GE Nuclear Energy

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Standardization Project Directorate
Associate Directorate for Advanced Reactors
and License Renewal
Office of the Nuclear Reactor Regulation

Subject: Submittal Supporting Accelerated ABWR Review Schedule - **DFSER Chapter 18 Outstanding Items**

Dear Chet:

Enclosed are markups addressing DFSER: Confirmatory Item 18.5.2.1-1; and COL Action Items 18.2.2.2-1, 18.2.2.2-2, 18.2.2.2-3, 18.3.2.2-1, 18.3.3-1, 18.6-1, 18.7.2.2-1, 18.7.2.2-4, 18.7.2.2-5 and 18.9.2.2.8-1. In addition, the enclosure provides selected updates of SSAR Chapter 18.

My letter dated April 7, 1993 transmitted clean markups of the HFE Tier 1 information and the new SSAR Appendix 18E without identifying the corresponding outstanding items. Based on GE/NRC Human Factors Assessment Branch discussions, the April 7, 1993 transmittal addresses DFSER: Confirmatory Items 18.3.2.1-1, 18.3.2.2-2, 18.9.2.2.1-1, 18.9.2.2.5-1, 18.9.2.2.6-2, 18.9.2.2.6-3, 18.9.2.2.7-1, 18.9.2.2.8-3, 18.9.2.2.8-4 and 18.9.2.2.8-5; and COL Action Items 18.7.2.2-1, 18.7.2.2-2, 18.7.2.2-3, 18.7.2.2-6 and 18.7.2.2-7.

Please provide a copy of this transmittal to Clare Goodman.

Sincerely,

Jack Fox

Jack Fox
Advanced Reactor Programs

cc: Norman Fletcher (DOE)
Keith Gregoire (GE)

JF93-84

CHAPTER 18

TABLE OF CONTENTS

Section	Title	Page
18.1	INTRODUCTION	18.1-1
18.2	DESIGN GOALS AND DESIGN BASES	18.2-1
18.3	PLANNING, DEVELOPMENT AND DESIGN	18.3-1
18.3.1	Introduction	18.3-1
18.3.2	Standard Design Features	18.3-2
18.3.3	Inventory of Controls and Instrumentation	18.3-3
18.3.4	Detailed Design Implementation Process	18.3-4
18.4	CONTROL ROOM STANDARD DESIGN FEATURES	18.4-1
18.4.1	Introduction	18.4-1
18.4.2	Standard Design Features	18.4-1
18.4.3	Control Room HSI Technology	18.4-7
18.5	REMOTE SHUTDOWN SYSTEM	18.5-1
18.6	SYSTEMS INTEGRATION	18.6-1
18.6.1	Safety Systems	18.6-1
18.6.2	Non-Safety Systems	18.6-1
18.7	DETAILED DESIGN OF THE OPERATOR INTERFACE SYSTEM	18.7-1
APPENDIX 18A	EMERGENCY PROCEDURE GUIDELINES	
APPENDIX 18B	DIFFERENCES BETWEEN BWROG EPG REVISION 4 AND ABWR EMERGENCY PROCEDURE GUIDELINES	
APPENDIX 18C	OPERATOR INTERFACE EQUIPMENT CHARACTERIZATION	
18.8	COL LICENSE INFORMATION	

18.1 INTRODUCTION

This chapter describes the human-system interface system (HSI) design development, the HSI design goals and bases, the standard HSI design features and the detailed HSI design and implementation process, with embedded design acceptance criteria, for the ABWR standard plant. The ABWR Emergency Procedure Guidelines and the inventory of instrumentation and controls needed by the control room staff for the performance of emergency operating procedures are also described. The incorporation of human factors engineering principles into all phases of the design of these interfaces is provided for as described in this chapter.

