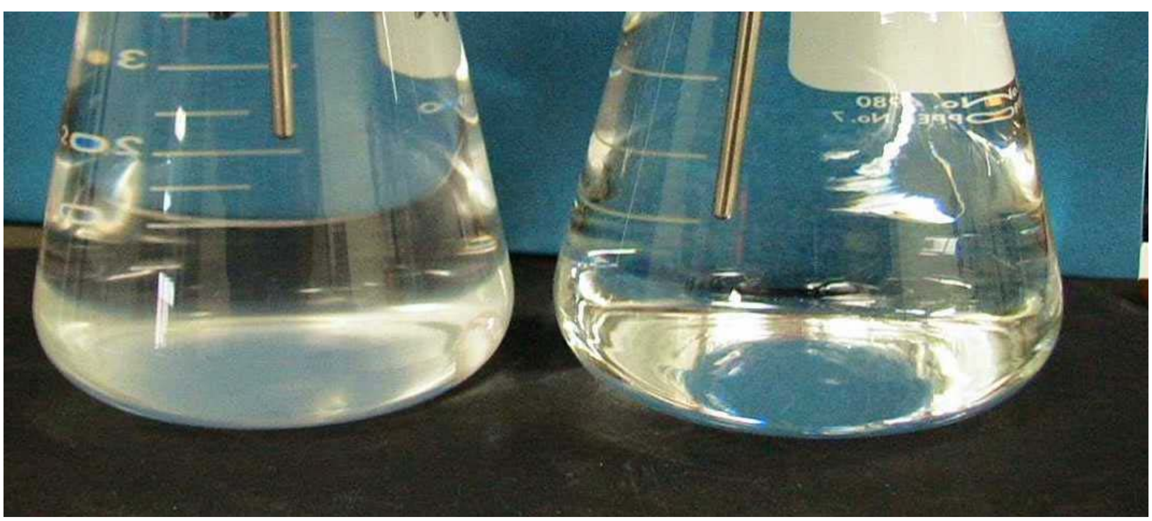

Figure 7: 2800 ppm B (boric acid) with 0.7 ppm Li, 180 ppm Al and TSP to pH 8.5 heated to 200° F for 24 hours then cooled at room temperature for 4 days (left) and RO water (for comparison) For the left solution, the observed deposit at the bottom of the flask should be crystalline AlOOH. The solution is also slightly cloudy.