

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 352-8205
SRP Section: 18 – Human Factors Engineering
Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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.

Response**Response to Action 1**

As stated in the RAI, the five types of actions are not yet assigned to the appropriate scenarios because there is insufficient information. Specifically, the set of tasks of each type are not yet completely identified and evaluated. Rather than adding a listing of unassigned tasks that have not yet been evaluated by the process outlined in the HF V&V IP, proceeding with the current plan to update the scenarios as the information is available is preferable. As described in Section 4.1.4 of the HF V&V IP, the scenarios will be updated prior to conducting ISV to address the required final plant parametric, operating procedures, or expected personnel actions. The criteria for identifying the tasks in each type of task are determined by the subject matter experts during their evaluation, as is also described in Section 4.1.4. Following identification and assignment of the tasks, Section 3.2 of the scenario document will be revised.

For consistency, note 1) of Table 4-2 in the HF V&V IP will be added to Section 3.2 of the HF V&V Scenarios. Additionally the position of notes 1), 2) and 3) in Table 4-3 of the HF V&V IP will be revised to correspond to the positioning in section 3.3 of the HF V&V Scenarios.

Response to Action 2

Since the term “major” has no significance in developing the scenarios, and the items listed are not necessarily “operator errors,” but rather failures that might result from various operator errors or equipment failures, Section 4.1 of the HF V&V Scenarios will be deleted.

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-I-NR-14010-NP, Rev.0, “Human Factors Verification and Validation Scenarios,” Sections 3.2 and 4, and APR1400-E-I-NR-14008-NP, Rev.0, “HF V&V

Implementation Plan,” Section 4.1.1.3 will be revised, as indicated in the attachment associated with this response.

TABLE OF CONTENTS

1.	PURPOSE.....	1
2.	SCOPE	2
2.1.	Applicable Documents	2
3.	SAMPLING OF OPERATIONAL CONDITIONS FOR THE INTEGRATED SYSTEM VERIFICATION.....	3
3.1.	Plant Conditions.....	3
3.2.	Types of Personnel Tasks.....	5
3.3.	Situational Factors or Error-Forcing Contexts	7
4.	SUMMARY OF THE APR1400 PROBABILISTIC RISK ASSESSMENT	8
4.1.	Major Operator Errors	8
4.2.	Total Core Damage Frequency of Initial Events	8
4.3.	Analysis of Significances	8
5.	APR1400 HUMAN FACTORS VERIFICATION AND VALIDATION SCENARIOS	9
5.1.	Small Break Loss-of-Coolant Accident with Computer-Based Procedure and Human-System Interface Display Failure	10
5.2.	Anticipated Transient without Trip with Ovation Distributed Control System Failure	12
5.3.	Excessive Steam Demand Event with Alarm Server Failure	13
5.4.	Loss of All Feedwater	14
5.5.	Station Blackout.....	15
5.6.	Steam Generator Tube Rupture	16
5.7.	Main Control Room FIRE	17
Appendix A	Small Break Loss-of-Coolant Accident with Computer-Based Procedure and Human-System Interface Display Failure (ISV-1)	A17
Appendix B	Anticipated Transient without Trip with Ovation Distributed Control System Failures (ISV-2).....	B17
Appendix C	Excessive Steam Demand Event with Alarm Server Failure (ISV3).....	C17
Appendix D	Loss of All Feedwater (ISV4).....	D1
Appendix E	Station Blackout (ISV5)	E1
Appendix F	Steam Generator Tube Rupture (ISV6)	F1
Appendix G	Main Control Room Fire (ISV7)	G1

3.2. Types of Personnel Tasks

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4. SUMMARY OF THE APR1400 PROBABILISTIC RISK ASSESSMENT**~~4.1. Major Operator Errors~~**

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4.1.

~~4.2. Total Core Damage Frequency of Initial Events~~

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4.2.

~~4.3. Analysis of Significances~~

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Table 4-3 SOC Dimension Matrix Example (Situational Factors or Error forcing Contexts)

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RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 352-8205
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Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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.

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

Response

A description of the error tolerance of the system and the ability of operators to recover from those errors will be added to Section 4.1.1.3 of the Human Factors Verification and Validation Implementation Plan “HF V&V IP,” as indicated in the attachment associated with this response.

The fourth bullet of Section 4.5.2, “Test Objectives,” of the HF V&V IP addresses personnel error recovery by stating an objective of the ISV tests is to, “Validate that the HSIs minimize personnel error and provide reasonable assurance of error detection and recovery capability when errors occur.”

Section 4.5.2 of the HF V&V IP will be revised to describe the error tolerance of the system and the ability of operators to recover from those errors, as indicated in the attachment associated with this response.

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-I-NR-14008-NP, Rev.0, "Human Factors Verification and Validation Implementation Plan," Sections 4.1.1.3 and 4.5.2 will be revised, as indicated in the attachment associated with this response.

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4.1.1.3. Situational Factors that are known to Challenge Human Performance

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4.5.2. Test Objectives

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4.5.3. Validation Testbeds

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RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 352-8205
SRP Section: 18 – Human Factors Engineering
Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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.