Design goals and design bases for the HSI in the main control room and in remote locations are established in Section 18.2. The overall design and implementation approach is described in Section 18.3. Section 18.4 contains a description of the main control room standard HSI design features. The remote shutdown system is described in Section 18.5. Section 18.6 discusses how the systems which make up the HSI are integrated together and with the other systems of the plant. Section 18.7 discusses the detailed design implementation process. The ABWR Emergency Procedure Guidelines, which provide the basis for a human factors evaluation of emergency operations, are contained in Appendix 18A. Appendix 18B discusses the differences between the ABWR Emergency Procedure Guidelines and the U.S. BWROG Emergency Procedure Guidelines, Revision 4. Appendix 18C presents a characterization of a main control room HSI equipment implementation that incorporates the ABWR standard design features discussed in Section 18.4. The input data and results of calculations performed during the preparation of the ABWR Emergency Procedure Guidelines are contained in Appendix 18D. A general description of the design and implementation process for the ABWR HSI [redacted] is presented in Appendix 18E. Appendix 18F contains the results of an analysis of information and control needs of the main control room operators during [redacted] emergency operations. The design development and validation testing of the main control room equipment and configuration are described in Appendix 18G.

18.2 DESIGN GOALS AND DESIGN BASES

The primary goal for HSI designs is to facilitate safe, efficient and reliable operator performance during all phases of normal plant operation, abnormal events and accident conditions. To achieve this goal, information displays, controls and other interface devices in the control room and other plant areas are designed and implemented in a manner consistent with good human factors engineering practices. Further, the following specific design bases are adopted:

1. During all phases of normal plant operation, abnormal events and emergency conditions, the ABWR shall be operable by two reactor operators. In addition, the operating crew will include one assistant control room shift supervisor, one control room shift supervisor, and two or more auxiliary equipment operators. During accidents, assistance is available to the operating crew from personnel in the Technical Support Center. Four licensed operators shall be on shift at all times, consistent with the staffing requirements of 10CFR50.54m. See subsection 18.8.1 for COL license information requirements

   The HSI design will promote efficient and reliable operation through application of automated operation capabilities,

3. The HSI design shall utilize only proven technology,

4. Safety-related systems monitoring displays and control capability shall be provided in full compliance with pertinent regulations regarding electrical separation and independence,

5. The HSI design shall be highly reliable and provide functional redundancy such that sufficient displays and control will be available in the main control room and remote locations to conduct an orderly reactor shutdown and to cool the reactor to cold shutdown conditions, even during design basis equipment failures,

6. The principle functions of the Safety Parameter Display System (SPDS) as required by Supplement 1 to NUREG-0737, will be integrated into the HSI design,

7. Accepted human factors engineering principles shall be utilized for the HSI design in meeting the relevant requirements of General Design Criterion 19, and

8. The design bases for the Remote Shutdown System shall be as specified in Section 7.4.

18.3 PLANNING, DEVELOPMENT AND DESIGN

18.3.1 Introduction

An integrated program plan to incorporate human factors engineering principles and to achieve an integrated design of the control and instrumentation systems and HSI of the ABWR was prepared and implemented. The program plan presents formal decision analysis procedures to facilitate selection of design features which satisfy top level requirements and goals of individual systems and the overall plant. Also included is a comprehensive, synergistic design approach with provisions for task analyses and human factors evaluations.

Specific procedures developed as parts of the implementation of the program plan are:

a. Implementation Procedure for Development of System Functional and Performance Requirements,

b. Implementation Procedure for Analysis of Tasks and Allocation of Functions,

c. Implementation Procedure for Evaluation of Human Factors and Human-Machine Interfaces,

d. Implementation Procedure for the Design of Hardware and Software, and

e. Implementation Procedure for the Verification and Validation of Hardware and Software.

The program plan and the associated procedures provided guidance for the conduct of the ABWR HSI design development activities including:

a. Definition of the standard design features of the control room HSI (see Subsections 18.3.2 and 18.4.2),

b. Definition of the inventory of controls and instrumentation necessary for the control room crew to follow the operation strategies given in the ABWR Emergency Procedure Guidelines and to complete the important operator actions described in the Probabilistic Risk Assessment (see Subsection 18.3.3 and Appendix 18F).

18.3.2 Standard Design Features

The ABWR control room HSI design contains a group of standard or basic features which form the foundation for the detailed HSI design. These features are described in Subsection 18.4.2.

The development and testing of the control room HSI standard design features was accomplished under a program which is described in Appendix 18G. This development program included consideration of existing control room operating experience; a review of trends in control room designs and existing control room data presentation methods; evaluation of new HSI technologies, alarm reduction and presentation methods; and validation testing of two full-scale prototypes. The prototypes were evaluated using test scenarios especially developed for the purpose and utilizing experienced nuclear plant control room operators. Following the completion of the prototype tests and employing their results, the basic control room HSI standard design feature were finalized.

