

KHNPDCDRAIsPEm Resource

From: Ciocco, Jeff
Sent: Tuesday, December 22, 2015 11:57 AM
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Cc: Walker, Jacqwan; Junge, Michael; Ward, William; Lee, Samuel
Subject: APR1400 Design Certification Application RAI 352-8205 (18 - Human Factors Engineering)
Attachments: APR1400 DC RAI 352 COLP 8205.pdf

KHNP,

The attachment contains the subject request for additional information (RAI). This RAI was sent to you in draft form. Your licensing review schedule assumes technically correct and complete responses within 30 days of receipt of RAIs. However, KHNP requests, and we grant, the following RAI question response times. We may adjust the schedule accordingly.

18-61: 60 days
18-62: 60 days
18-63: 60 days
18-64: 60 days
18-65: 60 days
18-66: 45 days
18-67: 60 days
18-68: 60 days
18-69: 60 days
18-70: 60 days
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18-76: 60 days
18-77: 60 days
18-78: 60 days
18-79: 60 days
18-80: 60 days
18-81: 60 days
18-82: 45 days

Please submit your RAI response to the NRC Document Control Desk.

Thank you,

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Protecting People and the Environment

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Issue Date: 12/22/2015
Application Title: APR1400 Design Certification Review – 52-046
Operating Company: Korea Hydro & Nuclear Power Co. Ltd.
Docket No. 52-046
Review Section: 18 - Human Factors Engineering
Application Section: 18.10

QUESTIONS

18-61

NUREG-0711, "Human Factors Engineering Program Review Model," Section 11.4.1, "Sampling of Operational Conditions," Criterion 11.4.1.1(2), states in part that "The applicant should include the following types of personnel tasks" in their sampling of operational conditions.

Evaluation: In APR1400-E-I-NR-14010-P, Rev. 0, "Human Factors Verification and Validation Scenarios" (HF V&V), Table 3.2 "Types of Personnel Tasks," there are five of these personnel task types that are blank, indicating that there is not yet sufficient information to assign these tasks to scenarios. The five personnel task types are: 1-important human actions (IHAs), 3-dominant systems from the PRA, 6-Operator Experience Review (OER)-identified problematic tasks, 12-procedures for controlling radioactivity, and 14-maintenance procedures. There is note 1 on IHAs in Table 4-2, "SOC [Sampling of Operational Conditions] Dimension Matrix Example (Types of Personnel Tasks)," of APR1400-E-I-NR-14008-P, Rev. 0, "Human Factors Verification and Validation Implementation Plan" (HFE V&V IP), but no such note in the Scenario document. The availability of IHAs has been partially addressed in previous RAIs.

Actions:

- Revise the scenario document to list tasks for each task type (tasks associated with five task types).
- Revise the V&V IP to explain the criteria used to identify tasks associated with each task type.
- Revise the V&V IP and scenario documents to address inconsistencies.

Evaluation: Related to this issue, Section 4.1, "Major Operator Errors," of the HF V&V Scenario document lists two errors. However, there is no explanation as to what "Major" means or why the two errors are listed here, particularly since elsewhere in document the Important Human Action information is blank.

Actions:

- Please clarify the use of the term "major"
- The listing of two major errors seems to contradict other statements elsewhere that important HAs cannot yet be identified. Revise the document to address this inconsistency.

18-62

NUREG-0711, Criterion 11.4.1.1(3) states in part that the applicant "should include situations specifically designed to create human errors to assess the system's error tolerance, and the ability of personnel to recover from any errors."

Evaluation: The staff was not able to determine if **error tolerance**, and the ability of personnel to **recover** from any errors was included in the V&V IP or the scenarios document.

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Action: Revise the V&V IP to provide specific information addressing this criterion.

18-63

NUREG-0711, Criterion (3) of section 11.4.1.1, "Sampling Dimensions," states that the sample of situational factors should, to the extent possible, include environmental conditions that may cause human performance to vary.