Response

The Human Factors Verification and Validation Implementation Plan (HF V&V IP), APR1400-E-I-NR-14008, states that environmental factors will be assessed in the V&V program. The document describes the process of assessing these factors in the Design Verification and Integrated System Validation (ISV) activities. The HF V&V IP continues to describe that when it is not realistic to simulate those environmental conditions of interest during the V&V element of the HFE program, the environmental conditions of interest will be assessed in the actual control facility during the Design Implementation element of the Human Factors Engineering (HFE) program.

Related existing sections of the HF V&V IP include:

- Section 4.1.1.3, page 9, bullet 3, Fatigue-“...environmental conditions that may cause human performance to vary (e.g., poor lighting, extreme temperatures, high noise, simulated radiological contamination).”
- Table 4-3, page 13, item 4- “Environmental factors”. This item is mislabeled as note 3). The document will be revised to read 4 superscript 3), as shown in the Attachment 2 to Question 18-61.
- Section 4.1.5, page 16, Scenario components, bullet 5- “Precise definition of workplace factors (e.g., environmental conditions...).”
- Section 4.4.2, page 23, General Methodology describes the process applied to the design verification process.
- Section 4.4.1(4), page 25, Environmental Factors addresses the factors that are included in the Design Verification and that due to economic and schedule impracticalities, the verification of the control room or other control locations environmental factors will be done during the DI element of the HFE program.
- Section 4.4.3, page 26, bullet 4 includes the identification, assessment, and closure of environmental factors into the HED process and issue tracking system (ITS).
- Section 29, page 30, bullet 4 describes the intent to include, as practical, environmental fidelity into the ISV simulator facility. Those that are not practical will be assessed during design implementation (DI).
- Section 4.5.5.1(5), page 37, “Anthropometric and physiological Measures”.

HF V&V Scenarios, Appendix D (ISV 4) is consistent with the main body of the HF V&V Scenarios, Section 3.3, ISV 4 Note 2. Appendix D, page D9, Section 1.6, “Applicable Operational Condition Sampling,” under “Situational Factors or Error-forcing Context,” in the note to line item 4, “Environmental factors” that, “Operators wear protective clothing based on contamination in the MCR.” Therefore, no revision is required.

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-I-NR-14008-NP, Rev.0, "Human Factors Verification and Validation Implementation Plan," Table 4-3 will be revised, as indicated in the attachment associated with the response to RAI 352-8205, Question 18-61.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

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Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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 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.

Response

The APR1400 Main Control Room design is for all applications. APR1400 plants, worldwide, will have the following minimum and normal crew members:

- Shift supervisor (SS)
- Shift technical advisor (STA)
- Reactor operator (RO)
- Turbine generator operator (TO)
- Electrical operator (EO)

The maximum number of crew members in the main control room is also 5. The maximum crew size is a design constraint for the main control room. The bases for this is discussed in APR1400-E-I-NR-14011-P, Rev 0, Basic Human System Interface, Section 4.1.2 Meeting Room, page 18- “the meeting room within the MCR is provided to accommodate shift turnover, crew briefings, and maintenance activities for personnel not actively engaged in operation activities in the main operating area...” The meeting room contains all needed equipment to support any additional staff and their assignments for all operating modes and plant conditions. The main control room design is such that staffing of 5 is the maximum staffing that is expected to be in the operating area and this will be administratively controlled during all plant states.

The integrated system validation (ISV) crew composition of 5 (one SS, one STA, one RO, one TO, and one EO) represents the minimum, normal and maximum crew that will be outside of the meeting room and in the operating area at any time, under all circumstances. The license status is explained in Section 4.1 of HFEPP as follows:

- The fundamental HFE design assumption is that it is possible to operate the plant with the following key personnel:
 - one reactor operator (RO) with a reactor operator license
 - one turbine operator (TO) with a reactor operator license
 - one electric operator (EO) with a reactor operator license
 - one shift supervisor (SS) with a senior reactor operator license
 - one shift technical advisor (STA) in the MCR during plant operating modes

The description of the MCR composition will be added to Section 4.5.4 of HF V&V IP, as indicated in the attachment associated with this response.

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-I-NR-14008-NP, Rev.0, "Human Factors Verification and Validation Implementation Plan," Section 4.5.4 will be revised, as indicated in the attachment associated with this response.

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4.5.4. Plant Personnel (Participants)

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RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 352-8205
SRP Section: 18 – Human Factors Engineering
Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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.

Response

The APR1400 has only one staffing level, 5 crew members, and it represents the minimum, normal and maximum staffing levels. This is described in section 4.5.4 of HF V&V IP, and is addressed by the response to RAI 352-8205, Question 18-67. Please refer to the response to RAI 352-8205, Question 18-67.

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

There is no impact on any Technical, Topical, or Environmental Report.

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APR1400 Design Certification

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RAI No.: 352-8205
SRP Section: 18 – Human Factors Engineering
Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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.
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.