18.3.3 Inventory of Controls and Instrumentation

The ABWR Emergency Procedure Guidelines (EPGs), presented in Appendix 18A, and the important operator actions identified in the Probabilistic Risk Assessment (PRA), presented in Chapter 19, provided the bases for an analysis of the information and control capability needs of the main control room operators based upon the operation strategies. This analysis defines a minimum set of fixed displays and a minimum set of controls which will enable the operating crew to perform the actions that would be specified in the emergency operating procedures. Appendix 18F contains the tabulated results of this analysis. Tables 18F-1 through 18F-11, ~~Appendix 18F~~, contain detailed descriptions of the steps of the EPGs and the information, alarms and controls needed by the operators to perform and validate the completion of those steps. ~~Table 18F-12 contains the same type of information for the important operator actions identified in the PRA.~~

Another set of three tables in Appendix 18F provide convenient summaries of the control, display and alarm listings developed in the previous tables. These latter tables are numbered 18F-12-1, 2 and 3, respectively. The listings in Tables 18F-12-1 through 3 are an inventory of the controls, displays and alarms which define the minimum control, information and alarm requirements on any ABWR control room design implementation.

18.3.4 Detailed Design Implementation Process

Finally, Table 18F-13 contains a list of the minimum set of controls, displays and alarms which are required to perform the operational strategies of the ABWR EPGs assuming that the first control action of each EPG step is successful. This list is a subset of the lists contained in Tables 18F-12-1, 2 and 3

18.4 CONTROL ROOM STANDARD DESIGN FEATURES

18.4.1 Introduction

This section presents, in Subsection 18.4.2, the standard design features of the HSI in the control room. These basic design features are based upon proven technologies and have been demonstrated, through broad scope control room dynamic simulation tests and evaluation, to satisfy the ABWR operator interface design goals and design bases as given in Section 18.2. The specific technologies utilized in the main control room HSI are listed in Subsection 18.4.3. Appendix 18C presents an example of a control room HSI design implementation which incorporates these design features. Validation of the implemented main control room design will include evaluation of the standard design features and will be performed as part of the design implementation process as defined by the acceptance criteria presented in Tables 18E.2-1 through 18E.2-4.

18.4.2 Standard Design Feature Descriptions

18.4.2.1 Listing of Features

The ABWR control room HSI design incorporates the following standard features:

a. A single, integrated control console staffed by two operators; the console has a low profile such that the operators can see over the console from a seated position.

b. The use of plant process computer system driven on-screen control video display units (VDUs) for safety system monitoring and non-safety system control and monitoring.

c. The use of a separate set of on-screen control VDUs for safety system control and monitoring and a separate on-screen control VDUs for non-safety system control and monitoring; the operation of these two sets of VDUs is entirely independent of the process computer system. Further, the first set of VDUs and all equipment associated with their functions of safety system control and monitoring are divisionally separate and qualified to Class 1-E standards.

d. The use of dedicated function switches on the control console.

e. Operator selectable automation of pre-defined plant operation sequences.

f. The incorporation of an operator selectable semi-automated mode of plant operations, which provide procedural guidance on the control console VDUs.

g. The capability to conduct all plant operations in an operator manual mode.

h. The incorporation of a large display panel which presents information for use by the entire control room operating staff.

i. The inclusion on the large display panel of fixed-position displays of key plant parameters and major equipment status.

j. The inclusion in the fixed-position displays of both 1E-qualified and non-1E display elements.

k. The independence of the fixed-position displays from the plant process computer.

l. The inclusion within the large display panel of a large video display unit which is driven by the plant process computer system.

m. The incorporation of a "monitoring only" supervisor's console which includes VDUs on which display formats available to the operators on the main control console are also available to the supervisors.

n The incorporation of the safety parameter display system (SPDS) function as part of the plant status summary information which is continuously displayed on the fixed-position displays on the large display panel.

o. The use of fixed-position alarm tiles on the large display panel.

p. The application of alarm processing logic to prioritize alarm indications and to filter unnecessary alarms.

q. A spatial arrangement between the large display panel, the main control console and the shift supervisors' console which allows the entire control room operating crew to conveniently view the information presented on the large display panel.