NUREG-0711, Criterion (3) of section 11.4.1.3, "Scenario Definition," calls for realistic simulation of these environmental conditions.

Evaluation: The HF V&V scenarios do not specifically address criterion 11.4.1.3(3) on simulating potentially harsh environments. For example, in the V&V Scenarios technical report, the Table for Section 3.3, "Situational Factors or Error-Forcing Contexts," Note 2 for Scenario 4 states that "Operators wear protective clothing...." But in reviewing Scenario 4 the staff did not find this activity.

Action: Revise the V&V IP or Scenarios technical report to explain how environmental factors are addressed in the V&V scenarios, and revise Scenario 4 to address inconsistency.

18-64

NUREG-0711, Criterion 11.4.2.2(4), "HED Documentation," states that the applicant should document human engineering discrepancies (HEDs) to identify the human-system interface (HSI), the tasks affected, and the basis for the deficiency (what aspect of the HSI was identified as not meeting task requirements).

Evaluation: Section 4.3.3, "HED Identification," of the HF V&V IP discusses task support verification HEDs and when they will be entered into the issue tracking system for evaluation and resolution. However, no information is provided as to what information is entered into the system for each HED.

Additionally, Section 4.6.1.2, "Human Engineering Discrepancies Entry," of APR1400-E-I-NR-14001-P, Rev. 0, "Human Factors Engineering Program Plan," (HFE PP) discusses HED entry more generically for the Issue Tracking System, however this section also does not provide the necessary detail.

Section 4.5.9.5, "HED Evaluation Documentation," of the V&V IP provides generic information on HED documentation, but does not provide specific information to be used for task support verification HEDs, e.g., the specific HSI and the basis for the HED such as the aspect of the HSI that was identified as not meeting task requirements.

Action: Revise the V&V IP to provide the information specified in Criterion 11.4.2.2(4).

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18-65

NUREG-0711, Criterion 11.4.2.3(2), "General Methodology," states in part that the applicant's HFE Design Verification methodology should include procedures for comparing the characteristics of the HSIs with HFE guidelines for the general environment in which HSIs are sited.

Evaluation: The HFE Design Verification methodology is described in Sections 4.4.1, "Verification Criteria," and 4.4.2, "General Methodology," of the V&V IP. The methodology is summarized in Figure 4-2, "Design Verification Process," of the IP. The methodology specifies five steps. It is not clear from the methodology description, how the Style Guide's criteria are used.

Action: Provide a more detailed description of how the Style Guide's criteria are used. Specifically

- Revise the V&V IP to state what is actually being reviewed during Step 2.
- Revise the V&V IP to show how the HSI inventory in Step 2 relates to the Step 1 checklist.

If the HSI are verified against the Style Guide, revise the IP to state that it is, and how it is done. If the HSI are not verified against the style guide provide an explanation as to why.

18-66

NUREG-0711, Section 11.4.3, "Integrated System Validation," Criterion 11.4.3.1(1), "Validation Team," states that the applicant should describe how the team performing the validation has independence from the personnel responsible for the actual design.

Evaluation: The applicant's validation team is described in Sections 4.5.1, "Validation Team," of the IP. While the IP states that the team is independent of the design organization, no information concerning the relationship and interfaces between the validation team and the design team is provided.

Action: Revise the V&V IP to describe any and all relationships and interfaces between the validation team and the design team, barriers to prevent them, so that the staff can verify their independence.

18-67

NUREG-0711, Criterion 11.4.3.4(3), "Plant Personnel," states that "in selecting personnel for participating in the tests, the applicant should consider the minimum shift staffing levels, nominal levels, and maximum levels, including shift supervisors, reactor operators, shift technical advisors, etc."