Response

1. Section 4.5.5.1, "Types of Performance Measures Used", of the Human Factors Validation and Verification Implementation Plan (HF V&V IP) will be revised to clearly describe that the determination of whether primary tasks were completed in a safe and timely manner, and that the primary tasks were completed error free, both individually and as a team, is distinct from the specific criteria provided for each primary task during the course of the scenario, as shown in the attachment associated with this response.
2. Section 1.3.2 of Appendix A of the HF V&V Scenarios will be revised to indicate that an initial misdiagnosis will be considered a failure, even if later corrected, as shown in the attachment associated with this response.

Section 4.5.5 of the HF V&V IP will be revised to state that a determination of "fail" should be based on initial action even if later corrected, , as shown in the attachment associated with this response. This will allow the cause of an incorrect initial action to be evaluated as an HED.

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-I-NR-14008-NP, Rev.0, "Human Factors Validation and Verification Implementation Plan," Section 4.5.5 and 4.5.5.1, and APR1400-E-I-NR-14010-NP, Rev.0, "Human Factors Validation and Verification Scenarios," Section 1.3.2 of Appendix A will be revised, as indicated in the attachment associated with this response.

4.5.5. Performance Measurement

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4.5.5.1. Types of Performance Measures Used

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1.3. Performance Measures

1.3.1. Important Human Actions (IHA)

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1.3.2. Primary Tasks

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RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

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Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 352-8205
SRP Section: 18 – Human Factors Engineering
Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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.

Response

A 7-point Likert rating scale is used for the primary and secondary tasks, as described in the Human Factors Verification and Validation Implementation Plan (HF V&V IP), Section 4.5.5.2, 2), and 3). Questionnaires or other rating scales, other than those currently in the HF V&V IP, will not be added.

Section 4.5.5.2 (3) of the HF V&V IP will be revised to describe the secondary task measures questionnaire, as shown in the attachment associated with this response.

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-I-NR-14008-NP, Rev.0, "Human Factors Verification and Validation Implementation Plan," Section 4.5.5.2 will be revised, as indicated in the attachment associated with this response.

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RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

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Docket No. 52-046

RAI No.: 352-8205
SRP Section: 18 – Human Factors Engineering
Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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.

Response

The APR1400 uses a three level process for the assessment of anthropometric and physiological measures.

The primary assessment of anthropometric and physiological measures is performed during the design verification phase of the verification and validation (V&V) program, as described in Section 4.4 of the Human Factors Verification and Validation Implementation Plan (HF V&V IP). This methodology is based on SMEs' judgment and a checklist based on the Style Guide, APR1400-E-I-NR-14012-P, Rev. 0.

Additional assessments of the final design as represented in the V&V test facility are conducted during the V&V program. When the V&V test facility cannot be used this assessment will be conducted in the design implementation (DI) program, as described in Section 4.5.5.1 (5) of the HF V&V IP.

The observer and operator questionnaires will be developed later in the design cycle, when more details of the final design are known. The basis for those questionnaires will be added to Section 4.5.5.2, 2) of the HF V&V IP, as indicated in the attachment.

The acceptability of this three level process is adequately demonstrated since the assessment of anthropometric and physiological measures take place in the design verification, V&V, and DI programs, and the primary assessment method is described in the design verification, Section 4.4.

Section 4.5.5.1, Item 5), “Anthropometric and Physiological Measures” of the HF V&V IP will be revised to change wording indicating that the assessment is an initial assessment, to indicate that the assessment is the primary assessment, as indicated in the attachment associated with this response.

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-I-NR-14008-NP, Rev.0, “Human Factors Verification and Validation Implementation Plan,” Section 4.5.5.1 will be revised, as indicated in the attachment associated with this response.

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TS

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Date of RAI Issue: 12/22/2015

Question No. 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.

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.

Response

Human Factors Verification and Validation Implementation Plan (HF V&V IP), Section 4.5.5, page 34, second paragraph will be revised to state “Subsection 4.5.5.1 identifies the types of performance measures,” not Subsection 4.3.5.1.

Subsection 4.5.5.1 of HF V&V IP will be revised to explain the relationship of the characteristics identified in Table 11-1, NUREG-0711, Rev. 3 and the performance measures discussed in

Section 4.5.5.1 of the HF V&V IP.

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-I-NR-14008-NP, Rev.0, "Human Factors Verification and Validation Implementation Plan," Section 4.5.5.1 will be revised, as indicated in the attachment associated with this response.

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4.5.5.1. Types of Performance Measures Used

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4.5.5.2. Performance Measure Information and Validation Criteria

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Table 4-5 Basis for Performance Criteria

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RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 352-8205
SRP Section: 18 – Human Factors Engineering
Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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 rational for selecting P/F vs. diagnostic measures.
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.

Response

1. Pass/fail measures will be limited to objective measures, including plant parameters, time, and anthropometric and physiological measures. Section 4.5.5.2 of the Human Factors Verification and Validation Implementation Plan will be revised to indicate that behavior categorization by observers and secondary task measures will use diagnostic measures to assess acceptance criteria, as indicated in the attachment associated with this response.
2. The response to question 1 also addresses question 2. Pass fail measures will only include directly observable performance data such as execution time, frequency of error, and measurable plant performance data taken from the test bed simulator. Results from BARS are not pass fail measures. The scenarios do, however, allow, at the discretion of the observing test personnel (operation SME and HFE lead), a measure not indicated to be pass fail to be made pass fail based on specific observations, as expressed in Note 1 of Section 1.3 of Appendices A through G of APR1400-E-I-NR-14010, Rev. 0, "Human Factors Verification and Validation Scenarios". This is to be an exception to the guidance that will be rare.

