MCB Issue List Regarding APR-1400, DCD Tier 2, SECTION 6.8

Issue #7 (AI 6-19.7)

Section 3.8.2, paragraph "3)" of the GSI-191 technical report states, "The maximum IRWST and spray pH profile is used to conservatively maximize dissolution and precipitate generation."

Revise the report to explain how "maximum pH profile" was defined and determined, and explain how this pH profile ensured maximum dissolution and precipitate generation.

Revised Response - (Rev. 1)

The RCS is operated within a pH range of 6.0 to 7.3 during the normal power operation and is controlled with the pH range of 4.2 to 7.3 during all plant operating modes. The IRWST water is maintained at a pH of about 4.4 using at least 4,000 ppm boric acid and is controlled at a pH range of 3.8 to 8.4 during all operating modes. A pH range of 4 to 10 is used for short term DBA condition at the reference plants in Korea. Based on these APR1400 operating conditions and past operating experiences, the IRWST and containment spray pH range for short term DBA condition is 4 to 10.

In the event of a LOCA, the initial sprayed volume runs down the containment building, collects in the HVT, and flows back into the IRWST. TSP dissolves and increases the pH from about 4.4 to above 7. The maximum pH value does not to exceed 8.5 for the maximum pH condition. Thus the IRWST and containment spray pH range is considered to be 7 to 8.5 for the long-term DBA condition.

According to WCAP-16530-NP-A, Section 6.5.2, longer durations at higher pH will result in more material dissolution and increased chemical precipitates. The chemical effects analysis uses the maximum pH values for short (10) and long (8.5) term DBA conditions to maximize dissolution and precipitate generation.

Impact on DCD

There is no impact on the DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports v

Technical Report APR1400-E-N-NR-14001-P/NP, Section 3.8.1 and 3.8.2, and Table 3.8-1 will be revised in the response to Action Item 6-19.8, Rev.1.

MCB Issue List Regarding APR-1400, DCD Tier 2, SECTION 6.8

Issue #8 (AI 6-19.8)

The pH of the post-loss-of-coolant-accident (LOCA) water is not clear to the staff. Section 3.8.1 ("Containment Spray pH Control") of the GSI-191 technical report contains the following statements:

- "…the calculated minimum and maximum pH values under any possible water chemistry conditions caused by a LOCA are between 7.0 and 8.5."
- "The calculated minimum and maximum IRWST pH during operation of the CSS is 7 and 10, respectively…The IRWST pH ranges are included in Table 3.8-1."

Report Table 3.8-1 lists the following post-LOCA pH values:

- pH between 4 and 10 for short-term design-basis accident (DBA) (up to 4 hours)
- pH between 7.2 and 8.5 for long-term DBA (4 hours to 30 days)

Report Table 3.8-5, which summarizes the chemical precipitate calculation, shows a pH value of 10 after 2 minutes and a minimum value of 8.5 from 4 hours to 30 days.

Some of these statements appear to be contradictory. For example, it is not clear how there can be a pH value of 10 if the minimum and maximum values under any possible conditions are 7.0 and 8.5. Clarify the descriptions of the pH values given in the GSI-191 technical report and explain how the pH transient represented in report Table 3.8-5 was derived.

Revised Response - (Rev. 1)

LOCA water pH values ranging from 4 to10 are used for the short-term DBA condition and pH values ranging from 7 to 8.5, using the tri-sodium phosphate as a buffering agent, are used for the long term DBA condition. The chemical effects analysis uses the maximum pH values for short (10) and long (8.5) term DBA conditions in order to maximize dissolution and precipitate generation as described in WCAP-16530-NP-A, section 6.5.2.

Based on the above, the GSI-191 Technical Report, Sections 3.8.1 and 3.8.2, and Table 3.8-1 will be revised.

Impact on DCD

There is no impact on the DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

MCB Issue List Regarding APR-1400, DCD Tier 2, SECTION 6.8

Impact on Technical/Topical/Environmental Reports

APR1400-E-N-NR-14001-P/NP, Sections 3.8.1 and 3.8.2, and Table 3.8-1 will be revised, as indicated in the attachment associated with this response.

The IRWST and containment spray pH ranges are 4 to 10 for short term DBA condition, based on APR1400 operating conditions and past operating experience, and 7 to 8.5, using the tri-sodium phosphate as buffering agent, for long term DBA condition. These values are based on the maximum and minimum pH calculations.

3.8 Chemical Effects

In order to assess potential chemical effects in the APR1400 sump, the materials that are in the containment building that may react with coolant in the post-accident containment environment have been identified. Reactive plant materials in the containment building are categorized as metallic and non-metallic items and generally include insulation and concrete, as well as other potential sources of aluminum. The materials inventory includes the overall mass, location in containment and potential for being sprayed with or immersed in coolant following a LOCA.

The WCAP-16530-NP methodology (Reference [3-11]) referenced in NRC RG 1.82 (Reference [1-1]) provides a conservative model to predict the corrosion and dissolution of containment materials in a post-LOCA environment and the formation of chemical precipitates for participating PWRs. The primary corrosion products contributing to these chemical precipitates are calcium, silicon, aluminum, and the precipitates that can form aluminum oxy-hydroxide, calcium phosphate, and sodium aluminum silicate. Surrogate suspensions of chemical precipitates representing this chemical debris can be included as an additional debris source to the strainer testing program to qualify the strainer for “chemical effects.” The quantities of chemical precipitates are based on reactive material surface areas and quantities, temperature, water level, pH, and other parameters related to the plant specific environment and post-accident evolution.

~~The results of the calculations show that the time required to reach a pH of 7.0 for the minimum pH condition is estimated to be 157 minutes after the onset of a LOCA, as shown in Figure 3.8-1.~~

3.8.1 Containment Spray pH Control

The pH of IRWST water is evaluated to provide reasonable assurance that the calculated minimum and maximum pH values under any possible water chemistry conditions caused by a LOCA are between 7.0 and 8.5. ~~The calculated minimum and maximum IRWST pH during operation of the CSS is 7 and 10, respectively.~~ ~~The minimum time to reach a minimum pH of 7.0 is 157 minutes, as shown in Figure 3.8-1.~~ The IRWST pH ranges are included in Table 3.8-1.

~~3) For short term DBA condition, the RCS pH design limit (between 4.2 and 10.7) listed in Table 5.2-5 of the DCD (Reference [3-1]) is conservatively used to maximize dissolution and precipitate generation.~~

3.8.2 Assumptions

1) The maximum IRWST water volume is used for the chemical effects analysis. Using the maximum water volume ensures that the maximum material dissolution and quantity of precipitates are analyzed.

2) Temperature data is only available from zero to 1,000,000 seconds post-LOCA. Since the mission time is 30 days (2,592,000 seconds), the containment air temperature and IRWST temperatures are extrapolated using a logarithmic fit of the last 9 days of available temperature data to predict the containment air and IRWST temperatures from 1,000,000 seconds to 2,592,000 seconds. This time period is chosen due to the consistently logarithmic temperature decrease for the entire time period.

~~3) The maximum IRWST and spray pH profile is used to conservatively maximize dissolution and precipitate generation.~~

5) ~~4)~~ The minimum ECCS flow case is used because it results in the highest sump temperatures, and therefore the highest corrosion rate of reactive materials in the sump. Both the minimum and maximum ECCS flow cases result in the comparable containment air temperature profiles.

3) ~~4)~~ The maximum IRWST and spray pH values of ~~10.7~~ 10 for short-term DBA and 8.5 for long-term DBA from Table 3.8-1 are conservatively used because total dissolution and precipitate generation increase as pH increases, as shown in Figure 6.5-5 of Reference [3-11].