Evaluation: The applicant addresses Integrated System Validation (ISV) crew staffing level in Section 4.5.4, "Plant Personnel (Participants)," of the V&V IP, Section 4.1 of the HFE PP, and the response to RAI 107-8039, Q 18-11, dated 9/15/2015 (ML15258A646). Crews participating in the ISV each consist of five crewmembers: shift supervisor (SS), shift technical advisor (STA), reactor operator (RO), turbine-

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generator operator (TO), and electrical operator (EO). Section 4.5.4 also states that “all operators are license holders.” The RAI response clarifies that the SS and STA have SRO licenses and the RO, TO, & EO have RO licenses. The V&V IP, Section 4.5.6.4, "Participant Training," states that the participants will have held previous positions that are similar to the ISV position. This crew composition and the crew member roles are somewhat different from typical crews used in U.S. plants. US plants do not typically have separate TO and EO positions.

The DCD Section 13.1.2.3, "Operating Shift Crews," states that “...operator licensing requirements ... and the minimum number of personnel planned for each shift” is the responsibility of the COL. If the ISV is conducted with 3 licensed ROs (the RO, TO & EO), then COL applicants could be obligated to implement that configuration even though it is greater than minimum staffing requirements of 50.54(m). Applicants could request a deviation from that part of the DCD, but such a deviation would have to be supported with a basis that demonstrates that the APR1400 design can be operated safely with 50.54(m) staff levels (e. g., only 2 ROs).

Action: Revise the V&V IP to:

- Describe for what type of main control room crew the APR1400 control room is being designed. Include in the description minimum, nominal, and maximum crew sizes.
- Explain the logic, or basis, for the selection of the ISV crew composition, size and license-status.

Discuss how control room responsibilities are divided between watch stations.

18-68

NUREG-0711, Criterion 11.4.3.4(3), states that “in selecting personnel for participating in the tests, the applicant should consider the minimum shift staffing levels, nominal levels, and maximum levels, including shift supervisors, reactor operators, shift technical advisors, etc.”

Evaluation: The applicant does not address the validation of different staffing levels in the IP or in the detailed scenario descriptions of the HF V&V Scenarios document.

Action: Revise the V&V IP to describe how the ISV will validate minimum shift staffing levels, nominal levels, and maximum levels.

18-69

For NUREG-0711, Criterion 11.4.3.5.1(2), "Types of Performance Measures," the high level goal is to ensure the applicant has identified the primary task measures applicable to each ISV scenario.

Evaluation: The applicant's general approach to primary task measurement is described in Section 4.5.5 "Performance Measurement," of the IP. The specific measures applicable to each scenario are contained in the detailed scenario descriptions in the HF V&V Scenarios document. The staff had two questions regarding the approach.

Actions:

1. At the end of each scenario in the instructions, observers are asked to evaluate whether all primary tasks were “completed in a safe and timely manner” and whether they were performed “error free both individually and as a team.” Revise the V&V IP to describe how this evaluation is different from the specific criteria provided for each primary task during the course of the scenario.

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2. In Appendix A, the “Small Break Loss-of-Coolant Accident with Computer-Based Procedure Failure and Human-System Interface Display Failure” scenario, the *pass* criterion for the primary task of “Determine that SG Downcomer Radiation Monitor is malfunctioning and respond per alarm procedure Alarm-3761-01, Radiation Monitoring System” is that “The crew determines the alarm is the result of an instrument failure and responds per Alarm-3761-01, Radiation Monitoring System.” The *failure* criterion is “The crew misdiagnoses the alarm as a Steam Generator Tube Leak (SGTL) and responds per specified SGTL procedures.”

Revise the V&V IP to describe how the pass/fail criterion will be applied, if the crew initially misdiagnoses the event but then recovers. For example, explain how the primary task will be rated (pass or fail), if the crew initially misdiagnoses it as a SGTL but they recover from it by realizing the error and then acting in correspondence with the pass criterion. If this is considered a “Pass,” describe how the initial misdiagnosis with subsequent recovery would be addressed in the V&V findings. Also, address in the IP the generic aspects of this question as it may apply to other scenarios.

18-70

NUREG-0711, Criterion 11.4.3.5.1(3), states that the applicant should identify the secondary task measures applicable to each scenario.

