

US-APWR

Staffing and Qualifications Implementation Plan

December 2011

**© 2010-2011 Mitsubishi Heavy Industries, Ltd.
All Rights Reserved.**

Prepared: Eisuke Noda 12/13/2011
Date
Eisuke Noda, Deputy Manager
Human Factor and Training Facility Engineering Section
Nuclear Electrical, Instrumentation & Control Engineering
Department

Prepared: Satoshi Hanada 12/13/2011
Date
Satoshi Hanada, Deputy Manager
Human Factor and Training Facility Engineering Section
Nuclear Electrical, Instrumentation & Control Engineering
Department

Prepared: Koji Ito 12/13/2011
Date
Koji Ito, Engineering Manager
Human Factor and Training Facility Engineering Section
Nuclear Electrical, Instrumentation & Control Engineering
Department

Reviewed: Hideaki Tokunaga 12/15/2011
Date
Hideaki Tokunaga, Deputy Manager
Human Factor and Training Facility Engineering Section
Nuclear Electrical, Instrumentation & Control Engineering
Department

Approved: Masanori Yokoyama 12/15/2011
Date
Masanori Yokoyama, Manager
Human Factor and Training Facility Engineering Section
Nuclear Electrical, Instrumentation & Control Engineering
Department

Approved: Yuzuru Yasui 12/16/2011
Date
Yuzuru Yasui, Director
Nuclear Electrical, Instrumentation & Control Engineering
Department

Signature History

	Rev. 0	Rev. 1		
Prepared	Satoshi Hanada	Eisuke Noda		
	Koji Ito	Satoshi Hanada		
		Koji Ito		
Reviewed	Hideaki Tokunaga	Hideaki Tokunaga		
Approved	Masanori Yokoyama	Masanori Yokoyama		
	Yoshinori Inazumi	Yuzuru Yasui		

Revision History

Revision	Date	Page (Section)	Description
0	April 2010	All	Original issued
1	December 2011	General	Revised capitalization of section titles.
		p.v (Abstract)	Revised number of figure. Revised the third sentence to “The staffing analysis covers tasks performed by ...” for response to RAI 725 (Question No. 18-102).
		p.2 (Section 2.0)	Added new paragraph to end of the section for response to RAI 725 (Question No. 18-102).
		p.4 (Section 4.1)	Added description about sources of data for response to RAI 725 (Question No. 18-98). Revised “descries” to “describes” for response to RAI 725 (Question No. 18-105)
		pp.5-6 (Section 4.2.1)	Revised “Shift Supervisor” to “Shift Manager” for response to RAI 792 (Question No. 18-140). (Overwrote the revision for response to RAI 725 (Question No. 18-105).) Added description about MCR Supervisor for response to RAI 792 (Question No. 18-140). Revised description about Shift Technical Advisor for response to RAI 792 (Question No. 18-140). Deleted “Shift Supervisor or” for response to RAI 792 (Question No. 18-140).
		pp.6-7 (Section 4.2.1.1)	Revised section title for response to RAI 725 (Question No. 18-98). Revised description about minimum operator staffing roles for response to RAI 792 (Question No. 18-140).

Revision	Date	Page (Section)	Description
		pp.7-8 (Section 4.2.2)	<p>Added two paragraphs about minimum staffing requirements for response to RAI 725 (Question No. 18-104).</p> <p>Added description about maximum operating staff numbers for RAI 725 (Question No. 18-98).</p> <p>Revised the first sentence under “Chemistry Technicians” to “Chemistry technicians monitor and maintain ...” for response to RAI 725 (Question No. 18-105).</p> <p>Revised the first sentence under “Engineering Support Personnel” to “Engineering support personnel contribute to ...” for response to RAI 725 (Question No. 18-105).</p>
		pp.14-15 (Section 4.4)	<p>Revised the description of the last paragraph for response to RAI 725 (Question No. 18-101).</p> <p>Added “performing tasks” in first paragraph for response to RAI 725 (Question No. 18-102).</p> <p>Deleted “risk important” in first paragraph for response to RAI 725 (Question No. 18-102).</p> <p>Added description to second bullet in second paragraph.</p> <p>Added “(expert panel)”.</p> <p>Added “Task”.</p> <p>Added “results”.</p>
		p.17 (Section 4.4.4)	<p>Revised section title.</p> <p>Added “(expert panel)”.</p>
		p.18 (Section 4.5)	<p>Added “Task”.</p> <p>Added description about results summary report.</p> <p>Revised “Analysis report” to “results summary report”.</p>

Revision	Date	Page (Section)	Description
		p.19 (Section 5.0)	Deleted a sentence of the section end. Added reference 5-14. Revised description of references.

© 2010-2011
MITSUBISHI HEAVY INDUSTRIES, LTD.
All Rights Reserved.

This document has been prepared by Mitsubishi Heavy Industries, Ltd. ("MHI") in connection with the U.S. Nuclear Regulatory Commission ("NRC") licensing review of MHI's US-APWR nuclear power plant design. No right to disclose, use or copy any of the information in this document, other than that by the NRC and its contractors in support of the licensing review of the US-APWR, is authorized without the express written permission of MHI.

This document contains technology information and intellectual property relating to the US-APWR and it is delivered to the NRC on the express condition that it not be disclosed, copied or reproduced in whole or in part, or used for the benefit of anyone other than MHI without the express written permission of MHI, except as set forth in the previous paragraph.

This document is protected by the laws of Japan, U.S. copyright law, international treaties and conventions, and the applicable laws of any country where it is being used.