See Subsection 18.8.4 for COL license information requirements.

operations, manual scram and reactor operating mode changes.

18.4.2.6 Automation Design

The ABWR incorporates selected automation of the operations required during a normal plant startup/shutdown and during normal power range maneuvers. Subsection 7.7.1.5 describes Power Generation Control (PGC) which is the primary ABWR system for providing the automation features for normal ABWR plant operations.

18.4.2.6.1 Automatic Operation

When placed in automatic mode, the PGC performs sequences of automated plant operations by sending mode change commands and setpoint changes to lower-level, non-safety related plant system controllers. The PGC cannot directly change the status of a safety-related system. When a change in the status of a safety-related system is required to complete the selected operation sequence, the PGC provides prompts to guide the operator in manually performing the change using the appropriate safety-related HSI controls provided on the main control console.

The operator can stop an automatic operation at any time. The PGC logic also monitors plant status, and will automatically revert to manual operating mode when a major change in plant status occurs (e.g., reactor scram or turbine trip). When such abnormal plant conditions occur, PGC automatic operation is suspended and the logic in the individual plant systems and equipment directs the automatic response to the plant conditions. Similarly, in the event that the operational status of the PGC or interfacing systems changes (e.g., equipment failures), operation reverts to manual operating mode. When conditions permit, the operator may manually re-initiate PGC automatic operation.

18.4.2.6.2 Semi-Automated Operation

The PGC also includes a semi-automatic operational mode which provides automatic operator guidance for accomplishing the desired normal changes in plant status; however, in this mode, the PGC performs no control actions. The operator must activate all necessary system and equipment controls for the semi-automatic sequence to proceed. The PGC monitors the plant status during the semi-automatic mode in order to check the progression of the semi-automatic sequence and to determine the appropriate operator guidance to be activated.

18.4.2.6.3 Manual Operation

The manual mode of operation in the ABWR corresponds to the manual operations of conventional BWR designs in which the operator determines and executes the appropriate plant control actions without the benefit of computer-based operator aids. The manual mode provides a default operating mode in the event of an abnormal condition in the plant. The operator can completely stop an automated operation at any time by simply selecting the manual operating mode. The PGC logic will also automatically revert to manual mode when abnormal conditions occur.

18.4.2.7 Large Display Panel

The large display panel provides information on overall plant status with real-time data during all phases of plant operation. The information on the large display panel can be viewed from the main control consol and the supervisors' console. The large display panel includes fixed-position displays (see Subsection 18.4.2.8), a variable display (see Subsection 18.4.2.9) and spatially dedicated alarm windows (see Subsection 18.4.2.12).

18.4.2.8 Fixed-Position Display

The fixed-position portion of the large display panel provides key plant information for viewing by the entire control room staff. The dynamic display elements of the fixed-position displays are driven by dedicated microprocessor-based controllers which are independent of the plant process computer system.

Those portions of the large display panel which present safety-related information are qualified to Class 1E standards.

The information presented in the fixed-position displays includes the critical plant parameter information, as defined by the SPDS requirements of NUREG-0737, Supplement 1, and the Type A post-accident monitoring (PAM) instrumentation required by Regulation Guide 1.97, Revision 3 (refer to Section 18.4.2.11 for a discussion of the SPDS and to Section 7.5 for a discussion of the PAM variables).

18.4.2.9 Large Variable Display

The large variable display which is included on the large display panel is a VDU which is driven by the plant process computer system. Any screen format resident in the process computer system can be shown on this large variable display.

18.4.2.10 Supervisors' Console

See Subsection 18.8.9 for COL license information requirements.

See Subsection 18.8.2 and 18.8.10 for COL license information requirements

A console is provided for the control room supervisors which is equipped with VDUs on which any screen format resident in the process computer system and available to the operators at the main control console is also available to the shift supervisor. The location of this console in the control room is discussed in Subsection 18.4.2.15.