Evaluation: The applicant’s general approach to secondary task measurement is described in Section 4.5.5 of the IP. The IP states that secondary tasks will be measured using observer evaluations and participant ratings. However, the IP does not specifically state how secondary task evaluations will be made.

Action: Revise the V&V IP to provide the rating scales, or other data collection forms, that show how secondary task evaluations will be made.

18-71

NUREG-0711, Criterion 11.4.3.5.1(6), states that the applicant should identify the anthropometric and physiological measures obtained for each scenario.

Evaluation: The applicant’s measurement of anthropometric and physiological factors is described in Section 4.5.5 of the IP. Evaluation of these factors will involve observer and operator questionnaires. The observer and operator questionnaires are not provided, thus the acceptability of the approaches cannot be determined.

Action: Revise the V&V IP to include the observer and operator questionnaires to be used.

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18-72

NUREG-0711, Criterion 11.4.3.5.2(2), "Performance Measure Information and validation Criteria," states that the applicant should specify when each measure is obtained (recorded), such as continuously, at specific points during the scenario, or after the scenario ends.

Evaluation: The applicant's description of when measures are collected is contained in Section 4.5.5 of the IP and in the detailed scenario descriptions contained in in the HF V&V Scenarios document. The staff has the following questions about when measures are taken.

Actions:

1. It appears that the situational awareness global assessment technique (SAGAT) measure of situational awareness (SA) is taken twice for each scenario; once during a scenario stoppage and the second time at the end of the scenario. One of the values of the SAGAT method is that the changes in SA over the course of a scenario can be measured since the assessment is usually made at several points. The staff is concerned that a onetime measurement of SA during the scenario may not provide an accurate assessment. For example, in the Anticipated Transient without Trip with Distributed Control System Failures scenario, SA isn't measured until approximately two hours into the event. The staff is also concerned that use of the SAGAT measure following scenario termination may be of limited value. SAGAT is designed to capture the operators' SA as events unfold. Some of the questions typically assess the operators' awareness of where events are leading. At the end of the scenario, the plant has been stabilized. Since SAGAT is not a retrospective measure, all it may show is that the operators' are aware they have achieved the stable condition. Revise the V&V IP to provide:
 - the rationale for selecting the number of scenario stoppages for SAGAT data collections,
 - specific information on when the scenarios are stopped, and
 - detailed information about SAGATs use once the scenario is completed.

The IP states that the task load index (TLX) will be collected at the end of each scenario. However, the detailed scenario descriptions in the HF V&V Scenarios document do not include the TLX in the list of "Post Exercise Evaluation" items. Within the scenarios, provide information describing where and when the TLX will be used.

18-73

NUREG-0711, Criterion 11.4.3.5.2(3), states that the applicant should "describe the characteristics (see Table 11-1, "Characteristics of Performance Measures," in NUREG-0711) of the performance measures."

Evaluation: The applicant's description of measurement characteristics is contained in Section 4.5.5 of the IP. While the characteristics are defined in the IP, they are given only cursory, and often incomplete, treatment in the description of the specific measures. For example, for the use of the Halden's behaviorally anchored rating scale (BARS) questionnaire, the IP states that "The behavior categorization by observers provides reliability and unobtrusiveness." Observer ratings may be reliable or unreliable, depending on the characteristics of the scales being used and the instructions given to observers on what the scales mean and how they should be used. The same can be said for unobtrusiveness. The IP does not mention the other characteristics that are listed in Table 11-1 of NUREG-0711. Another example, in the discussion of the SAGAT measure of SA, the IP simply has "(construct validity, reliability)" at the end of one sentence with no explanation.

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Action: Revise the IP to provide an explanation that shows how the measurement characteristics, for the measures selected, achieve the attributes described in Table 11-1 of this NUREG-0711 criterion, and that are defined on Page 34 of the V&V IP.

18-74

NUREG-0711, Criterion 11.4.3.5.2(4), states that the applicant should identify the specific criterion for each measure used to judge the acceptability of performance and describe its basis.