Mitsubishi Heavy Industries, Ltd.
16-5, Konan 2-chome, Minato-ku
Tokyo 108-8215 Japan

Abstract

This document presents the implementation plan for the US-APWR staffing and qualifications analysis. The US-APWR staffing and qualifications complies with 10 CFR 50.54 (i) through (m). The staffing analysis covers tasks performed by both licensed operating staff and non-licensed positions (e.g., maintenance and testing staff) directly related to plant safety. Initial staffing level goals for the US-APWR are based on staffing levels of predecessor PWR plants with modifications reflecting the changes in US-APWR technology and plant system designs. The staffing analysis begins by identifying changes of the US-APWR from predecessor plants (i.e., typical PWR plants), in design, staffing levels/qualifications or operating practice assumptions. Analyses are then conducted to establish the adequacy of US-APWR staffing assumptions for those cases where changes are identified. The staffing analysis uses as input results of prior HFE program elements including operating experience review, functional requirements analysis and function allocation and task analysis. The analysis approach utilizes multiple complementary methods, including review of data from operational experience; Table Top Analyses; and review of results of simulator studies conducted as part of the HSI design program element.

The result of staffing and qualifications analysis is used as input to other HFE elements including Human-System Interface Design, Procedure Development and Training program development.

Table of Contents

List of Figures.....	vii
List of Acronyms.....	viii
1.0 Purpose.....	1
2.0 Scope.....	2
3.0 Applicable Codes, Standards and Regulatory Guidance.....	3
4.0 Implementation Plan	4
4.1 Overview of Staffing and Qualifications Analysis Approach	4
4.2 Initial Staffing Level and Qualifications Goals and Their Bases	4
4.2.1 Operating Staff Roles and Responsibilities	5
4.2.2 Other Plant Staff Roles and Responsibilities.....	7
4.3 Relation of Staffing and Qualifications Analysis to Overall HFE Program.....	8
4.3.1 Operating Experience Review	10
4.3.2 Function Requirement and Function Allocations	10
4.3.3 Task Analysis.....	11
4.3.4 Human Reliability Analysis	12
4.3.5 HSI Design	13
4.3.6 Procedure Development.....	13
4.3.7 Training Program Development.....	14
4.4 Methodology for Establishing Adequacy of Staffing Levels and Qualifications	14
4.4.1 Identify Significant Differences from Predecessor Plants.....	15
4.4.2 Identify Tasks to be Analyzed and Analysis Technique.....	16
4.4.3 Identify Relevant Operational Experience Data.....	17
4.4.4 Conduct Staffing and Qualification Evaluation from Table Top Task Analyses Results.....	17
4.4.5 Review Relevant Simulator Study Results	17
4.5 Results.....	18
5.0 References.....	19

List of Figures

Figure 4.3-1 HFE Overall Work Flow 9

List of Acronyms

AOO	anticipated operational occurrence
CBP	computer-based procedure
CFR	Code of Federal Regulations
COL	combined license
COLA	combined license application
DAS	diverse actuation system
DCD	design certification document
ECCS	emergency core cooling system
EOF	emergency operations facility
EOP	emergency operating procedure
ERG	emergency response guidelines
FA	function allocation
FRA	functional requirements analysis
FSAR	final safety analysis report
GDC	general design criteria
GTG	generic technical guidelines
HA	human action
HED	human engineering discrepancy
HFE	human factors engineering
HRA	human reliability analysis
HSI	human-system interface
HSIS	human system interface system
I&C	instrumentation and control
ITAAC	inspection, test, analysis, and acceptance criteria
LCS	local control station
MCR	main control room
MHI	Mitsubishi Heavy Industries, Ltd.
NRC	Nuclear Regulatory Commission, U.S.
OER	operating experience review
OSD	operational sequence diagram

PA	postulated accidents
PAM	post-accident monitoring
PRA	probabilistic risk assessment
PSF	performance shaping factor
QA	quality assurance
RG	Regulatory Guide
RO	reactor operator
SA	staffing and qualifications analysis
SER	significant event report
SG	steam generator
SOER	significant operating experience report
SRO	senior reactor operator
TA	task analysis
TSC	technical support center
US, U.S.	United States
US-APWR	United States – Advanced Pressurized Water Reactor
V&V	verification and validation
VDU	visual display unit

1.0 Purpose

This document describes the staffing and qualifications implementation plan for the US-APWR. The objective of the staffing and qualifications analysis (SA) is to determine the numbers and qualifications of personnel required for safe and efficient plant operation in a systematic manner. It is based on a thorough analysis of task requirements and review of applicable regulatory requirements.

2.0 Scope

The plant personnel who are addressed by the staffing and qualifications analysis include licensed control room operators as defined in 10 CFR 50.54(m), and the following categories of personnel defined in 10 CFR 50.120:

- Non-licensed operators
- Shift supervisors
- Shift technical advisor
- I&C technicians
- Electrical maintenance personnel
- Mechanical maintenance personnel
- Radiological protection technicians
- Chemistry technicians
- Engineering support personnel.

Tasks directly related to plant safety are addressed in this analysis in the full range of plant operating modes, including the following:

- Startup / Shutdown
- Normal operations
- Abnormal and Emergency operations
- Transient conditions

The scope of tasks covered by the analysis includes operational tasks, plant maintenance tasks, and plant surveillance and testing.

The personnel required for all tasks directly related to plant safety are included in the scope of the analysis. In addition, the analysis ensures that tasks not directly related to plant safety do not cause an adverse effect on tasks or personnel performing tasks directly related to plant safety.

3.0 Applicable Codes, Standards and Regulatory Guidance

The compliance to the applicable codes and standards for the US-APWR HSIS design and HFE Process is identified in section 3.0 of the topical report “HSI System Description and HFE Process”, MUAP-07007 (Reference 5-2). The topical report includes following standards and guidelines.

- Code of Federal Regulations
- Staff Requirements Memoranda
- NRC Regulatory Guides
- NRC Branch Technical Positions
- NUREGs
- Other Reference Guidelines

4.0 Implementation Plan

4.1 Overview of Staffing and Qualifications Analysis Approach

The staffing and qualifications analysis begins with initial staffing level and qualifications goals. These are described in Section 4.2, and are based on typical staffing levels for Pressurized Water Reactor (PWR) plants in the U.S. and Japan. These staffing levels conform to U.S. regulations listed in Section 3.0 and comply with 10 CFR 50.54 (i) through (m).