No revisions to the DCD Tier 2 page 18.10-8 are needed.

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-I-NR-14008-NP, Rev.0, "Human Factors Verification and Validation Implementation Plan," Section 4.5.5.2 will be revised, as indicated in the attachment associated with this response.

TS

Table 4-6 Summary of Performance Measures

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4.5.6. Test Design

TS

4.5.6.1. Scenario Sequencing

TS

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 352-8205
SRP Section: 18 – Human Factors Engineering
Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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

Response

The detailed and standardized instructions for test crew briefing will be added in Sections 1.1 and 1.2 of the Human Factors Verification and Validation Scenarios, as indicated in the attachments associated with this response.

The need for guidance regarding how and when to interact with test crews when difficulties occur is identified in APR1400-E-I-NR-14008-P, Rev 0, Section 4.5.6.2, page 44. The section describes that the test procedure includes the embedded scenario-specific test procedures and the general test procedure. Section 4.5.6.2.1, 5th bullet, page 44 identifies the specific need to include instructions on when and how to interact with the test crew or participants when difficulties occur. The specific guidance to the test crew regarding procedures to govern conduct

when difficulties occur during simulation or testing will be added as a new Attachment 5, as shown in the attachments associated with this response.

The scenarios (ISV 1 through ISV 7) contained in Appendix A through Appendix G of the HF V&V Scenarios will be revised, as indicated in the attachments associated with this response.

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-I-NR-14010-NP, Rev.0, "Human Factors Verification and Validation Scenarios," Appendix A through Appendix G will be revised, as indicated in the attachments associated with this response.

TABLE OF CONTENTS

1.	OVERVIEW	A3
1.1.	Human Factors Verification and Validation Objectives	A3
1.2.	Scenario Overview.....	A4
1.3.	Performance Measures	A5
1.3.1.	Important Human Actions (IHA).....	A5
1.3.2.	Primary Tasks.....	A5
1.4.	Other Performance Measures	A9
1.5.	List of Important Human Actions	A10
1.6.	Applicable Operational Condition Sampling	A10
2.	FACILITATORS INFORMATION	A12
2.1.	Scenario Timeline	A12
2.2.	Procedure Flowpath.....	A14
2.3.	Emergency Plan	A14
2.4.	Technical Specifications	A14
2.5.	Scenario Termination Criteria.....	A14
2.6.	Anticipated Scenario Length.....	A14
3.	SIMULATOR EXERCISE EVALUATION.....	A15
3.1.	Evaluation Preparation	A15
3.2.	Evaluation	A16
3.2.1.	Event-1 Run ESW Pump 02A.....	A16
3.2.2.	Event-2 SG1 Downcomer Radiation Monitor Malfunction	A17
3.2.3.	Event-3 SBLOCA + SIAS Automatic Actuation Failure	A18
3.2.4.	Event 4 Computer Based Procedure System (CBP) Failure.....	A33
3.2.5.	Event-5 Loss of all Operator Console Displays and LDP with resulting RCS Cooldown at the Safety Console	A33
3.3.	Debrief	A46
3.3.1.	Post Exercise Evaluation	A46
3.3.2.	Data Acquisition.....	A46
ISV-1 ATTACHMENT 1 - TRENDING PARAMETERS.....		A47
ISV-1 ATTACHMENT 2 - SBLOCA MALFUNCTIONS.....		A50
ISV-1 ATTACHMENT 3 - SHIFT TURNOVER SHEET.....		A51
ISV-1 ATTACHMENT 4 - ANTICIPATED DIALOG.....		A52
 <div style="border: 1px solid red; padding: 5px; display: inline-block;"> ISV-1 ATTACHMENT 5 - GUIDANCE WHEN DIFFICULTIES OCCUR DURING SIMULATION OR TESTING </div>		

