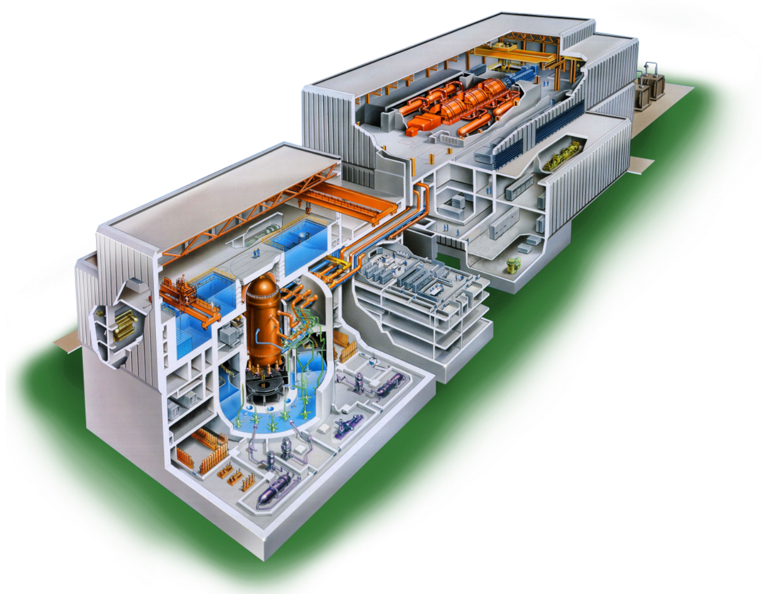
GE Hitachi Nuclear Energy

25A5675AW
Revision 7
October 2019

ABWR
Design Control Document
Tier 2



Chapter 18
Human Factors Engineering

Chapter 18
Table of Contents

Table of Contents (Continued)

Chapter 18
List of Tables

Chapter 18
List of Figures

18.0 Human Factors Engineering

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. 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 (HFE) 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 and HSI technologies. 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. Section 18.8 discusses the HFE related COL license information requirement. 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 is presented in Appendix 18E. Appendix 18F contains the results of the requirements for an analysis of information and control needs of the standard control room operators during emergency operations. The design development and validation testing of the standard control room design features 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 HFE 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 10CFR50.54(m). The main control room staff size and roles shall be evaluated by the COL applicant (Subsection 18.8.2).

(2) 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 HFE principles shall be utilized for the HSI design in meeting the relevant requirements of General Design Criterion 19.

(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 HFE 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 part of the implementation of the program plan are:

(1) Implementation Procedure for Development of System Functional and Performance Requirements

(2) Implementation Procedure for Analysis of Tasks and Allocation of Functions

(3) Implementation Procedure for Evaluation of Human Factors and Human-Machine Interfaces

(4) Implementation Procedure for the Design of Hardware and Software

(5) 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:

(1) Definition of the standard design features of the control room HSI (Subsections 18.3.2 and 18.4.2)

(2) 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 (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 (1) consideration of existing control room operating experience; (2) a review of trends in control room designs and existing control room data presentation methods; (3)

evaluation of new HSI technologies, alarm reduction and presentation methods; and (4) validation testing of two full-scale prototypes. The prototypes were evaluated using test scenarios especially developed for the purpose of 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 features 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 controls, displays, and alarms which will enable the operating crew to perform the actions that would be specified in the emergency operating procedures and the important operator actions identified in the PRA. Appendix 18F contains the tabulated results of this analysis. The controls, displays and alarms needed by the operators to perform and validate the completion of those steps and important actions are listed in Tables 18F-1 through 18F-3, respectively.

18.3.4 Detailed Design Implementation Process

The process by which the detailed equipment design implementation of the ABWR HSI will be completed is discussed in Section 18.7 and in Appendix 18E. This process builds upon the standard HSI design features and design technologies which are discussed in Subsection 18.4.2 and 18.4.3, respectively. Embedded in the process, (Figure 18E- 1) are a number of NRC conformance reviews in which various aspects and outputs of the process are evaluated against the established acceptance criteria presented in Tables 18E-1 through 18E-4.

18.4 Control Room Standard Design Features

18.4.1 Introduction

This section presents the standard design features of the HSI in the control room (Subsection 18.4.2). 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 MCR 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-1 through 18E-4. See Subsection 18.8.5 for COL license information requirements.

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:

(1) 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.

(2) 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.

(3) The use of a separate set of on-screen control VDUs for safety system control and monitoring and 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 1E standards.

(4) The use of dedicated function switches on the control console.

(5) Operator selectable automation of predefined plant operation sequences.

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

(7) The capability to conduct all plant operations in an operator manual mode.

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

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

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

(11) The independence of the fixed-position displays from the plant process computer.

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

(13) 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.

(14) 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.