A systematic process is then used to evaluate these initial staffing assumptions, and modify them as appropriate, to establish the numbers and qualifications of personnel required for safe and efficient plant operations. Details of this methodology are provided in section 4.4. The process begins by identifying significant differences between the US-APWR and predecessor plants (i.e., typical PWR plants), in design, staffing or operating practice assumptions. Analyses are then conducted to establish the adequacy of US-APWR staffing assumptions for those cases where differences in design, staffing or operating practice are identified. The analysis approach utilizes multiple converging measures, including review of data from operational experience; Table Top Analyses; and simulator studies.

Sources of data from operational experience include the staffing defined in the EPRI "Advanced Light Water Reactor Utility Requirements Document" Volume II Chapter 10, Section 4.2.3, and current staffing at pressurized water reactor plants.

The staffing and qualifications analysis utilizes an iterative process. Staffing level and qualifications goals are reviewed and modified, if necessary, based on inputs from other elements of the human factors engineering (HFE) plan, including operating experience review; functional requirements analysis and function allocation and task analysis.

The result of staffing and qualifications analysis is used as input to other HFE elements including Human-System Interface Design, Procedure Development and Training program development.

Issues relating to staffing level or qualifications assumptions may be identified during any HFE element of the HFE program, including HSI design, procedure development and training program development. Any identified issues are entered into the HED database and evaluated and resolved per the standard HED evaluation process described in Part 1, Section 6 of MUAP-09019. The HED resolution may include modification to the staffing level or staff qualifications requirements.

Section 4.2 specifies the initial US-APWR staffing level and qualifications goals and their bases. Section 4.3 describes how the staffing and qualifications analysis fits within the overall HFE program, including specification of the HFE elements that feed into the staffing and qualifications analysis, and the HFE elements that rely on the outputs of the staffing and qualifications analysis. Section 4.4 describes the methodology that will be used to evaluate staffing level and qualifications assumptions.

4.2 Initial Staffing Level and Qualifications Goals and Their Bases

Initial staffing level goals for the US-APWR are based on staffing levels of predecessor PWR plants with modifications reflecting the changes in the US-APWR technology and plant system

designs. These initial assumptions for staffing levels are described below and comply with 10 CFR 50.54.

Training and qualifications requirements for the US-APWR staff are consistent with training and qualifications requirements in current U.S. PWR plants and reflected in personnel job titles as described below.

4.2.1 Operating Staff Roles and Responsibilities

The US-APWR plant design assumes the plant operating staff described below, who have qualifications for safely operating the US-APWR during normal power operation, as well as during transient and accident events included in the plant design basis. This includes licensed control room operators as defined in 10 CFR 50.54(m) and 50.55.

Operating staff positions and associated qualifications:

- Shift Manager

The Shift Managers are responsible for supervising the evolutions conducted during their shift and ensuring that they are conducted in accordance with the operating license, station procedures, and applicable directives and policies. The Shift Managers are responsible for supervising shift operations personnel and for conducting on-shift training. During periods when senior management personnel are not on site, the Shift Manager assumes responsibility for all station activities. Each Shift Manager is required to maintain a Senior Reactor Operator (SRO) License pursuant to 10 CFR Part 55.54 "Senior Operator".

- MCR Supervisor

The MCR Supervisors (also referred to as Shift Supervisors or Control Room Supervisors) report directly to the Shift Manager, and are members of management who assist the Shift Managers in discharging their responsibilities for supervision of the plant operation. The MCR Supervisors may assume the duties of the Shift Managers in their absence. The MCR Supervisor is required to maintain a SRO License.

- Shift Technical Advisor

Shift Technical Advisors (STAs) report to the Shift Manager. For minimum staffing, the STA responsibilities may be assigned to the MCR Supervisor during normal operations. To fulfill this role the MCR Supervisor will have both SRO and STA qualifications. During emergency operations, a person present at the facility during its operation with SRO or STA qualifications will relieve the MCR Supervisor of his combined SRO/STA duties, allowing a single focus during emergency conditions. Alternately, STA duties may be assigned to a dedicated STA; this dedicated position is assumed in the maximum staffing configuration. The person fulfilling the role of STA shall have the qualifications described in Option 1 of the Commission Policy Statement on Engineering Expertise (50 Federal Registry 43621, October 28, 1985).

- Reactor Operators

The Reactor Operators report directly to the MCR Supervisor, and are responsible for routine evolutions on their assigned unit and for monitoring the status of that unit. Each Reactor Operator is licensed pursuant to 10 CFR Part 55.54 "Operators".

- Auxiliary Operators (Non-licensed Operators)

The auxiliary operator works under the direction of a Shift Manager or MCR Supervisor. The auxiliary operator responsibilities include operating and servicing equipment remote from the MCR at the direction of Control Room operators.

4.2.1.1 Minimum and Maximum Operating Staff Numbers

The US-APWR staffing and qualifications complies with 10 CFR 50.54 (i) through (m). No exemption from these requirements is being sought.

The minimum operator staffing roles and responsibilities that are the basis for the US-APWR design are assumed as follows:

- 1 SRO located at the plant fulfilling the role of Shift Manager.
- 1 SRO located within the MCR fulfilling the role of MCR Supervisor and STA, during normal operation
- 1 RO located at the controls of the plant in the MCR
- 1 RO located at the plant
- At least one more person present at the facility during its operation with SRO or STA qualifications. During emergency conditions, this person will relieve the MCR Supervisor of either the supervisor or STA responsibilities. This person can be shared by multiple units.

For plants with multiple US-APWR units, each US-APWR unit will fulfill these minimum staffing requirements.

The second RO is required to be at the plant, but not in the MCR. The second RO will normally support maintenance and testing activities. During emergency conditions, the second RO may be used to restore success paths that may not have responded correctly to emergency actuation signals. The second RO may also be used for local control actions during degraded HSI conditions (i.e., for common cause failure of digital systems).