1. OVERVIEW

1.1. Human Factors Verification and Validation Objectives

TS

1.2. Scenario Overview

TS



ISV-1 Attachment 4 - Anticipated Dialog

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TABLE OF CONTENTS

1.	OVERVIEW	B3
1.1.	Human Factors Verification and Validation Objectives	B3
1.2.	Scenario Overview.....	B4
1.3.	Performance Measures	B5
1.4.	Other Performance Measures	B9
1.5.	List of Important Human Actions	B10
1.6.	Applicable Operational Condition Sampling	B10
2.	FACILITATORS INFORMATION	B11
2.1.	Scenario Timeline	B11
2.2.	Procedure Flowpath.....	B12
2.3.	Emergency Plan	B12
2.4.	Technical Specifications	B12
2.5.	Scenario Termination Criteria	B12
2.6.	Anticipated Scenario Length.....	B12
3.	SIMULATOR EXERCISE EVALUATION	B13
3.1.	Evaluation Preparation	B13
3.2.	Evaluation	B13
3.2.1.	Event 1 Enter Mode 2 and achieve criticality	B13
3.2.2.	Event-2 Charging Control Valve (CV-212P) Fails Close	B14
3.2.3.	Event-3 Start a Turbine Driven Main Feedwater Pump (TDMFWP) and stop the Start-up Feedwater Pump (SUFWP).....	B15
3.2.4.	EVENT-4 Pressurizer Spray Valve Fails Open With ATWT.....	B16
3.2.5.	EVENT-5 ATWT	B17
3.2.6.	EVENT-6 RCS Ovation DCS Failures (common mode failures).....	B24
3.3.	Debrief	B25
	ISV-2 ATTACHMENT 1 - TRENDING PARAMETERS.....	B26
	ISV-2 ATTACHMENT 2 – MALFUNCTION LIST.....	B29
	ISV-2 ATTACHMENT 3 - SHIFT TURNOVER SHEET	B30
	ISV-2 ATTACHMENT 4 - ANTICIPATED DIALOG	B31

← **ISV-2 ATTACHMENT 5 - GUIDANCE WHEN DIFFICULTIES OCCUR DURING SIMULATION OR TESTING**

1. OVERVIEW

1.1. Human Factors Verification and Validation Objectives

TS

1.2. Scenario Overview

TS

TS

TS

Page intentionally blank

TABLE OF CONTENTS

1.	OVERVIEW.....	C3
1.1	Human Factors Verification and Validation Objectives	C3
1.2	Scenario Overview.....	C4
1.3	Performance Measures	C5
1.4	Other Performance Measures	C9
1.5	List of Important Human Actions.....	C10
1.6	Applicable Operational Condition Sampling	C10
2.	FACILITATORS INFORMATION	C12
2.1	Scenario Timeline	C12
2.2	Procedure Flowpath.....	C13
2.3	Emergency Plan	C13
2.4	Technical Specifications	C13
2.5	Scenario Termination Criteria	C13
2.6	Anticipated Scenario Length.....	C13
3.	SIMULATOR EXERCISE EVALUATION.....	C14
3.1	Evaluation Preparation	C14
3.2	Evaluation	C14
3.2.1	Event 1 Control rod partial movement surveillance test	C14
3.2.2	Event-2 CVCS letdown Heat Exchanger tube leak	C15
3.2.3	Event-3 Rapid power decrease in response to LPMS alarms.....	C16
3.2.4	Event-4 Two MFWPs Trip with Automatic Initiation Failure of RPCS	C17
3.2.5	Event-5 Alarm Server A and B Failures	C18
3.2.6	Event-6 Main Steam Line 2B Break IRC	C20
3.3	Debrief	C30
3.3.1	Post Exercise Evaluation	C30
3.3.2	Data Acquisition	C30
	ISV-3 ATTACHMENT 1 - TRENDING PARAMETERS.....	C31
	ISV-3 ATTACHMENT 2 - MALFUNCTION LIST.....	C34
	ISV-3 ATTACHMENT 3 - SHIFT TURNOVER SHEET	C35
	ISV-3 ATTACHMENT 4 - ANTICIPATED DIALOG	C36

← **ISV-3 ATTACHMENT 5 - GUIDANCE WHEN DIFFICULTIES
OCCUR DURING SIMULATION OR TESTING**

1. OVERVIEW

1.1 Human Factors Verification and Validation Objectives

TS

1.2 Scenario Overview

TS

Page intentionally blank

TABLE OF CONTENTS

1.	OVERVIEW.....	D3
1.1	Human Factors Verification and Validation Objectives	D3
1.2	Scenario Overview.....	D4
1.3	Performance Measures	D5
1.4	Other Performance Measures	D8
1.5	List of Important Human Actions.....	D9
1.6	Applicable Operational Condition Sampling	D9
2.	FACILITATORS INFORMATION	D10
2.1	Scenario Timeline	D10
2.2	Procedure Flowpath.....	D11
2.3	Emergency Plan	D12
2.4	Technical Specifications	D12
2.5	Scenario Termination Criteria	D12
2.6	Anticipated Scenario Length.....	D12
3.	SIMULATOR EXERCISE EVALUATION.....	D13
3.1	Evaluation Preparation	D13
3.2	Evaluation	D14
3.2.1	Event 1 CVCS Letdown Line Leak Upstream Control Valve CV-201P/Q.....	D14
3.2.2	Event 2 13.8kV SW-02M, SW-02N BUS FAULT	D16
3.2.3	Event 3 MD AFWP 2A and 2B Trip, Loss Of All Feedwater (LOAF)	D23
3.3	Debrief	D33
3.3.1	Post Exercise Evaluation	D33
3.3.2	Data Acquisition	D33
	ISV-4 ATTACHMENT 1 - TRENDING PARAMETERS.....	D34
	ISV-4 ATTACHMENT 2 - MALFUNCTION LIST	D37
	ISV-4 ATTACHMENT 3 - SHIFT TURNOVER SHEET	D38
	ISV-4 ATTACHMENT 4 - ANTICIPATED DIALOG	D39