Evaluation: The applicant's description of the specific criterion to be used for each measurement and its basis is contained in Section 4.5.5 of the IP and in the HF scenarios document. The staff has the following questions related to the specific criterion for each measure:

Actions:

1. The specific criteria to be used for many of the measures are in the detailed instructions for the validation scenarios. However, specific criteria are not provided for all measures, e.g., for the BARS, SA, and workload measures. Revise the V&V IP to provide the specific criteria to be used in the evaluation of all of the performance measures.
2. The bases for the criteria are summarized in Table 4-5, "Basis for Performance Criteria." The IP states that the criteria basis for SAGAT and TLX are benchmarked to "a predecessor or reference plant." The staff was unable to determine which plant SAGAT and TLX were benchmarked. Revise the V&V IP to identify the benchmarking plant and how the criteria were established for SAGAT and TLX.

18-75

NUREG-0711, Criterion 11.4.3.5.2(5), states that the applicant should identify whether each measure is a pass/fail one or a diagnostic one.

Evaluation: The applicant's identification of pass/fail vs. diagnostic measures is contained in Section 4.5.5 of the V&V IP. The applicant defines each category as follows:

Pass/fail measures are identified in each scenario before the start of the ISV and are used to determine whether the design is validated. Diagnostic measures are collected to assess personnel performance during each scenario and to analyze errors and their root causes as they relate to the HSI design.

Actions:

1. While pass/fail (P/F) measures are important, and clearly needed, the staff notes that the relative proportion of P/F vs. diagnostic measures is heavily weighted to P/F measures. The staff notes that KHNP is establishing a high bar for validation, however having so many P/F measures that are based on observer judgment and questionnaire data may make it difficult to validate that design. Provide the rationale for selecting P/F vs. diagnostic measures.

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2. The staff also notes that the IP seems to include more P/F measures than one would expect based on the DCD. On page 18.10-8, the DCD states “The pass or fail performance evaluation measures include directly observable performance data such as the execution time of operator tasks, frequency of human error, and measurable plant performance data collected by the test bed simulator.” Based on this definition, the staff would not expect measures such as the behaviorally anchored rating scale (BARS) to be included as P/F measures as they are in the IP. Revise both documents to address this inconsistency.

18-76

NUREG-0711, Criterion 11.4.3.6.2(1), states in part that the applicant should use detailed, unambiguous procedures to govern the conduct of the tests. And that these procedures should include detailed and standardized instructions for briefing the participants, and guidance on when and how to interact with participants when difficulties occur in simulation or testing.

Evaluation: The applicant’s test procedures are described in Section 4.5.6.2 of the IP. The HF V&V Scenarios document contains many aspects of the procedures that are specific to each of the seven scenarios. There are two aspects of the test procedures that were not addressed.

Action: Revise the Scenario document to describe:

- the detailed and standardized instructions used to brief participants
- the guidance to test conductors for when and how to interact with participants when difficulties occur in simulation or testing

18-77

NUREG-0711, Criterion 11.4.3.6.2(2), states that the applicant’s test procedures should minimize the opportunity for bias in the test personnel’s expectations and in the participant’s responses.

Evaluation: The applicant’s use of test procedures to minimize bias is described in Section 4.5.6.2 of the IP. The IP states that the procedures will minimize bias, but little information is provided on how they will do so.

Action: Revise the V&V IP to describe specifically how the use of the test procedures will minimize bias.

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18-78

NUREG-0711, Criterion 11.4.3.7(2), "Data Analysis and HED Identification," states that the applicant should discuss the method by which data is analyzed across trials, and include the criteria used to determine successful performance for a given scenario.

Evaluation: The data analysis is described in Sections 4.5.7.1 and 4.5.7.2 of the IP. The staff has two actions related to the data analysis described in these sections.