The initial starting point for the maximum staffing in the staffing and qualification analysis is based on providing HSI accommodations (i.e., space and layout) in the MCR for the following personnel:

- Two ROs, responsible for the operation of controls in MCR
- One MCR supervisor (Licensed senior reactor operator (SRO)), responsible for the direct supervision of the operators in MCR
- One shift supervisor (SRO), responsible for overall plant operation
- One shift technical advisor (STA), responsible for providing engineering support

The initial starting point for the maximum staffing in the staffing and qualification analysis is based on providing physical and habitability accommodations within the MCR envelope for the following active observer:

- One shift crew assistant, responsible for assisting the shift supervisor and handling communications

- One additional RO, responsible for assisting the above two ROs and interacting with other members of the plant staff
- One from the NRC
- One from the Plant Owner's management
- Two equipment operators

4.2.2 Other Plant Staff Roles and Responsibilities

The staffing and qualifications analysis also covers categories of non-licensed personnel defined by 10 CFR 50.120 that are responsible for operations and maintenance directly related to risk-important plant safety.

These additional personnel are not necessarily located in the MCR nor located at the nuclear facility at all times. The minimum qualifications requirements (degree of school, period of job experience, etc.) for the following types of personnel are described in the Appendix A of NUREG-0711 "Human Factors Engineering Program Review Model," ANSI/ANS 3.1 Rev.1 - 1999, "Selection, Qualification, and Training of Personnel for Nuclear Power Plants" and ANSI N18.7-1976/ANS-3.2, "Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants":

- I&C technicians

I&C technicians conduct maintenance, calibration, periodic test and trouble shooting for digital/analog I&C equipments and instrumentation & control devices (i.e., sensors, transmitters and cables, etc.).

- Electrical maintenance personnel

Electrical maintenance personnel conduct maintenance, calibration, periodic test and trouble shooting for all breakers, motor control centers, batteries and control circuits (TD relays, aux relays, and switches).

- Mechanical maintenance personnel

Mechanical maintenance personnel conduct mechanical component maintenance including major component surveillance testing.

- Radiological protection technicians

Radiological protection technicians conduct radiation protection at nuclear facilities dealing with radiation protection problems and programs similar to those at nuclear power plants. The individual shall be familiar with the design features and operations of nuclear power stations that affect the potential for exposures of persons to radiation. The individual have the technical competence to establish radiation protection programs and the supervisory capability to direct the work of technicians, and journeymen required to implement the radiation protection programs.

- Chemistry technicians

Chemistry technicians monitor and maintain the chemistry of the station's fluid systems. They are to respond appropriately to unusual chemistry transients and incidents and to anticipate and prevent such events. In normal or emergency cases, they are to grab samples manually and analyze them. Also, they must understand the potential impact of

chemistry actions on the plant and be aware of conditions that might compromise safe and reliable plant operation.

- Engineering support personnel.

Engineering support personnel contribute to the safe and reliable operation of the nuclear power plant by maintaining and repairing nuclear plant equipment. They should understand the fundamentals of nuclear power plant technology. Engineering personnel must have a healthy respect for the unique safety challenges posed by nuclear technology and be competent in their roles of supporting plant operation.

The initial US-APWR staffing level for non-operating staff categories of personnel are based on staffing levels of predecessor PWR plants, as follows:

I&C technicians	33-45
Electrical maintenance personnel	33-40
Mechanical maintenance personnel	33-50
Radiological protection technicians	36
Chemistry technicians	13-16
Engineering support personnel	33-60

The ranges of numbers represent the variations in the operating plants to which the US-APWR will be compared.

Analyses described in Section 4.4 will then be used to evaluate the appropriateness of these initial staffing levels. The staffing numbers for these non-operations categories of personnel is also defined based on the analyses in Section 4.4 of the S&Q IP.

4.3 Relation of Staffing and Qualifications Analysis to Overall HFE Program

Part 1 of the Technical Report MUAP-09019 "HSI Design" (Reference 5-3) describes the US-APWR Human Factors Engineering (HFE) Overall Program Implementation Plan, which is described in Chapter 18 of the US-APWR DCD (Reference 5-1).

Figure 4.3-1 shows the relationship and flow of the staffing and qualifications analysis within the larger HFE program.

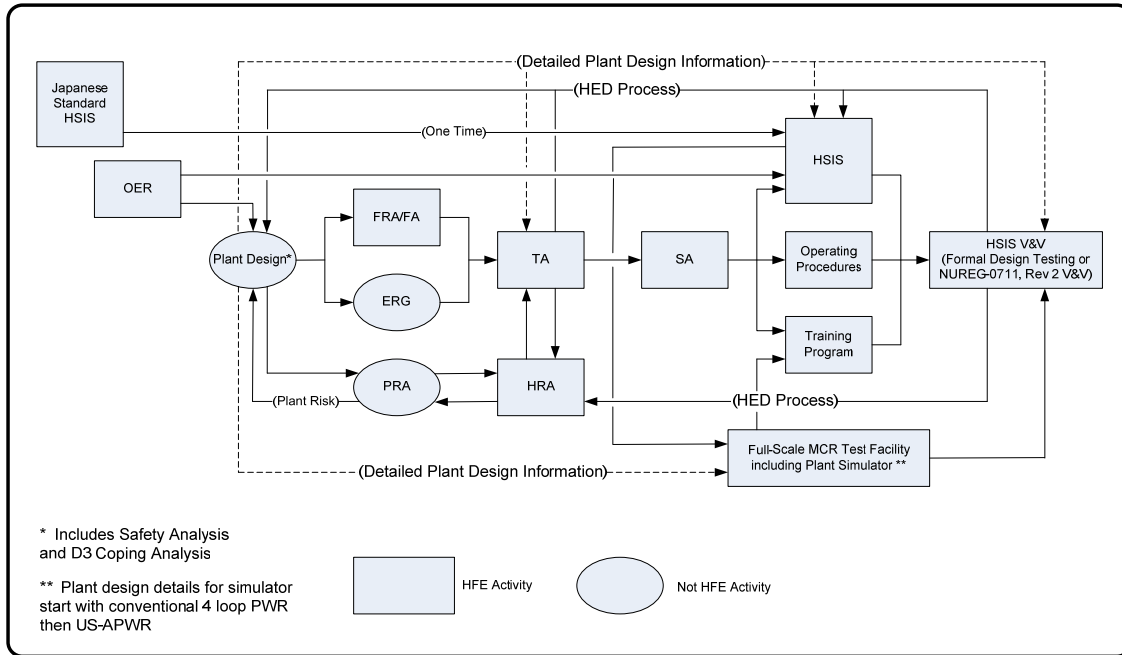


Figure 4.3-1 HFE Overall Work Flow

The staffing analysis starts with initial staffing goals as specified in Section 4.1 of this document. These initial staffing goals are then reviewed, and if necessary modified, in an iterative manner, based on inputs from other HFE elements within the overall HFE program.

HFE elements providing direct inputs to the staffing and qualifications analysis include Operating Experience Review, Functional Requirements Analysis and Function Allocation (FRA/FA), Task Analysis and Human Reliability Analysis. Outputs of the staffing analysis are used to inform HSI design, procedure development and training program development. In turn, results of HSI design, procedure development and training program development, are used to provide feedback, and if necessary modification, to the staffing and qualifications specification.

A primary mechanism for providing input and feedback across HFE elements is the Human Engineering Discrepancy (HED) documentation and tracking process. Issues concerning staffing levels and qualifications that are identified during any HFE element are documented as HEDs. These HEDs are then reviewed to assess their impact on staffing and qualifications assumptions. If warranted, modifications to staffing and qualifications may be made.

The HED identification, tracking and resolution process is described in Section 6 of Part 1 of the Technical Report MUAP-09019.

Below we summarize the HFE program elements that will provide inputs to the staffing and qualifications element as well as the HFE program elements that will use the outputs of the staffing and qualifications element as an input. It should be noted that several of the program elements, specifically Operating Experience Review, Functional Requirements Analysis and Function Allocation, and Human Reliability Analysis, have already been completed and documented. The products of these elements will be used to inform the staffing and qualifications element.

4.3.1 Operating Experience Review

The US-APWR plant design is based on conventional PWR designs. As a consequence, initial staffing levels and qualifications goals for the US-APWR are based on staffing levels and staff qualifications for predecessor Japanese and U.S. PWR plants.

Major differences in plant design or planned operations will be identified and analyzed to determine whether these differences impose significant changes in performance demands on staff requiring modification to staffing levels and/or staffing qualifications.

In addition, operating experience at predecessor Japanese and U.S. PWR is reviewed, as part of the Operating Experience Review HFE element, to identify any issues in staffing levels or qualifications in current plants that need to be addressed, in specifying US-APWR staffing level and qualifications requirements.

The operating experience review (OER) report documented as MUAP-08014 Part 1 identifies and analyzes HFE related problems in conventional PWR plants in the U.S. and Japan. This OER reviews multiple sources including NUREG/CR-6400, IN 95-48, IN 97-78 (Reference 5-9,11,12). The OER also analyzes non-nuclear industrial applications of digital technology with screen based HSI.

The OER identified aspects of the US-APWR HSI System, as documented in Topical Report MUAP-07007, that adequately address historical human factors problems. Where a problem is not adequately resolved by the US-APWR HSI System, a Human Engineering Discrepancy (HED) was generated to document the problem and potential solutions. The HED is used to track the issue until it is adequately addressed in the US-APWR HSI design, staffing levels and qualifications, operating procedures or training program.

4.3.2 Function Requirement and Function Allocations

The functional requirements analysis (FRA) determines the plant functions that must be performed to satisfy the plant safety objectives. The FRA also identifies the plant power production functions since power production is an important aspect of plant performance. The function allocation (FA) allocates the identified functions for plant safety and plant power production to human system resources considering personnel characteristics, or to automated resources.

The FRA/FA of the US-APWR has been completed and is documented in Part 2 of the Technical Report MUAP-09019 "HSI Design" (Reference 5-3). It serves as a primary input to the staffing and qualifications analysis, in that it identifies the primary changes in plant system design from predecessor PWR plants that may impact the roles, responsibilities, and qualifications requirements of plant personnel – including operations, maintenance, and plant surveillance and testing personnel.

The primary changes of the US-APWR functions from the convention PWR plant's functions are:

- An automatic Emergency Feedwater isolation of the broken steam generator (SG).
- Elimination of recirculation of ECCS and Containment Vessel Spray
- Four train system configuration (Contribute for high reliability, redundancy)
- Advanced steam generators and accumulators, other improved design equipment, gas

turbine generator for backup system

Generally, the above changes are expected to reduce operating staffs' workload and potential human errors, increasing confidence that the staffing level assumptions documented in subsection 4.2.1.1 are acceptable. These staffing assumptions are further evaluated as part of the task analysis HFE element, and will be definitively confirmed in the Phase 2b US-APWR V&V test.

The system changes from predecessor PWR plants may also impact the roles, responsibilities, and qualifications requirements for maintenance and plant surveillance and testing personnel. For example, the change to a four train system (from two trains used in predecessor PWR plants) will increase the number of safety-related components/valves that need to be maintained/tested by maintenance personnel. However, it is expected that this increase in workload will be counter-balanced by a reduction in workload associated with periodic inspection because of the application of on-line maintenance/test. This suggests that it is reasonable to assume the same number of maintenance staff.

I&C maintenance workload may be considered to increase because of the adoption of full digital protection and control system, but it is expected to be compensated and more to significantly reduced due to the feature of digital technologies, such as self-diagnoses, automatic test function, elimination of useless test for setpoints, etc.

Similarly the introduction of a gas turbine generator system will impose additional knowledge and skill requirements on maintenance personnel. This impact on maintenance personnel qualifications requirements will be documented in the staffing and qualifications report. However, the gas turbine generator system is simpler in view of components to be maintained than that of diesel generator system. As a consequence this change is not expected to increase the number of staff required in spite of the increase in the number of generators in total.

The discussion above provides examples of US-APWR features that may result in staffing changes. The impact of these features on staffing requirements will be more fully evaluated as part of the staffing and qualifications analysis. The methodology to be used is described in Section 4.4.

Another major change from predecessor plants relates to the application of fully digitalized I&C system and computerized HSI. These are key features of the US-APWR design, and may have impacts on the roles, responsibilities and knowledge and skill requirements, of operations, maintenance and plant surveillance and testing personnel. As a consequence the impact of changes to the I&C and the HSI on staffing levels and qualifications requirements will also be analyzed.

As specified in Section 4.4, the FRA/FA will be reviewed to identify significant changes from predecessor plants that may impact the staffing levels and qualifications. These changes will then be further analyzed using table top analyses and/or simulator studies to determine whether any changes are required to the initial US-APWR staffing level and qualifications assumptions.

4.3.3 Task Analysis

The functions assigned to plant personnel define their roles and responsibilities. Human actions are performed to accomplish these functions. Human actions can be divided into groups. A group of related activities that have a common objective or goal is a task. The

purpose of the TA is to identify requirements for accomplishing these tasks; which in turn specify requirements for the HSI design including display screens, alarms, controls, data processing, operating procedures, and training programs that support the accomplishment of the tasks.

MUAP-09019, Part 2, Section 3 documents the US-APWR task analysis methodology and results for risk important tasks. Additional task analyses are conducted in Phase 2b. Phase 2b task analyses will cover a broader range of representative and important tasks from the areas of operations, maintenance, test, inspection and surveillance and a broader range of operating modes.

The task analyses provide an important input to the staffing and qualifications analysis in that they specify the number and complexity of cognitive and physical activities that are required to perform a task. The results of the task analyses provide the basis for assessing the adequacy of staffing level and qualifications assumptions. As is explained in Section 4.4, task analysis results will be used as input to Table Top analyses that will be conducted to determine whether the assumed staffing levels and qualifications are adequate for safe and efficient plant operation

4.3.4 Human Reliability Analysis

The Human Reliability Analysis (HRA) identifies risk-important human actions (HA) from the PRA/HRA assumptions. It generates probabilistic human reliability estimates for these risk-important human actions, based on assumptions of the quality of HSI and related task support, and assumptions regarding plant staffing and their qualifications. This includes explicit or implicit assumptions regarding the number of personnel and their skill level.

The HRA serves as an important input to the staffing and qualifications analysis. In particular, as specified in Section 4.4.4 Table Top analyses are conducted to confirm the adequacy of staffing and qualifications assumptions which were credited in minimizing the potential for error on risk-important human actions. Factors to be considered include:

- Number of personnel

The number of personnel required to perform actions as specified in the HRA/PRA is determined. Stated or implied assumptions used in the HRA/PRA are identified and potential issues listed. These may include:

- Conflicts between tasks and personnel (simultaneous/parallel tasks or operators using the same controls)
- Workload issues addressing whether tasks can be accomplished within time and performance criteria
- Personnel interactions involving decision making, coordination and feedback within the control room and between the control room and local control stations and support centers.

- Personnel skill level

Information is extracted from the HRA/PRA relative to stated or implied operator capabilities. This parameter usually is reflected in operator designation/qualifications (i.e., SRO, RO, Auxiliary Operator, fire brigade, Emergency Medical) and is used to support an HA being classified as Skill-of-the-craft or justifying the designation of an HA as a memorized action. Training requirements are implicitly reflected in personnel job titles.

Results of the staffing analysis will be used to confirm the adequacy of the staffing assumptions in the HRA.

Results from the SA that are considered to be discrepancies with staffing assumptions in the HRA will result in an HED being generated and entered into the HED data base for resolution

4.3.5 HSI Design

The US-APWR HSIS is designed based on the FRA/FA, TA and SA results. In turn feedback from HSI design activities, including person-in-the-loop evaluations, such as Phase 1a and 1b tests that are reported in MUAP-07007 and MUAP-090919, are used to confirm staffing level and qualifications assumptions as well as to identify potential issues. Considerations include:

- Staffing demands resulting from the locations and use (especially concurrent use) of controls and displays
- Coordinated actions between individuals in the MCR, and staff located at outside of the MCR or temporarily working in the MCR.
- Decreases in the availability or accessibility of information needed by personnel due to plant system and HFE modifications
- Physical configuration of the control room, control consoles and other facilities for operating staff as well as other staff temporarily working in the MCR
- Availability of plant information from individual workstations and group-view interfaces and communication method.

Issues that arise during HSI design related to staffing level or qualifications are entered into the HED database and evaluated and resolved per the standard HED evaluation process described in Part 1, Section 6 of MUAP-09019.

4.3.6 Procedure Development

Staffing level and qualifications assumptions are also used as input to procedure development. The US-APWR procedures assume specific personnel numbers, skills, knowledge, abilities, and authority.

During procedure development, issues may be identified related to staffing levels and qualifications assumptions. For example, requirements for concurrent use of multiple procedures may indicate a need for additional staff. The actions called for in a procedure may require additional knowledge or skills.

Issues that arise during procedure development related to staffing level or qualifications are entered into the HED database and evaluated and resolved per the standard HED evaluation process described in Part 1, Section 6 of MUAP-09019.

4.3.7 Training Program Development

Staffing and qualifications analysis also serves as input to training program development. The US-APWR Training Program is developed based on staffing level assumptions and required qualifications to be acquired and maintained by the plant staffs.

Training program development may identify issues related to staffing or qualifications. For example workload issues may emerge, leading to recommendation for additional staffing. Knowledge, skill or abilities requirements may suggest a need for different staff qualifications.