(15) The use of fixed-position alarm tiles on the large display panel.

(16) The application of alarm processing logic to prioritize alarm indications and to filter unnecessary alarms.

(17) 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 Class 1E large display panel.

(18) The use of VDUs to provide alarm information in addition to the alarm information provided via the fixed-position alarm tiles on the large display panel.

Validation of the design of each of the main control room standard design features is a COL license information requirement (Subsection 18.8.5).

The remainder of this subsection provides further descriptions of these standard design features.

18.4.2.2 Main Control Console

The main control console comprises the work stations for the two control room plant operators. It is configured such that each operator is provided with controls and monitoring information necessary to perform their assigned tasks and allows the operators to view all of the displays on the large display panel (Subsection 18.4.2.7) from a seated position.

The main control console, in concert with the large display panel, provides the controls and displays required to operate the plant during normal plant operations, abnormal events and emergencies. These main control console controls and displays include the following:

(1) On-screen control VDUs for safety system monitoring and non-safety system control and monitoring which are driven by the plant process computer system (Subsection 18.4.2.3).

(2) A separate set of on-screen control VDUs for safety system control and monitoring and 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 IE standards (Subsection 18.4.2.4).

(3) Dedicated function switches (Subsection 18.4.2.5).

The main control console is also equipped with a limited set of dedicated displays for selected functions (e.g., the Standby Liquid Control System and the synchronization of the main generator to the electrical grid).

In addition to the above equipment, the main control console is equipped with both intraplant and external communications equipment and a laydown space is provided for hard copies of procedures and other documents required by the operators during the performance of their duties.

18.4.2.3 Process Computer Driven VDUs

A set of onscreen control VDUs is incorporated into the main control console design to support the following activities:

(1) Monitoring of plant systems, both safety and non-safety-related

(2) Control of non-safety system components

(3) Presentation of system and equipment alarm information

This set of VDUs is driven by the plant process computer system. Thus, data collected by the process computer is available for monitoring on these VDUs. All available display formats can be displayed on any of these VDUs.

18.4.2.4 Process Computer Independent VDUs

A set of VDUs which are independent of the process computer are also installed on the main control console. These VDUs are each driven by independent processors. They are divided into two subsets:

(1) The first subset consists of those VDUs which are dedicated, divisionally separated devices. The VDUs in this group can only be used for monitoring and control of equipment within a given safety division. The VDUs are qualified, along with their supporting display processing equipment, to Class 1E standards.

(2) The second subset of process computer independent VDUs are used for monitoring and control of non-safety plant systems. The VDUs in this subset are not qualified to Class 1E equipment standards.

18.4.2.5 Dedicated Function Switches

Dedicated function switches are installed on the main control console. These devices provide faster access and feedback compared to that obtainable with soft controls. These dedicated switches are implemented in hardware, so that they are located in a fixed-position and are dedicated in the sense that each individual switch is used only for a single function, or two very closely related functions (e.g., valve open/close).

The dedicated function switches on the main control console are used to support actions such as initiation of automated sequences of safety and non-safety system 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 7.7.1.5.1 describes the Power Generation Control (PGC) System, 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 System 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 System 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 System 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.

Evaluation of the effects of automation strategies on operator reliability and the appropriateness of the ABWR automation design is a COL license information requirement (Subsection 18.8.3).

Also, a consideration of malfunctions of the PGCS is a COL license information requirement. (See Subsection 18.8.10).

18.4.2.6.2 Semi-Automated Operation

The PGC System 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 System performs no control actions. The operator must activate all necessary system and equipment controls for the semi-automatic sequence to proceed. The PGC System 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 operation 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 System 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 console and the supervisors' console. The large display panel includes fixed-position displays (Subsection 18.4.2.8), a variable display (Subsection 18.4.2.9) and spatially dedicated alarm windows (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 COL applicant shall address the human factors aspects of TMI Item I.E.3, Safety System Status Monitoring, as a COL license information requirement (Subsection 18.8.9).

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 Regulatory Guide 1.97 (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

The console provided for the control room supervisors is equipped with VDUs on which any screen format resident in the process computer system 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 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. Selection of the parameters for inclusion in the SPDS display is based upon the ABWR Emergency Procedure Guidelines (Appendix 18A). 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 are integrated into the overall control room display capabilities in a manner which complies with all relevant requirements of NUREG-0737, Supplement 1. Displays of critical plant variables sufficient to provide information to plant operators about the following critical safety functions are continuously displayed 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

(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). It is the responsibility of the COL applicant 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) Drywell oxygen concentration (when monitors are in operation)

(11) Drywell hydrogen concentration (when monitors are in operation)

(12) Wetwell oxygen concentration (when monitors are in operation)

(13) Wetwell hydrogen concentration (when monitors are in operation)

(14) 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-2. