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Designer's Input to Determination of the AP600 Main Control Room Staffing Level

Westinghouse Energy Systems

WESTINGHOUSE NON-PROPRIETARY CLASS 3

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Designer's Input to Determination of the AP600 Main Control Room Staffing Level

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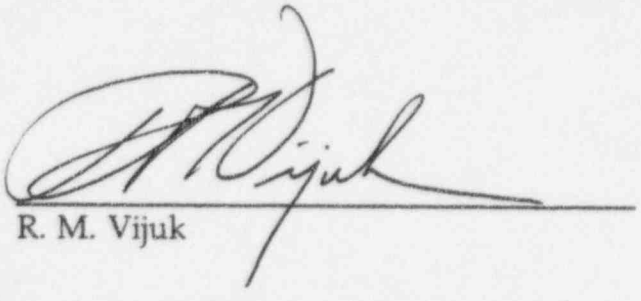
Approved: 

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AP600 RESPONSIBLE MANAGER	**SIGNATURE***	**APPROVAL DATE**
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LIST OF ACRONYMS AND ABBREVIATIONS

COL	Combined License
CPS	Computerized Procedure System
HFE	Human Factors Engineering
HRA	Human Reliability Analysis
HSI	Human System Interface
MCR	Main Control Room
MMIS	Man-Machine Interface System
OER	Operating Experience Review
OSA	Operational Sequence Analysis
PRA	Probabilistic Risk Assessment
PWR	Pressurized Water Reactor
RO	Reactor Operator
SSAR	Standard Safety Analysis Report
STA	Senior Technical Advisor
V&V	Verification and Validation

1 INTRODUCTION

As stated in the AP600 Standard Safety Analysis Report (SSAR) subsection 18.6, plant staffing is a Combined License (COL) applicant responsibility. COL applicants referencing the AP600 design will address the staffing levels and qualifications of plant personnel, including operations, maintenance, engineering, instrumentation and control technicians, radiological protection technicians, security, and chemists. The number of operators needed to directly monitor and control the plant from the main control room (MCR), including the staffing requirements of 10 CFR 50.54(m), will be addressed. The AP600 control room staffing arrangement will be confirmed as adequate. In addition, the roles and responsibilities of the shift supervisor and shift foreman will be addressed.

This document provides input from the designer to the AP600 COL applicant for the determination of the staffing level of the operating crew in the AP600 MCR.

2 INDUSTRY STANDARDS, GUIDELINES, AND PRACTICES

The following documents should be used as guidance to address staffing issues:

- 10 CFR 50.54 U.S. Code of Federal Regulations Part 50, "Conditions of Licenses"
- 10 CFR 50.47 U.S. Code of Federal Regulations Part 50, "Emergency Plans"
- NUREG-0800, "Standard Review Plan," Sections 13.1.2 through 13.1.3, 1984
- NUREG-0654, "Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants," 1980
- Reg Guide 1.114, "Guidance to Operators at the Controls and to Senior Operators in the Control Room of a Nuclear Power Unit," May 1989
- Regulatory Guide 1.8, "Qualification and Training of Personnel for Nuclear Power Plants," Revision 2, April 1987
- NUREG-0711, "Human Factors Engineering Program Review Model," USNRC, July 1994

3 DESIGN GOALS AND DESIGN BASIS FOR STAFFING OF THE MAIN CONTROL ROOM

A design goal for the AP600 MCR and its operating crew is to design the plant and the human system interface (HSI) such that one reactor operator (RO) and one senior RO (the shift foreman) can safely monitor and control the plant under all conditions including normal operation, abnormal events, and accident conditions. In addition, the operating crew will include one control room shift supervisor (senior RO licensed) and two auxiliary equipment operators. During accidents, assistance is available to the operating crew from personnel in the Technical Support Center. The control room shift supervisor will execute the duties and responsibilities of the senior technical advisor (STA) under the assumption that the individual meets the applicable engineering expertise requirements.

The following elements of the AP600 human factors engineering (HFE) design program are used as the basis to help achieve, verify, and validate the design goal stated above:

- Operating Experience Review
- Function Analysis and Allocation
- Task Analysis
- Human Reliability Assessment
- Human System Interface Design
- Procedures
- Training
- Human Factors Engineering/Verification and Validation

3.1 OPERATING EXPERIENCE REVIEW

An input to the HFE design of the AP600 and its advanced HSI is an operating experience review (OER). The objective of this OER is to identify and analyze HFE-related problems and issues encountered in previous designs that are similar to the AP600 so that they are avoided in the AP600, or to retain positive features. The results of the review are used as input to the design process so that adequate consideration is given to these issues. Refer to SSAR subsection 18.3 and WCAP-14645 (Reference 1) for the description and results of the OER conducted for the AP600. The operational problems and strengths of the MCR staffing levels in currently operating Westinghouse pressurized water reactors (PWRs) are identified as part of the OER. These problems and issues need to be addressed by the design of the AP600 HSI to help achieve the MCR operating crew design goal stated in Section 3.0.