Issues that arise during training program development related to staffing level or qualifications are entered into the HED database and evaluated and resolved per the standard HED evaluation process described in Part 1, Section 6 of MUAP-09019.

4.4 Methodology for Establishing Adequacy of Staffing Levels and Qualifications

The objective of the staffing level and qualifications analysis is to evaluate the adequacy of the staffing levels and qualifications assumptions in the staffing plan. This includes staffing levels and qualifications assumptions for both operating staff as well as other categories of personnel (e.g., maintenance and test personnel) performing tasks directly related to plant safety. (See Section 4.2.2 for more details). The output of the analysis are documented results establishing that the staffing levels and qualifications in the staffing plan meet performance requirements, and supports safe operation of the plant.

The analysis will employ a combination of methods that include:

- Data from Operational Experience
- Table Top Analysis which employs task analysis tables
- Results of Simulator Studies (e.g., conducted as part of HSI Design Element)

Overview descriptions of these staffing and qualifications analysis methods can be found in NUREG/CR-6838 as well as standard human factors methods handbooks such as Kirwan and Ainsworth (Reference 5-10, 13).

The analysis will be conducted by a multidisciplinary team that includes expertise in:

- US-APWR plant design, including reactor system design, turbine system design, and HSI and I&C design
- Plant operations in a typical U.S. PWR plant across all modes of operation including, outage, startup, low power and normal operation
- Plant maintenance and plant surveillance and testing practice in a typical U.S. PWR plant
- PWR Operator training
- Human Factors

The team makeup will vary depending on the tasks being analyzed. For example, when we analyze I&C tasks, the team will include expertise in system design as well as in maintenance of I&C. Similarly, when analyzing tasks related to pump testing the team will include expertise in mechanical systems design and maintenance.

This multi-disciplinary team (expert panel) will be responsible for supporting:

- (1) Identifying significant differences from predecessor plants that may impact staffing levels and qualifications;
- (2) Identifying representative operations, maintenance, and plant surveillance and testing tasks to be analyzed to evaluate appropriateness of staffing level and qualifications assumptions and determining appropriate analysis method(s);
- (3) Identifying relevant operational experience that can be used to inform evaluation of staffing level and qualifications assumptions for the tasks identified in (2);
- (4) Conducting Table Top Task Analyses to evaluate appropriateness of staffing levels and qualifications assumptions for the tasks identified in (2) for evaluation via Table Top Task Analysis results;
- (5) Recommending modifications to staffing levels and qualifications, if warranted based on staffing and qualifications analysis results.

4.4.1 Identify Significant Differences from Predecessor Plants

The staffing and qualifications analysis begins with the initial US-APWR staffing level and qualifications assumptions. The staffing assumptions for operating staff are explicitly presented in Section 4.2.1. As explained in Section 4.2.2, for non-operating staff, the initial staffing level and qualifications assumptions are based on typical staffing in predecessor plants. Relevant predecessor plants are typical U.S. PWR plants.

The first step in the analysis is to identify significant differences between the US-APWR and predecessor plants in design, staffing or operating practice assumptions. Analyses are then conducted to establish the adequacy of US-APWR staffing assumptions for those cases where significant differences in design, staffing or operating practice are identified.

The criteria for determining whether a difference is 'significant' is whether it has the potential to impact the number, roles, responsibilities, or qualifications of personnel needed to support operations, maintenance or plant surveillance and testing activities relative to number and qualifications of personnel required for corresponding activities in predecessor plants.

An example of a significant difference in plant design is the change from two trains used in predecessor PWR plants to four trains in the US-APWR. This change has the potential to impact operations, maintenance and plant surveillance and testing in that involves twice as many safety related components/valves. This has the potential to impact mental and physical workload during operations as well as during maintenance and plant surveillance and testing.

An example of significant difference in operating practice is the shift from a three-person control room crew (a reactor operator, a balance of plant operator and a supervisor) typical of current PWR plants to a two-person control room crew (an operator responsible for reactor and balance of plant control actions and a supervisor). This redistribution of responsibilities has the potential to impact mental and physical workload during operations.

The interdisciplinary team is responsible for identifying significant differences from predecessor plants in design, staffing, or operating practice assumptions. Identification of significant differences between US-APWR and predecessor plants will primarily be accomplished via review of the FA/FRA report provided in Part 2, Section 1 of MUAP-09019, as well as the description of the US-APWR HSI and philosophy of operation provided in the DCD Chapter 13.

The output of this activity is an itemization of differences between the US-APWR and a typical U.S. PWR plant in plant design, HSI design, I&C design, and operating practice, an indication of which of these differences are considered to be significant from the perspective of impact on staffing numbers, and a justification for that determination (i.e., why a given difference is considered 'significant' or not.) Note that design differences need not be major, in themselves, to impact staffing numbers. Several small differences can also impact the staffing numbers. In combination these would be considered 'significant' from a staffing level perspective and so noted in the analysis results.

4.4.2 Identify Tasks to be Analyzed and Analysis Technique

The next activity is to identify specific operations, maintenance, and plant surveillance and testing activities associated with each of the 'significant differences' from predecessor plants, that need to be evaluated to assess impact, if any, on staffing levels and qualifications. This includes tasks directly related to plant safety across all modes of plant operations including:

- Startup / Shutdown
- Normal operations
- Abnormal and Emergency operations
- Transient conditions

This activity will be led by the interdisciplinary team. The interdisciplinary team will review each 'significant difference' item identified in 4.4.1. For each item they will:

- identify specific, representative, operations, maintenance and plant surveillance and testing activities that could potentially be impacted by this change. This will include representative tasks across all operating modes.
- insure availability of a task analysis for each of these tasks. (These task analyses will be performed as part of the Task Analysis HFE element.)
- specify the appropriate method(s) for evaluating the staffing and qualifications requirements for each task.