Table 3.8-1 Post-LOCA IRWST Chemistry

Short-Term DBA (Accident Initiation up to 4 hours)	Long-Term DBA (4 hours up to 30 days)
• 4,400 ppm boron as H_3BO_3 • 0 - 50 ppm hydrazine as N_2H_4 • ~~4~~ ≤ pH ≤ ~~10~~ ~~4.2~~ ~~10.7~~ 4 10	• 4,400 ppm boron as H_3BO_3 • 0 - 50 ppm hydrazine as N_2H_4 • ~~7.2~~ ≤ pH ≤ 8.5 • Tri-sodium phosphate as buffering agent 7.0

AI 6-19_6.8_#8_Rev.1

Non-Proprietary

Attachment (3/3)

Table 3.8-5 Results for the APR1400, Maximum Water Volume, Minimum ECCS Flow

Interval Duration (min)	Start of Interval (hrs)	End of Interval (hrs)	Average Interval pH	Average Temp (°F)	NaAlSi3O8 Precipitate (kg)	AlOOH Precipitate (kg)	Ca3(PO4)2 Precipitate (kg)
2.0	0.00	0.0	10	135.6	0.001	0.561	0.000
1.6	0.04	0.1	10	139.2	0.0	1.1	0.00
1.2	0.06	0.1	10	141.0	0.0	1.5	0.00
3.0	0.08	0.1	10	143.8	0.0	2.6	0.00
3.2	0.13	0.2	10	147.9	0.0	3.7	0.00
4.9	0.19	0.3	10	153.0	0.0	5.3	0.00
5.5	0.27	0.4	10	158.9	0.0	7.1	0.00
9.4	0.36	0.5	10	165.5	0.0	10.1	0.01
11.6	0.52	0.7	10	173.0	~~0.0~~ 0.1	13.6	0.01
22.9	0.71	1.1	10	183.1	0.1	20.0	0.02
76.1	1.09	2.4	10	202.2	0.3	38.7	0.05
98.4	2.36	4.0	10	222.6	0.8	~~58.6~~ 58.5	0.09
0.0	4.00	4.0	9.25	230.0	0.8	58.6	0.09
241.9	4.00	8.0	8.5	233.6	1.6	69.9	~~0.20~~ 0.21
210.9	8.03	11.5	8.5	235.0	2.3	77.6	0.30
237.8	11.55	15.5	8.5	229.4	3.0	84.4	0.39
291.4	15.51	20.4	8.5	221.6	3.8	90.8	0.40
617.2	20.37	30.7	8.5	209.7	4.2	100.5	0.40
746.4	30.66	43.1	8.5	~~196.2~~ 196.1	4.2	108.2	0.41
1578.7	43.10	69.4	8.5	183.5	4.2	119.0	0.43
2392.0	69.41	109.3	8.5	172.0	4.2	129.6	0.45
3306.3	109.27	164.4	8.5	162.8	4.2	139.5	0.47
3382.5	164.38	220.8	8.5	156.2	4.2	147.2	0.49
2635.0	220.75	264.7	8.5	152.1	4.2	152.2	0.51
3035.5	264.67	315.3	8.5	148.4	4.2	157.1	0.53
3035.5	315.26	365.9	8.5	144.9	4.3	161.3	0.55
3035.5	365.86	416.4	8.5	142.2	4.3	164.9	0.56
3035.5	416.45	467.0	8.5	139.8	4.3	168.2	0.58
3035.5	467.04	517.6	8.5	137.6	4.3	171.1	0.60
3035.5	517.63	568.2	8.5	135.7	4.3	173.8	0.61
3035.5	568.22	618.8	8.5	133.9	4.3	176.2	0.63
3035.5	618.82	669.4	8.5	132.3	4.3	178.5	0.64
3035.5	669.41	720.0	8.5	130.8	4.3	180.6	0.66

10.7

0.4
1.0

1.8
2.5
3.3
4.0

77.5
84.3

Delete this row for AI 6-19.11.