↖ **ISV-4 ATTACHMENT 5 - GUIDANCE WHEN DIFFICULTIES
OCCUR DURING SIMULATION OR TESTING**

1. OVERVIEW

1.1 Human Factors Verification and Validation Objectives

TS

1.2 Scenario Overview

TS

ISV-4 ATTACHMENT 4 - ANTICIPATED DIALOG

TS

Page intentionally blank

TABLE OF CONTENTS

1.	OVERVIEW.....	E3
1.1	Human Factors Verification and Validation Objectives	E3
1.2	Scenario Overview.....	E4
1.3	Performance Measures	E5
1.4	Other Performance Measures	E8
1.5	List of Important Human Actions.....	E9
1.6	Applicable Operational Condition Sampling	E9
2.	FACILITATORS INFORMATION	E11
2.1	Scenario Timeline	E11
2.2	Procedure Flowpath.....	E12
2.3	Emergency Plan	E12
2.4	Technical Specifications	E12
2.5	Scenario Termination Criteria	E12
2.6	Anticipated Scenario Length.....	E12
3.	SIMULATOR EXERCISE EVALUATION.....	E13
3.1	Evaluation Preparation	E13
3.2	Evaluation	E14
3.2.1	Event 1 Equipment Rotation -- Charging Pump from 1A to 1B	E14
3.2.2	Event-2 CVCS VCT LT-227 Fails Low	E14
3.2.3	Event-3 Deaerator Level Controller LIK-0318NO1 Fails Low	E15
3.2.4	EVENT-4 100% to 75% Power Operation and Severe Weather (Tornado Warning)	E16
3.2.5	Event-5 Loss of Offsite Power	E17
3.2.6	EVENT-6 Station Black Out.....	E26
3.3	Debrief	E31
3.3.1	Post Exercise Evaluation	E31
3.3.2	Data Acquisition	E31
	ISV-5 ATTACHMENT 1 - TRENDING PARAMETERS.....	E32
	ISV-5 ATTACHMENT 2 - MALFUNCTION LIST.....	E35
	ISV-5 ATTACHMENT 3 - SHIFT TURNOVER SHEET	E36
	ISV-5 ATTACHMENT 4 - ANTICIPATED DIALOG	E37

← **ISV-5 ATTACHMENT 5 - GUIDANCE WHEN DIFFICULTIES
OCCUR DURING SIMULATION OR TESTING**

1. OVERVIEW

1.1 Human Factors Verification and Validation Objectives

TS

1.2 Scenario Overview

TS

TS

Page intentionally blank

TABLE OF CONTENTS

1.	OVERVIEW.....	F3
1.1	Human Factors Verification and Validation Objectives	F3
1.2	Scenario Overview.....	F4
1.3	Performance Measures	F5
1.4	Other Performance Measures	F9
1.5	List of Important Human Actions.....	F10
1.6	Applicable Operational Condition Sampling	F10
2.	FACILITATORS INFORMATION	F11
2.1	Scenario Timeline	F11
2.2	Procedure Flowpath.....	F12
2.3	Emergency Plan	F12
2.4	Technical Specifications	F12
2.5	Scenario Termination Criteria	F12
2.6	Anticipated Scenario Length.....	F12
3.	SIMULATOR EXERCISE EVALUATION.....	F13
3.1	Evaluation Preparation	F13
3.2	Evaluation	F14
3.2.1	Event 1 Equipment Rotation -- CCWP from 1A & 1B to 2A & 2B	F14
3.2.2	Event-2 Condenser A Left Hotwell Tube Leak	F15
3.2.3	Event-3 100% to 75% Power Operation.....	F16
3.2.4	EVENT-4 RRS Tavgr Fail Low	F17
3.2.5	Event-5 Steam Generator Tube Leak with Secondary Radiation Monitor Failures.....	F18
3.2.6	Event 6 Steam Generator Tube Rupture (SGTR)	F20
3.3	Debrief	F38
3.3.1	Post Exercise Evaluation	F38
3.3.2	Data Acquisition	F39
	ISV-6 ATTACHMENT 1 - TRENDING PARAMETERS.....	F40
	ISV-6 ATTACHMENT 2 - MALFUNCTION LIST.....	F43
	ISV-6 ATTACHMENT 3 - SHIFT TURNOVER SHEET	F44
	ISV-6 ATTACHMENT 4 - ANTICIPATED DIALOG.....	F45
	ISV-6 ATTACHMENT 5 - GUIDANCE WHEN DIFFICULTIES OCCUR DURING SIMULATION OR TESTING	