In addition to review of items identified as 'significant differences' from predecessor plants, the interdisciplinary team will also review the outputs of OER and HRA HFE elements for additional specific operating, maintenance and/or plant surveillance and testing tasks that need to be included in the staffing and qualifications analysis.

The interdisciplinary team will identify the most appropriate analysis method(s) for each task to be evaluated. There are multiple accepted methods for evaluating the appropriateness of staffing levels and qualifications (see Reference 5-10). Options include review of operating experience data, table top analysis and simulator studies. Factors to be considered in selecting evaluation method(s) include availability of relevant operational experience data; suitability of table top analysis; need for data on cognitive, collaborative, and physical task demands that can only be obtained via walk-through/talk-through exercises using a simulator and/or dynamic person-in-the-loop simulator exercises.

4.4.3 Identify Relevant Operational Experience Data

Operating experience reviews are a common practice within the nuclear industry for identifying issues, comparing performance and assessing best practice, including issues associated with staffing levels and qualifications (see Reference 5-10). Experience from predecessor plants will be drawn on in evaluating US-APWR staffing and qualifications goals. This includes experience from U.S. PWRs as well as experience from Japanese PWR plants.

Since the operating experience review program element for the US-APWR has been completed, the operating experience information will be drawn from the results of this operating experience review element as well as from the personal experiences of the individuals on the multi-disciplinary team.

4.4.4 Conduct Staffing and Qualification Evaluation from Table Top Task Analyses Results

Table top analyses will be conducted to evaluate the appropriateness of staffing and qualifications assumptions (for the tasks designated in 4.4.2 for evaluation by table top analysis).

The Table top analysis will be conducted by the multi-disciplinary team (expert panel), who, as a group, consist of people with expertise in the US-APWR plant, HSI and I&C design and planned operating practice; current staffing levels, qualifications and operating practice in U.S. PWRs.

A group leader will walk the team through each of the tasks, in each case reviewing the results of the task analysis for that task. The team will discuss the task analysis results and determine if the proposed staffing complement is adequate to meet the safety needs for the plant.

The team will review the proposed numbers and types of personnel and the job definitions for each of the positions. The group leader will step the group through the task analysis soliciting more detailed information about personnel tasks and performance. The group may have access to additional data, such as data from operating plant experience (from 4.3.3) to help inform assessments. They may use tools such as Gantt charts to help track timing, personnel usage and workload, during a representative task scenario.

After reviewing the task analysis, the group forms a consensus regarding whether the task can be safely performed with the proposed number and qualifications of personnel. The consensus conclusion, supporting data and rationale are documented in a traceable manner, such that an independent review of the analysis and conclusions can be performed.

The team will recommend modifications to staffing levels and qualifications, if warranted based on the results of the Table Top Task Analysis.

4.4.5 Review Relevant Simulator Study Results

Another source of data supporting a staffing and qualifications analysis is results of simulator studies. The simulator studies can include operator walk-throughs / talk-throughs of task scenarios using a moderate or high fidelity simulator, as well as dynamic person-in-the-loop

exercises using simulator. The dynamic evaluation studies conducted as part of Phase 1a and Phase 1b that are documented in MUAP-08014 and MUAP-09019 provide examples of simulator studies, conducted as part of the HSI design element, that provide data in support of staffing and qualifications analysis. Those studies examined the ability of two-person operator crews to handle a range of representative normal, abnormal and emergency scenarios. Performance measures included both objective outcome measures (e.g., ability to take appropriate control actions; time to take actions), as well as process measures such as situation awareness and workload.

4.5 Results

The Staffing and Qualifications results which are described in Section 4.1 through 4.4 are summarized in a Staffing and Qualifications implementation results summary report. This report will be made available for NRC for review. This report is intended to fulfill the reporting requirements of the Inspections, Tests, Analyses, and Acceptance Criteria defined in Tier 1 of the DCD.

The US-APWR Staffing and Qualifications results summary report will describe:

- Methods and results of the staffing level and qualifications analyses conducted
- Final specification of staffing levels and qualifications for the standard US-APWR plant

5.0 References

- 5-1 Design Control Document for the US-APWR, Chapter 18, Human Factors Engineering, MUAP-DC018 , Revision 3, MHI, March 2011
- 5-2 HSI System Description and HFE Process, MUAP-07007, Revision 4, MHI, July 2011
- 5-3 US-APWR Human System Interface Verification and Validation (Phase1a), MUAP-08014, Revision 1, MHI, May 2011
- 5-4 US-APWR HSI Design, MUAP-09019, Revision 0, MHI, June 2009
- 5-5 US-APWR HSI Design Implementation Plan, MUAP-10009, Revision 0, MHI, April 2010
- 5-6 US-APWR Procedure Development Implementation Plan, MUAP-10010, Revision 0, MHI, April 2010
- 5-7 US-APWR Training Program Development Implementation Plan, MUAP-10011, Revision 0, MHI, April 2010
- 5-8 US-APWR Verification and Validation Implementation Plan, MUAP-10012, Revision 0, MHI, April 2010
- 5-9 HFE Insights For Advanced Reactors Based Upon Operating Experience, NUREG/CR-6400, U.S. Nuclear Regulatory Commission
- 5-10 Technical Basis for Regulatory Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m), NUREG/CR-6838, U.S. Nuclear Regulatory Commission, February 2004
- 5-11 Results of Shift Staffing Study, Information Notice 95-48, U.S. Nuclear Regulatory Commission, 1995
- 5-12 Crediting of Operator Actions in Place of Automatic Actions and Modifications of Operator Actions, Including Response Times, Information Notice 97-78, U.S. Nuclear Regulatory Commission, 1997
- 5-13 A Guide to Task Analysis, Kirwan, B. and Ainsworth, L. K., London, UK: Taylor & Francis, Ltd, 1992
- 5-14 Advanced Light Water Reactor Utility Requirements Document, Volume II, ALWR Evolutionary Plant, Chapter 10, Man-Machine Interface Systems, EPRI, Revision 7, December 1995