This Table will be updated in the response to RAI 391-8462 Question 06.02.02-35

MCB Issue List Regarding APR-1400, DCD Tier 2, SECTION 6.8

Issue #9 (AI 6-19.9)

In the GSI-191 technical report, the chemical effects analysis includes both aluminum and concrete that is unsubmerged. Since corrosion of the unsubmerged materials is a result of containment spray system (CSS) operation, revise the report to clarify the operating time of the CSS used in the analysis and how it was determined to be conservative with respect to chemical precipitation.

Revised Response - (Rev. 1)

The CSS is considered to be operated from the accident initiation and continually operated until 30 days in order to maximize the exposure of containment spray to unsubmerged aluminum. Table 3.8-1 lists the post-LOCA IRWST and containment spray chemistry which is applied to the submerged and unsubmerged materials. The maximum pH values for short and long term DBA conditions are used for the chemical effects analysis to generate the maximum chemical precipitates.

Impact on DCD

There is no impact on the DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

Technical Report APR1400-E-N-NR-14001-P/NP, Section 3.8.2 will be revised as indicated in the attachment associated with this response.

3.8 Chemical Effects

In order to assess potential chemical effects in the APR1400 sump, the materials that are in the containment building that may react with coolant in the post-accident containment environment have been identified. Reactive plant materials in the containment building are categorized as metallic and non-metallic items and generally include insulation and concrete, as well as other potential sources of aluminum. The materials inventory includes the overall mass, location in containment and potential for being sprayed with or immersed in coolant following a LOCA.

The WCAP-16530-NP methodology (Reference [3-11]) referenced in NRC RG 1.82 (Reference [1-1]) provides a conservative model to predict the corrosion and dissolution of containment materials in a post-LOCA environment and the formation of chemical precipitates for participating PWRs. The primary corrosion products contributing to these chemical precipitates are calcium, silicon, aluminum, and the precipitates that can form aluminum oxy-hydroxide, calcium phosphate, and sodium aluminum silicate. Surrogate suspensions of chemical precipitates representing this chemical debris can be included as an additional debris source to the strainer testing program to qualify the strainer for “chemical effects.” The quantities of chemical precipitates are based on reactive material surface areas and quantities, temperature, water level, pH, and other parameters related to the plant specific environment and post-accident evolution.

3.8.1 Containment Spray pH Control

The pH of IRWST water is evaluated to provide reasonable assurance that the calculated minimum and maximum pH values under any possible water chemistry conditions caused by a LOCA are between 7.0 and 8.5. The calculated minimum and maximum IRWST pH during operation of the CSS is 7 and 10, respectively. The minimum time to reach a minimum pH of 7.0 is 157 minutes, as shown in Figure 3.8-1. The IRWST pH ranges are included in Table 3.8-1.

3.8.2 Assumptions

1) The maximum IRWST water volume is used for the chemical effects analysis. Using the maximum water volume ensures that the maximum material dissolution and quantity of precipitates are analyzed.

2) Temperature data is only available from zero to 1,000,000 seconds post-LOCA. Since the mission time is 30 days (2,592,000 seconds), the containment air temperature and IRWST temperatures are extrapolated using a logarithmic fit of the last 9 days of available temperature data to predict the containment air and IRWST temperatures from 1,000,000 seconds to 2,592,000 seconds. This time period is chosen due to the consistently logarithmic temperature decrease for the entire time period.

3) The maximum IRWST and spray pH profile is used to conservatively maximize dissolution and precipitate generation.

4) The minimum ECCS flow case is used because it results in the highest sump temperatures, and therefore the highest corrosion rate of reactive materials in the sump. Both the minimum and maximum ECCS flow cases result in the comparable containment air temperature profiles.

~~6) Aluminum and concrete which are not submerged are conservatively assumed to be submerged to maximize chemical precipitate generation.~~

6) The CSS is operated from the accident initiation an continued for 30 days to maximize the exposure of containment spray to unsubmerged materials.