Actions:

1. The first question concerns the use of the $p \leq .05$ significance level. This is the typical significance level used to test hypotheses in behavioral science research, and the minimum set for claiming two means are significantly different. However, its application to the integrated system validation analyses is unclear. Using workload as an example, if the average workload of the APR1400 design is found to be 3.5, and the average for the reference plant is 4, but the difference is not statistically significant, what conclusion regarding the acceptability of the workload can be drawn? One cannot conclude the workload levels are statistically the same; that would be confirming the null hypothesis, which is not statistically justified. Provide greater specificity in the V&V IP on the use of the $p \leq .05$ significance level and its application to the integrated system validation analyses.
2. For the statistical tests conducted separately for each scenario, the means are based on three data points (three crews). Such a situation will lead to very few degrees of freedom for the statistical test and a great chance of failing to find statistical significance. Revise the V&V IP to address the issue of low degrees of freedom for scenario evaluations. For the statistical tests conducted separately for each scenario, the means are based on three data points (three crews). Such a situation will lead to very few degrees of freedom for the statistical test and a great chance of failing to find statistical significance. Revise the V&V IP to address the issue of low degrees of freedom for scenario evaluations.

18-79

NUREG-0711, Criterion 11.4.3.7(2), states that the applicant should discuss the method by which data is analyzed across trials, and include the criteria used to determine successful performance for a given scenario.

Evaluation: The data analysis is described in Sections 4.5.7.1 and 4.5.7.2 of the IP. In all cases, the criteria for successful performance are defined. In Section 4.5.7.1, item 1) of the IP states that the "Performance evaluation is based on whether the operator performed the scenario successfully by comparing the flow of scenario execution against the" The method used to complete this comparison is not clear.

Action: Revise the V&V IP to specifically describe how the above referenced comparison is made. Also, revise the IP to describe how the statistical tests (e.g., T-tests) are used to support the comparisons.

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18-80

NUREG-0711, Criterion 11.4.3.7(3), states that the applicant should evaluate the degree of convergence between related measures.

Evaluation: In the fifth paragraph of Section 4.5.5 of the IP, the applicant states that "Industry-accepted practices, both objective and subjective measures, are applied as one way to assess" However, **how** this evaluation is performed is not discussed in Section 4.5.7. The applicant discusses the consistency of measures in Sections 4.5.7.1 of the IP. Within the context of the BARS measures, the IP states that in order to confirm the consistency of SME evaluations, a correlation will be computed for each of the BARS dimensions. Such an analysis would establish the inter-rater reliability of the BARS measure rather than convergence of related measures.

Action: Revise the V&V IP to describe how the evaluation of **convergence** between related measures is accomplished.

18-81

NUREG-0711, Criterion 11.4.3.7(4), states that when interpreting test results, the applicant should allow a margin of error to reflect the fact that actual performance may be slightly more variable than observed validation-test performance.

Evaluation: The applicant's data analysis is described in Section 4.5.7 of the Verification and Validation implementation plan. The discussion does not specifically address margin of error in the interpretation of performance. Margin is discussed in Section 4.5.9, "HED Resolution Review Criteria," but with respect to HED prioritization rather than interpretation of performance and does not appear to be applicable to this criterion.

Action: Describe how margin of error is addressed with respect to the interpretation of actual performance.

18-82

NUREG-0711, Criterion 11.4.4(2), states in part that "the applicant should conduct an evaluation to identify which HEDs to correct," and that "HEDs the applicant should correct are those with direct safety consequences, namely, those that could adversely impact personnel performance such that the margin of plant safety may be reduced below an acceptable level. ..."

Evaluation: In both the Human Factors Engineering (HFE) Program Plan (PP) and the HFE Verification and Validation Implementation Plan (V&V IP) the applicant defines Priority 1, 2, & 3 Human Engineering Discrepancies (HED), but they are not completely the same. For Priority 1 HEDs, the PP in section 4.6.1.4 defines them as "...the margin of plant safety may be reduced below an acceptable level ..." The V&V IP, in section 4.5.9.2, defines them as "...the margin of plant safety is reduced to below an acceptable level."

Action: Revise documents as necessary to correct this inconsistency.