1. OVERVIEW

1.1 Human Factors Verification and Validation Objectives

TS

1.2 Scenario Overview

TS

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TABLE OF CONTENTS

1.	OVERVIEW.....	G3
1.1	Human Factors Verification and Validation Objectives	G3
1.2	Scenario Overview.....	G4
1.3	Performance Measures	G5
1.4	Other Performance Measures	G9
1.5	List of Important Human Actions.....	G10
1.6	Applicable Operational Condition Sampling	G10
2.	FACILITATORS INFORMATION	G11
2.1	Scenario Timeline	G11
2.2	Procedure Flowpath.....	G12
2.3	Emergency Plan	G12
2.4	Technical Specifications	G12
2.5	Scenario Termination Criteria	G12
2.6	Anticipated Scenario Length.....	G13
3.	SIMULATOR EXERCISE EVALUATION.....	G14
3.1	Evaluation Preparation	G14
3.2	Evaluation	G15
3.2.1	Event 1 MFWP B Vibration High and associated 100% to 75% Power Operation	G15
3.2.2	Event 2 Charging line leak on the Regenerative Hx Outlet IRC, with containment radiation monitors failed low.....	G16
3.2.3	Event-3 Downpower from 75% to Hot Standby followed by a cooldown to Mode 4	G17
3.2.4	Event-4 Steam Generator 2 FW Master controller fails low	G18
3.2.5	Event 5 Fire in the MCR with Required RCS Cooldown from the RSR	G19
3.3	Debrief	G21
3.3.1	Post Exercise Evaluation.....	G21
3.3.2	Data Acquisition.....	G21
ISV-7 ATTACHMENT 1 - TRENDING PARAMETERS.....		G22
ISV-7 ATTACHMENT 2 - MALFUNCTION LIST.....		G25
ISV-7 ATTACHMENT 3 - SHIFT TURNOVER SHEET		G26
ISV-7 ATTACHMENT 4 - ANTICIPATED DIALOG.....		G27

← **ISV-7 ATTACHMENT 5 - GUIDANCE WHEN DIFFICULTIES OCCUR DURING SIMULATION OR TESTING**

1. OVERVIEW

1.1 Human Factors Verification and Validation Objectives

TS

1.2 Scenario Overview

TS

ISV-7 ATTACHMENT 4 - ANTICIPATED DIALOG

TS

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 352-8205

SRP Section: 18 – Human Factors Engineering

Application Section: 18.10

Date of RAI Issue: 12/22/2015

Question No. 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.

Response

Sections 4.5.6.1 and 4.5.6.2 of the Human Factors Verification and Validation Implementation Plan (HF V&V IP) will be revised to describe how the procedures minimize bias, as indicated in the attachment associated with this response.

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-I-NR-14008-NP, Rev.0, "Human Factors Verification and Validation Implementation Plan," Section 4.5.6.2 and 4.5.6.2.1 will be revised, as indicated in the attachment associated with this response.

4.5.6.2. Test Procedures

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4.5.6.2.1. Test Procedure Requirements

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RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 352-8205
SRP Section: 18 – Human Factors Engineering
Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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.

Response

1. Although desired, several factors make a statistical analysis, as one would apply to research derived data, difficult, and on its own, impractical to perform for integrated system validation (ISV):
 - 1) In an ISV there is a need to test the system under a wide range of operating conditions which results in not having sufficient data under one set of conditions to provide reliable estimates of performance.
 - 2) ISV data analysis must be cautious when considering deviations from optimal or mean performance due to the fact that each operator or crew strategy can be expected to vary.

Therefore, although simple quantitative statistical tools are applied to support the understanding of the meaning of the ISV data, the APR1400 ISV data analysis must rely on qualitative methods. These include the application of SME analysis and the assessment of the degree of convergence of multiple measures of performance, convergent validity. As an example; if the APR1400 workload is found to be lower than the average for the reference plant, however, the difference is calculated to be not statistically significant, additional evaluation is warranted. When this occurs, it is documented and other measures are assessed to help determine the workload. If the additional evaluation does not result in a workload with good confidence, then an HED is initiated and resolved.

In statistical null hypothesis testing, the P value is a simple, well accepted, test that measures the likely hood of obtaining a result equal to or more extreme that what was actually observed. In order to define "more extreme," prior to the ISV, a threshold value, or significance level, for the test must be chosen. Traditionally this is set as either a P value of 1% or 5%. Therefore, for the APR1400 ISV, a value of less than or equal to 5% has been chosen. Note:

- A small P value (less than or equal to 5%) indicates strong evidence against the null hypothesis so it is rejected
- A large P value (greater than 5%) indicates weak evidence against the null hypothesis
- A P value close to 5% is considered to be marginal and require more attention

Thus, generally speaking, the smaller the P value, the larger the significance informing the analysis that the hypothesis may not adequately explain the observation.

This being said, the p value is dependent on sample size, which is small in the case of an ISV, and has been criticized for its inherent shortcomings and potential for misunderstanding based on its binomial results (reject or cannot reject). Therefore, the

conclusions drawn from the ISV use the resulting P values to only inform the qualitative analysis, therefore, the selection of the significance level is non critical to the outcome of the analysis.

2. As discussed in the response to question 1, an ISV must test for a large range of operating conditions, and therefore realistically must limit the number of independent test crews for each scenario and therefore relies on a limited number of statistical degrees of freedom. The sampling of operating conditions process, as describe in Section 4.1 of the Human Factors Verification and Validation Implementation Plan (HF V&V IP), defines the number and content of the scenarios in order to cover the range of operating conditions, while the number of test crews and participants are determined by an evaluation of the required number to draw realistic conclusions and the resource constraints. The APR1400 approach to controlling the potential impact of having a limited number of degrees of freedom, 3 test crews, is to:

- assess not only the crews collective performance but also the performance of each crew member
- apply convergent validity by observing the same performance by independent measures

Section 4.5.7 of the HF V&V IP will be revised as indicated in the attachment associated with this response.