3.2 FUNCTIONAL REQUIREMENTS ANALYSIS AND ALLOCATION

The objective of the Functional Requirements Analysis and Allocation is to define the safety functional requirements and to assign function allocations that take advantage of human strengths and avoid allocating functions that would be negatively affected by human limitations. The function allocation process is used to help establish and support the desired MCR staffing level. This process involves determination of which functions are achieved through automation and which functions are allocated to personnel. Preliminary decisions, with respect to system automation, are made by plant designers based on a variety of criteria, including "lessons learned" from operating experience of current Westinghouse PWRs. The role of the HSI designers is to evaluate these function allocation decisions with respect to:

- Achieving maximized human and system performance without placing excessive demands upon the operators

- Determining the "post-conditions" that result from automating a task

When a task is automated, additional human tasks are added, and subsequently, an assessment is made of the operator's ability to accomplish these new tasks. These added human tasks usually deal with issues such as supervisory control of the automated systems. The operator may need to determine whether or not the automatic system made the correct decision, whether or not to switch to "Manual" control from "Automatic" control, and, in the case of automatic protection systems, whether or not the full capability of the system is needed. Refer to SSAR subsection 18.4 and WCAP-14644 (Ref. 2) for a description of the AP600 function allocation process and its results.

Many of the function allocation results are analyzed as part of the Task Analysis, specifically the workload analysis, to help determine the demands placed upon the MCR operators. The function allocation process is part of the iterative process described in Section 4 that determines and confirms the MCR staffing level. In this manner, the task analysis and function allocations are used to help achieve and verify the MCR operating crew design goal and staffing level.

3.3 TASK ANALYSIS

The AP600 Task Analysis has the following objectives:

- Provide one of the bases for HSI design decisions
- Ensure that human performance requirements do not exceed human capabilities

- Provide input to procedure development
- Provide input to staffing, training, and communications requirements of the plant

Task Analysis provides input to the MCR staffing levels by including workload analysis as part of the overall Task Analysis process. During the functional design phase of the HSI, a workload analysis (Operations Sequence Analysis [OSA-2]) is performed to establish that the HSI design adequately supports operator performance for important operator tasks. OSA employs Man-In-The-Loop tests of rapid prototypes of the HSI, as well as analytic techniques to establish that operators are able to accomplish important task sequences within the available time. The workload analysis is performed for a subset of the tasks used in the first OSA, including tasks identified to be time critical and tasks identified to be critical human actions or risk important. The objective of the workload analysis is to provide an early verification that the control room HSI adequately supports operator performance. In cases where the workload analysis indicates a task with high operator workload values, or insufficient time available for performance, alternative staffing assumptions, changes to the HSI design, or function allocation to reduce operator workload are evaluated. For additional information regarding Task Analysis, including workload analysis, refer to SSAR subsection 18.5.

3.4 HUMAN RELIABILITY ANALYSIS

The Human Reliability Analysis (HRA) evaluates the potential for and mechanisms of human error that may affect plant safety. The design of the HSI is an important contributor to human reliability. The goal is to design the HSI to minimize the potential for human error and to provide for error detection and recovery capability, particularly for any critical human actions and risk-important tasks.

The AP600 design draws on lessons learned from existing plant experience and the results of past HRAs and probabilistic risk assessments (PRAs) to reduce the potential for human error. One approach to increase human reliability in the AP600 is to simplify the plant design and reduce the number of human actions required.

Integration of HRA activities within the HSI design process is accomplished by:

- Task Analysis - Results of HRAs/PRAs are used to identify critical human actions and risk-important tasks as input to task analysis activities. Critical actions and risk-important tasks are examined using operational sequence task analyses, including workload analysis.

- HSI Design and Procedure Development - Results of man-machine interface system (MMIS)/HSI design and procedure development activities will be used to

confirm or refine HRA assumptions. Tasks that are identified in the HRA/PRA that pose challenges to plant safety and reliability will be reexamined by task analysis, HSI design, and procedure development, to identify changes to the operator task or the control and display environment to reduce or eliminate sources of error.

- HFE/Verification and Validation (V&V) - HRA performance assumptions (actions to be performed; time within which they are completed) will be validated as part of the HFE Integrated System Validation.

The HRA/HFE integration/implementation plan is discussed in SSAR subsection 18.7 and WCAP-14651 (Ref. 3).

3.5 HUMAN SYSTEM INTERFACE DESIGN

The HSI includes design of the operations and control centers, and HSI subsystems intended to support personnel performance. Activities performed as part of the functional design phase include development of rapid prototypes and mockups, Man-In-The-Loop testing, and development of guidelines documents.

An important element of the HSI design process is the conduct of Man-In-The-Loop concept tests used to establish the adequacy of HSI design concepts. One objective of the Man-In-The-Loop testing is to establish that the MCR staffing level, and the HSI and MCR functional design is adequate to support operator performance in the range of activities and situations that are anticipated to arise.

A full-scale mockup of the MCR working area, including main control consoles (workstations) and the wall panel display, is constructed. The mockup is constructed to the required anthropometric profiles and arranged in the floor layout intended for the AP600 plant MCR. The mockup is primarily used to verify physical layout aspects such as availability of workspace, physical access, visibility, and related anthropometric and HFE issues. It is also used for walk-through exercises to examine issues such as staffing levels, task allocation, and procedure usage.

For additional information on the HSI/MMIS design, refer to SSAR subsection 18.8.

3.6 PROCEDURES

The Computerized Procedure System (CPS) is an HSI/MMIS resource that provides the interface for the operators to execute procedures. The CPS helps achieve the staffing goal for the MCR by reducing the mental burden and workload of the operators. This is accomplished by reducing the number of parallel activities performed by the operators. For

example, when a procedure requires the operator to execute a specific action only after the plant reaches a given state, the CPS monitors and alerts the operator when the plant state exists. This frees the operator from the burden of monitoring for this state, in parallel with performing further steps in the procedure. For additional information on the Procedure Development and the CPS, refer to SSAR subsection 18.8, 18.9, and WCAP-14690 (Ref. 4).

3.7 TRAINING

Training program development is the responsibility of the COL applicant as stated in subsection 13.2 of the SSAR. Refer to SSAR subsection 18.10 and WCAP-14655 (Ref. 5) for a discussion of the Training Program Development.

3.8 HUMAN FACTORS ENGINEERING/VERIFICATION AND VALIDATION

As described in SSAR subsection 18.11 and WCAP-14401 (Ref. 6), an HFE/V&V is part of the HFE design process. The Integrated System (HSI/M-MIS) Validation, conducted as part of the HFE/V&V, includes the following evaluations:

- Establish the adequacy of the integrated MMIS for achieving HFE program goals
- Confirm allocation of function and the structure of tasks assigned to personnel
- Establish the adequacy of MCR staffing levels and the adequacy of the MMIS to support the staff in accomplishing their tasks
- Validate the emergency operating procedures
- Confirm the dynamic aspects of the MMIS for task accomplishment
- Evaluate and demonstrate error tolerance to human and system failures

If it is determined from the integrated validation testing that the MCR staffing and HSI design goals are not achieved, a decision is made to either redesign the appropriate system (such as HSI, instrumentation and control system, fluid systems) or modify the proposed MCR staffing.

4 NUMBER AND QUALIFICATIONS OF PERSONNEL

As stated in Section 3 of this document, a design goal of the AP600 MCR and its operating crew is to design the plant and the HSI such that one RO and one senior RO (shift foreman) can safely monitor and control the plant under all plant conditions, including normal operation, abnormal events, and accident conditions. In addition, the operating crew will include one control room shift supervisor (senior RO, licensed) and two auxiliary equipment operators. During accidents, assistance is available to the operating crew from personnel in the Technical Support Center. Refer to AP600 SSAR subsections 16.1.5.1 and 16.1.5.2 for the organization and responsibilities of the unit management and staff. The elements of the HFE design process, as described in Section 3 of this document, are used to achieve, verify, and validate this design goal.

Potential iterations to the MCR staffing level occur during or following the HFE program elements listed below:

- The qualitative workload analysis conducted as part of the Task Analysis
- The quantitative workload analyses conducted as part of the Man-In-The-Loop concept test phase of the HSI design
- The integrated system validation conducted as part of the HFE/V&V

An alternative to iterating the staffing level is to appropriately modify the system design (HSI, instrumentation and control systems, or fluid systems) or the function allocation in order to achieve the staffing level initially assumed. The COL applicant will address the number of operators needed to directly monitor and control the plant from the MCR, including the staffing requirements of 10 CFR 50.54(m).

Refer to AP600 SSAR subsection 16.1.5.3 for the qualifications of unit staff personnel.

5 REFERENCES

1. WCAP-14645, "Human Factors Engineering Operating Experience Review Report for the AP600 Nuclear Power Plant"

2. WCAP-14644, "AP600 Functional Requirements Analysis and Functional Allocation"

3. WCAP-14651, "Integration of Human Reliability Analysis with Human Factors Engineering Design Implementation Plan"

4. WCAP-14690, "Designer's Input to Procedure Development for the AP600"

5. WCAP-14655, "Designer's Input for the Training of the Human Factors Engineering Verification and Validation Personnel"

6. WCAP-14401, "Programmatic Level Description of the AP600 Human Factors Verification and Validation Plan"