TABLE 1

APR1400 Pre-Application Audit – NRC Observations on GSI-191

Item	Topic	Issue
1	RG 1.82, Revision 4 comparison	The GSI-191 technical report (APR1400-E-A-T(NR)-13001-P, Rev A) provides a Table that compares the APR1400 design to RG 1.82, “Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident,” Revision 4 positions. KHNP states that they “comply” or “comply with substance,” to various positions. Staff recommends changing “comply” to “conform” and requests that KHNP clarify (define) what is meant by “comply with substance.”
2	Technical reports - Incorporated by Reference	The staff did not find a description (typically in Tier 2, Chapter 1, Section 1.9) of the Technical Reports that were incorporated by reference. For example, the GSI-191 technical report was not listed.
3	Insulation in containment	The staff did not find a clear discussion about the types of insulation used inside containment and where and in what quantities each type is used (RG 1.206, “Combined License Applications for Nuclear Power Plants (LWR Edition),” guidance).
4	Debris Generation/ Zone of Influence (ZOI)	• Staff routinely heard that APR1400 was an all ‘reflective metal insulation’ (RMI) plant, but did not find this clearly stated in the DCD. • Staff did not identify a clear statement that fiber insulation was excluded from containment. Therefore, a fiber ZOI should be designated and the evaluation results discussed. • Staff did not find a listing of the total surface area of all signs, placards, tags, tape, and similar miscellaneous materials in containment.
5	Debris Characteristics	Details were missing regarding debris characteristics (for example latent debris and coatings) to include sizing, size distribution, density, concentration etc. to support analysis and testing (for example downstream effects ex-vessel evaluations)

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6	Latent Debris	• Cleanliness program detail is not clear and needs to be improved. It should specifically list the containment performance criteria that Combined License (COL) applicants would need to meet for implementing the cleanliness program (related to COL Item). • For RMI/low-fiber plants, provide a description of programmatic controls to maintain the latent debris fiber source term into the future to ensure assumptions and conclusions regarding inability to form a thin bed of fibrous debris remain valid. • Provide a summary of the foreign material exclusion programmatic controls in place to control the introduction of foreign material into the containment. • Provide a description of how permanent plant changes inside containment are programmatically controlled so as to not change the analytical assumptions and numerical inputs of the licensee analyses supporting the conclusion that the reactor plant remains in compliance with 10 CFR 50.46, “Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors” and related regulatory requirements. • Provide a description of how maintenance activities including associated temporary changes are assessed and managed in accordance with the Maintenance Rule, 10 CFR 50.65, “Requirements for monitoring the effectiveness of maintenance at nuclear power plants.” • Provide a description of the sacrificial strainer surface area allotted to miscellaneous latent debris or a basis for not considering sacrificial area due to miscellaneous debris.

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7	Debris Transport	• In the GSI-191 technical report, section 3.4, “Debris Transport,” the design basis is described as 100% debris transport to one strainer. However the very next section (3.5, “Debris Head Loss”) assumes 25% debris transport to one strainer. During audit discussions, KHNP acknowledged this inconsistency and plans to correct it. • The transport argument for RMI needs to be strengthened…”RMI is dense”…flow rates are “small” such that RMI is not transported to the APR1400 strainer. Staff are looking for the technical details that support this evaluation result (consider flow velocities in transport path (Holdup Volume Tank (HVT), transfer pipes, In-containment Refueling Water Storage Tank (IRWST), at strainer screen) in comparison to settling and lift-over velocities (identify any curbs in path to strainer or at strainer). • The trenches (no detailed information identified such as length, depth, hold-up volume etc.) and trash racks (relatively small area and opening size) are situated at the entrance to the HVT. Details should be provided regarding their expected performance during a LOCA to inhibit transport and contribute to debris and water holdup on the 100’ elevation containment floor. Applicant should address the ability of the design to accommodate the maximum volume of debris that is predicted to arrive at the screen

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8	Coatings	• The staff was not able to determine from Draft DCD Tier 2 Section 6.1.2 and the GSI-191 technical report whether the APR1400 design will conform to Regulatory Guide (RG) 1.54, "Service Level I, II, and III Protective Coatings Applied to Nuclear Power Plants" on coatings. The DCD states that it meets the "recommendations and intent." The version of the RG being referenced is also unclear. The DCD references RG 1.54, Revision 2. The GSI-191 technical report references RG 1.54, Revision 1. This will also need to be consistent with DCD Tier 2 Section 1.9. • The staff observed an apparent contradiction in the GSI-191 technical report about how the applicant calculated the coatings quantity. Pages 3-5 describe two different methodologies. • The staff observed inconsistencies or a lack of clarity in the revisions of ASTM standards on coatings. Such details are important in the staff's review because RG1.54 approves specific versions of ASTM standards. • The staff did not find a clear description in the DCD of which types of coatings are used on which substrates. • The staff observed that Draft DCD Tier 2, Section 6.1.2 is not clear about how the coating Service Level I requirements will be applied to both structures and purchased components in containment. • The staff observed that Draft DCD Tier 2, Section 6.1.2 does not describe the coatings program, nor does it require the COL applicant to describe their program. • The staff did not find a description on the mass of coating material that would be generated in the ZOI. The documents listed a total volume of coatings debris generated, but given that there were various coating thicknesses and coating densities, the exact makeup of the coating debris was not able to be determined. • The GSI-191 technical report listed coatings used in containment – epoxy and inorganic zinc (IOZ). Only one ZOI was specified (four diameters of the pipe that breaks - 4D) but the type of coating involved was not identified. • Since there is IOZ inside the containment, the staff expects to see a ZOI analysis (10D) for IOZ, even if there is no IOZ in the ZOI. • The coating debris quantity includes a 10 percent increase in the volume of coatings debris to account for gratings and miscellaneous. It was not clear to the staff if 10 percent was an arbitrary choice or if it was determined to be a conservative estimate.

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9	Strainer Head Loss	• The staff did not find a description of the tests performed or a reference to test reports available that demonstrate the behavior of the strainer. • The “clean plant” criteria per SECY-12-0093 and an NRC letter to the Nuclear Energy Institute (NEI) dated May 2, 2012 (ADAMS Accession No. ML120730181) was applied by the applicant however, sufficient information was not provided to show correct application (or applicability in general) of this NRC-approved guidance. • It was not clear to the staff why there were two different minimum IRWST water levels, yielding two different minimum strainer submergence values. In the GSI-191 technical report, the minimum strainer submergence calculation uses a minimum IRWST water level of 5’ (5’ – 3’ = 2’, where 3’ is top of strainer), whereas the minimum submergence in the IRWST water calc uses a minimum IRWST level of 4.75’ (4.75’ – 3’ = 1.75’). • If the IRWST minimum water level is 4.75’ as outlined in calculation (1-447-N371-001) and strainer submergence (1.75 feet) is less than head loss (2 feet), then a detailed deaeration and flashing analysis must be performed. However, one was not available for the audit. • Staff did not find an evaluation of vortexing in the sump strainer flow. • KHNP did not provide a summary of the methodology, assumptions, and bases for the assumptions, for the clean strainer head loss calculation. • In the GSI-191 technical report, 2 feet of strainer head loss is assigned at 230°F. Using the analysis method described (viscosity correction); the head loss at 200°F would exceed 2 feet. Since there is only 2 feet of submergence, when viscosity corrections are applied at 212°F, the design basis head loss would exceed submergence. This is inconsistent with the design basis flashing and deaeration analyses which were assessed based on strainer head loss not exceeding submergence. This inconsistency in analysis needs to be addressed.

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10	NPSH	The following observations are made regarding net positive suction head (NPSH): • The GSI-191 technical report describes the calculation of NPSH Allowed (NPSHA) as being consistent with RG 1.82, Revision 4, position 1.3.1.1. This position requires assuming "…no increase in containment pressure from that present before the postulated LOCA." KHNP indicates they "comply" with this position despite use of containment pressure greater than that present before the postulated accident, when assessing NPSHA at IRWST temperatures greater the 212°F. This needs to be addressed. Either demonstrate conformance to the position or provide an alternative method for staff review (see last bullet on this page) • The staff did not find the basis for the required NPSH values, (e.g., three percent head drop or other criterion) • The staff did not find the system response scenarios for small break LOCAs. • The staff identified non-conservative assumptions included in the analysis to ensure a minimum IRWST water level is used in determining NPSH margin. For example, minimum water level appeared to be inconsistent between GSI-191 technical report (5' above floor bottom) and calculation 1-447-N371-001 (4.75' above floor bottom) and water holdup calculation on 100 ft containment elevation was non-conservative (at least 8 inches too low in annular region) • The Safety Injection (SI) and Containment Spray (CS) pump NPSHA calculations (e.g., 1-441-N371-002) were inconsistent with GSI-191 technical report (APR1400-E-A-T(NR)-13001-P Rev A). The GSI-191 technical report assumed 2 feet for strainer head loss. SI and CS pump NPSHA calculations assumed 1.5 feet. • The SI and CS pump NPSH calculations did not address NPSH Required (NPSHR) uncertainty. • The staff did not find an evaluation of NPSHA as a function of time consistent with RG 1.82 R4 position 1.3.1.9. • When IRWST temperature exceeds 212°F, the NPSH analysis takes credit for containment accident pressure (CAP) in determining available NPSH ($H_{atm} = H_{vap}$), however KHNP did not provide a clear discussion about how CAP is used (see SECY 11-0014 on CAP and NPSH) and instead describes that containment overpressure is not used. A clear discussion of the use of CAP, in accordance with the SECY paper discussed above should be provided. In addition, the applicant does not assess the risk associated with a loss of CAP (See NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition, (SRP), section 6.2.2).

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11	Structural	• The staff did not find a description of the methods used to attach the trash rack screens and the sump screens to the containment structures to preclude the possibility of debris bypassing the screening (RG 1.206 item). The submittal did not provide verification that the trash racks and sump screens are capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under flow conditions. The submittal needs to, but what was reviewed did not do the following: • Summarize the design inputs, design codes, loads, and load combinations utilized for the sump strainer and trash rack structural analysis. • Summarize the structural qualification results and design margins for the various components of the sump strainer structural assembly. • Summarize the evaluations performed for dynamic effects such as pipe whip, jet impingement, and missile impacts associated with high-energy line breaks (as applicable). • If a backflushing strategy is credited, provide a summary statement regarding the sump strainer structural analysis considering reverse flow.
12	Upstream effects	• The GSI-191 technical report, Section 3.6.2 describes that the Reactor Cavity can overflow through the hot leg and cold leg openings. Please provide the geometry (area, length etc.) of the openings and the flow rate (and direction) through these openings. In addition, describe how these parameters are factored into the resultant level in the Reactor Cavity, surrounding areas, and ultimately the sump level. • The staff did not find an assessment of water holdup at installed curbs and/or debris interceptors. The staff is aware of trash racks. Are curbs used in anywhere in containment? • Staff did not find details on what types and sizes of debris can reach the refueling cavity drain paths from the different break locations. Simply stating that blockage at entrance is unlikely is not sufficient. There could be valves or piping bends that could serve as debris traps and restrict flow or block flow all together, due to collection of smaller debris sizes that the piping diameter. Evaluation should consider all insulation debris types (anti-sweat, RMI etc) and the possibility of installing a debris screen to limit size of debris that could enter and clog the drain piping. This cavity has the potential to holdup large quantities of water that could impact IRWST level. Therefore a detailed evaluation should be provided.

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Item	Topic	Issue
13	Ex-Vessel	The submittal needs to, but what was reviewed did not do the following: • Identify all ex-vessel components in the downstream ex-vessel evaluation. • Specify the amount debris that will bypass the sump strainer and enter the ECCS (type, quantity, size, density, concentration (ppm), etc.). Describe basis for the debris bypass. • Specify bypass debris concentration (ppm) based on volume of recirculation fluid. • Pumps (including their mechanical seals) and valves are to be qualified in accordance with QME-1-2007 as endorsed by RG 1.100, “Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants,” revision 3, to operate with the post-LOCA fluids for the required mission time of 30 days. ITAAC are needed to verify pump and valve qualification with the post-LOCA fluids for the required mission time. • Describe the heat exchanger evaluations for plugging, wear, fouling and thermal performance to ensure heat exchangers will operate as designed with the post-LOCA fluids for the required mission time. Inspections, tests, analyses, and acceptance criteria (ITAAC) are needed to verify heat exchanger performance with the post-LOCA fluids for the required mission time. • System performance evaluations should conclude that system flow parameters are acceptable for the 30-day mission time when components and piping reach their maximum wear. ITAAC verification may be needed. • Provide an evaluation of chemical effects on downstream ex-vessel system operation and components. • Further describe the evaluation methodology used to determine that debris will not block instrument tubing.