18.4.2.11 SPDS

NUREG–0737 provided guidance for implementing Three Mile Island (TMI) action items. NUREG–0737, Supplement 1, clarifies the TMI action items related to emergency response capability, including item I.D.2, "Safety Parameter Display System" (SPDS). The principal purpose of the the SPDS is to aid control room personnel during abnormal and emergency conditions in determining the safety status of the plant and in assessing whether abnormal conditions warrant corrective action by operators to prevent core damage. During emergencies, the SPDS serves as an aid in evaluating the current safety status of the plant, in executing symptom–based emergency operating procedures, and in monitoring the impact of engineered safeguards or mitigation activities. The SPDS also operates during normal operation, continuously displaying information from which the plant safety status can be readily and reliably assessed. The ABWR does not provide a separate SPDS, but rather, the principal functions of the SPDS (as required by NUREG–0737, Supplement 1) are integrated into the overall control room display capabilities. Displays of critical plant variables sufficient to provide information to plant operators about the following critical safety functions are provided on the large display panel as an integral part of the fixed-position displays:

1. Reactivity control,
2. Reactor core cooling and heat removal from the primary system,
3. Reactor coolant system integrity,
4. Radioactivity control, and
5. Containment conditions.

Displays to assist the plant operator in execution of symptom–based emergency operating procedures are available at the main control console VDUs. Examples of these VDU displays are trend plots and operator guidance. Information regarding entry conditions to the symptomatic emergency procedures is provided through the fixed-position display of the critical plant parameters on the large display panel. The critical plant parameters on the large display panel are also viewable from the control room supervisors' monitoring station. The supplemental SPDS displays on the VDUs on the main control console are also accessible at the control room supervisors' monitoring station and may be provided in the technical support center (TSC) and, optionally, in the emergency operations facility (EOF), which are the responsibility of the applicant referencing the ABWR design to provide.

Entry conditions to the symptomatic EOPs are annunciated on the dedicated hardware alarm windows on the large display panel. The large display panel also displays the containment isolation status, safety systems status, and the following critical parameters:

1. RPV pressure,
2. RPV water level,
3. Core neutron flux (startup range and power range instruments),
4. Suppression pool temperature,
5. Suppression pool water level,
6. Drywell temperature,
7. Drywell pressure,
8. Drywell water level,
9. Control rod scram status,
10. Primary containment oxygen concentration,
11. Primary containment hydrogen concentration (when monitors are in operation),
12. Containment radiation levels.

The oxygen monitoring instrumentation system is normally in continuous operation and hence the large display panel also includes continuous fixed-position display of wetwell and drywell oxygen concentrations. The hydrogen monitoring instrumentation is automatically started on a LOCA signal and hence continuous display is not required. Additional post accident monitoring parameters, such as effluent stack radioactivity release (Refer to Section 7.5 for a list of post accident monitoring parameters), may be displayed at the large variable display or at the main control console VDUs on demand by the operator.

The SPDS is required to be designed so that the displayed information can be readily perceived and comprehended by the control room operating crew. Compliance with this requirement is assured because of the incorporation of accepted human factors engineering principles into the overall control room design implementation process (Refer to Subsection 18.7 for a discussion of the design implementation process).

~~All of the continuously displayed information necessary to satisfy the requirements for the SPDS, as defined in NUREG-0737, Supplement 1, is included in the fixed-position displays listed in Table 18F-13.1. Table 18F-13.1 also includes other displays, beyond those required for the SPDS.~~

Selection of the parameters for inclusion in the SPDS display is based upon the ABWR Emergency Procedure Guidelines (Appendix 18A)

See Subsections 18.8.3 and 18.8.8 for COL license information requirements.

18.5 REMOTE SHUTDOWN SYSTEM

The remote shutdown system (RSS) provides a means to safely shutdown the plant from outside the main control room. It provides control of the plant systems needed to bring the plant to hot shutdown, with the subsequent capability to attain cold shutdown, in the event that the control room becomes uninhabitable.

The RSS system design is described in Subsections 7.4.1.4 and 7.4.2.4. All of the controls and instrumentation required for RSS operation are identified in Subsection 7.4.1.4.4 and in Figure 7.4-2.

The RSS uses conventional, hardwired controls and indicators to maintain diversity from the main control room. These dedicated devices are arranged in a mimic of the interfacing systems process loops.

See Subsection 18.8.5 for COL license information requirements.

18.7 DETAILED DESIGN OF THE OPERATOR INTERFACE SYSTEM

The standard design features of the ABWR main control room HSI, discussed in Subsection 18.4.2, provide the framework for the detailed equipment hardware and software designs that will be developed following a design and implementation process described in Appendix 18E. This process is made up of eight major elements and illustrated in Figure 18E.1-1.

As part of the Appendix 18E discussion of the HSI design and implementation process, detailed acceptance criteria are specified that shall be used to govern and direct all ABWR HSI design implementations which reference the Certified Design. These detailed acceptance criteria, presented in Section 18E.2 of Appendix 18E, encompass the set of necessary and sufficient design implementation related activities required to maintain the implemented HSI design in compliance with accepted human factors principles and accepted digital electronics equipment and software development methods.

As part of the detailed design implementation process described in Appendix 18E, operator task analyses will be performed as a basis for evaluating details of the design implementation and HSI requirements will be specified. These HSI requirements will include the instrumentation and controls listed in Tables 18F-13.1 through 3 as a subset. The evaluation of the integrated control room design will include the confirmation of the ABWR main control room standard design features.

18..8 COL LICENSE INFORMATION

18.8.1 Number of Operators Needing Controls Access

COL ACTION ITEM #18.2.2.2-1, 18.2.2.2-2

The number of operators needing access to the controls on the main control panel shall be evaluated and the ABWR control room staffing arrangement (see Subsection 18.2, Item 1) shall be confirmed as adequate.

18.8.2 Automation Strategies and Their Effect on Operator Reliability

COL ACTION ITEM #18.2.2.2-3

Automation strategies for plant operation shall be evaluated for effects on operator reliability and the appropriateness of the ABWR automation design (see Subsection 18,4.2.6.1) shall be confirmed.

18.8.3 SPDS Design Conformance With NUREG-0737, Supplement 1

COL ACTION ITEM #18.3.2.2-1

The SPDS design (see Subsection 18.4.2.11) shall be evaluated against the criteria of Section 3.8a of NUREG-0737, Supplement 1, and confirmed to be in compliance wit i these criteria.

18.8.4 Standard Design Features Design Validation

COL ACTION ITEM #18.3.3-1

The design of each of the main control room standard design features (see Subsection 18.2.4) shall be validated using the applicable criteria in Table 18E.2.1.VIII.

18.8.5 Remote Shutdown System Design Evaluation

CONFIRM. ISSUE #18.5.2.1-1

Digital versus analog design approaches for the Remote Shutdown System (RSS) shall be evaluated for reliability and the adequacy of the ABWR RSS design (see Section 18.5) shall be confirmed

18.8.6 Local Valve Position Indication

COL ACTION ITEM #18.6-1

The necessity for providing local valve position indication (VPI) for each valve in any of the following categories shall be evaluated:

1. All power-operated valves (e.g., motor, hydraulic and pneumatic),

2. All large manual valves (i.e., 5 cm or larger),

3. Small manual valves (i.e., less than 5 cm) which are important to safe plant operations.

These evaluation records shall be placed in the HFE Issue Tracking System (see Subsection II.2.of Table 18E.2.2.1).

18.8.7 Operator Training

COL ACTION ITEM #18.7.2.2-1

An operator training program which meets the requirements of 10 CFR Part 50 shall be established (see Subsection II.1.c of Table 18E.2.2.1).

18.8.8 SPDS Availability

COL ACTION ITEM #18.7.2.2-4

The COL applicant shall address NUREG-0933, Item 125.I.3, "SPDS Availability" as part of the detailed design implementation process (see Subsection 18.4.2.11).

18.8.9 Safety System Status Monitoring

COL ACTION ITEM #18.7.2.2-5

The COL applicant shall address the human factors aspects of TMI Item I.E.3, "Safety System Status Monitoring" as part of the detailed design implementation process (see Subsection 18.4.2.8).

18.8.10 PGCS Malfunctions

COL ACTION ITEM #18.9.2.2.8-1

As part of the verification and validation effort, the COL applicant shall consider malfunctions of the Power Generation Control function of the process computer system (see Subsection 18.4.2.6.1).