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-I-NR-14008-NP, Rev.0, "Human Factors Verification and Validation Implementation Plan," Section 4.5.7 will be revised, as indicated in the attachment associated with this response.

TS

4.5.7. Data Analysis and HED Identification

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RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 352-8205
SRP Section: 18 – Human Factors Engineering
Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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.

Response

Section 4.5.7.1 will be revised to describe the method by which data is analyzed across trials, and what criteria are used to determine successful performance of a scenario, as indicated in the attachment associated with this response.

Statistical tests (e.g., T-tests) are not used to compare the flow of the scenario execution by the operator to the simulator logging data.

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-I-NR-14008-NP, Rev.0, "Human Factors Verification and Validation Implementation Plan," Section 4.5.7.1 will be revised, as indicated in the attachment associated with this response.

4.5.7.1. Individual Performance Measures

TS

Table 4-8 Example of BARS T-test

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RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 352-8205
SRP Section: 18 – Human Factors Engineering
Application Section: 18.10
Date of RAI Issue: 12/22/2015

Question No. 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.

Response

Section 4.5.5 of the Human Factors Verification and Validation Implementation Plan (HF V&V IP) will be revised to describe how the evaluation of convergence between related measures is to be accomplished, as shown in the attachment associated with this response.

A new paragraph will be added to Section 4.5.5 of the HF V&V IP, as follows:

Consistency between different measures that are used to evaluate the same aspect of performance are assessed during the scenarios:

1. This initially occurs during the post scenario debriefs. To first establish inter-rater reliability between the test personnel observing the scenario, prior to the scenario debriefing, the test personnel meet to identify significant points, based on their

observations, that need to be explored during the debriefing. At this time, the test personnel identify any variations between their individual observations, and if these cannot be resolved between the members, they are documented on the observer questionnaires for evaluation later in the ISV program.

2. During each scenario's debriefing, the test personnel ask questions of the test crew members to assess areas where their observations vary from the crew's questionnaire responses and individual crew descriptions of the events that occurred during the scenario. The crew's responses are documented in the notes of the debriefing. At the end of each day, the test observers meet to review the notes from each of the day's scenarios and compare their observations to the crew's questionnaires and discuss. If a consensus cannot be reached, the variation is documented in the notes of the meeting.
3. Once all scenarios have been completed for a test crew, the test personnel meet and reevaluate the observations, as compared to the crew responses. During this process, video and audio files along with preliminary simulator plant parameters may be used to confirm the consensus results. Results, and all remaining differences, related to the same measure are documented for further evaluation during the data analysis.
4. The most intensive assessment of the convergent validity of the ISV is performed during the data analysis and identification of HED part of the program. During this activity, detailed plant parameters are compared to the notes from the test personnel. When the test personnel identify errors, loss of situation awareness, or work load increase, they are compared to the recorded plant parameters to evaluate the measure of performance. The video and audio recordings may also be used to support conclusions on the validity of the results. As needed, the test personnel may be questioned to resolve any remaining open differences. Results of unresolved variation, if any, between the measures are documented, tracked, and resolved as HEDs.

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-I-NR-14008-NP, Rev.0, "Human Factors Verification and Validation Implementation Plan," Section 4.5.5 will be revised, as indicated in the attachment associated with this response.

4.5.5. Performance Measurement

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RAI No.: 352-8205
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Question No. 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.

Response

The Human Factors Verification and Validation Implementation Plan will be revised to describe how the margin of error in the observation of human performance is addressed by adding Section 4.5.7.4, "Margin of Error," as shown in the attachment associated with this response.

A new Section 4.5.7.4 will be added to the HF V&V IP, as follows:

4.5.7.4 Margin of Error

The variation that may exist between actual as built plant performance and that observed or represented by the simulator plant parameters during the ISV tests is expected to be, if it is experienced, small. This conclusion is based on the criteria described in Section 4.5.3, page 29, including the criteria contained in ANSI/ANS 3.5- 2009 (Reference 13, the simulator purchase specification acceptance testing program and the pilot test. The pilot test will identify any significant variations that may impact the conclusions if the ISV program by the comparison of

expected results to those observed by SMEs with HFE, plant operations, and safety analysis backgrounds.

Even with this conclusion, there may still be a residual margin of error that could exist and that must be addressed in the data analysis. This will be accomplished by the same process as that used in the pilot test evaluation by:

- SME's with PWR operating experience assessing the results against expected results that would be seen in actual operating plants.
- SME's with safety analysis experience, and knowledge of the DCD Chapter 15 analysis, assessing the difference between scenario simulated plant parameters and those done for the safety analysis.
- SME's with HFE and HRA backgrounds evaluating if there is a difference between observed human performance and that expected.

If a margin of error is identified, the data analysis will conservatively consider this uncertainty in the conclusions of the ISV.

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-I-NR-14008-NP, Rev.0, "Human Factors Verification and Validation Implementation Plan," Section 4.5.7.4 will be added, as indicated in the attachment associated with this response.

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4.5.7.3. Extent of the Issue Determination

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4.5.8. Validation Conclusions

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