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14	In-Vessel	• The applicability of the “clean plant” assumptions to the APR1400 design and fuel and sump strainer design (such as the 45 percent debris bypass assumption) needs to be justified with tests (existing or new). • The applicant must provide a technical basis (based on representative testing) applicable to their fuel design to demonstrate that the debris induced flow blockage would not impede long-term core cooling. • The GSI-191 technical report provides hand calculations of the available driving head for the hot leg break and cold leg break conditions, respectively. The calculations are based on some assumptions that may not be conservative. Further justification of the assumptions is needed. • The available driving head calculations were performed for the hot leg break and cold leg break conditions with the safety injection into the direct vessel injection lines. Since there is an operator action to switch the safety injection to simultaneous hot-leg and direct vessel injection about 90 minutes after the event initiation, the available driving heads for this safety injection configuration need to be evaluated by the applicant.
15	Chemical Effects	• The staff observed that KHNP calculated a chemical precipitate quantity using a methodology approved by the staff (WCAP-16530-NP-A). The staff did not examine the calculation in great detail or perform any confirmatory calculations. • The staff notes a possible error in Table 3.8-3 of the GSI-191 technical report for the chemical effects results at 109 hours, where the time interval is shown as a negative number. • The staff observed that the design does not limit the surface area of exposed aluminum (both immersed and sprayed) to that analyzed for chemical effects. Draft DCD Tier 2, Section 6.1.1 states only that the use of aluminum and zinc is minimized. • The staff observed a discrepancy in the quantity of chemical effects reported in the GSI-191 technical report. Table 3.8-3 reports the precipitate mass in kilograms, while Section 3.5.1 reports the same numbers but in pounds. (See SECY-96-098 for the NRC Policy on using metric units). • The pH transient shown in the chemical effects calculation was unexpected because the pH was more characteristic of sodium hydroxide buffer than trisodium phosphate buffer. The GSI-191 technical report attributes this to hydrazine in the pool. The staff will likely require additional information about this topic in its review of primary water chemistry.

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16	Other – Miscellaneous	• Draft DCD Section 6.2.2 describes two CS System pumps & heat exchangers per train. There are two 100 percent capacity trains and each train has only one pump. Staff communicated this issue to KHNP personnel and they acknowledged that it was an editorial error and would be corrected. • Technical Specification (TS) 3.5.2 Note 2 has error. It refers to non-diagonal trains being inoperable but uses a diagonal train as an example. Staff communicated this issue to KHNP personnel and they acknowledged that it was an editorial error and would be corrected. The following comments are based on the Table in GSI-191 technical report that addresses conformance with positions in RG 1.82, revision 4. • RG 1.82, position 1.1.1.1, describes the APR1400 design as containing four redundant trains. However there are only two trains of CS that automatically function in an accident. KHNP should explain how can all four trains considered to be redundant. (No questions, just observations). • RG 1.82, position 1.1.1.8, requires assessment of air ingestion (e.g., vortexing). However, no vortexing evaluation was identified in the documentation provided during the audit. • RG 1.82, position 1.1.1.13, indicates prototypical head loss testing should be done to verify suction strainer designs. KHNP identifies use of SECY-12-0093 and clean plant criteria guidance and did not conduct design-specific testing. However, as discussed above, the applicant has not demonstrated that this guidance is applicable to the APR1400 design. KHNP should evaluate if existing testing is applicable to APR1400 design in order to demonstrate that no additional design-specific testing is required or conduct design-specific testing. Testing currently serves as the technical basis for establishing the design/licensing basis, unless alternative methods can be justified. • RG 1.82, position 1.3.1.2, see NPSH and containment accident pressure (CAP) discussion in Item 10 of this table.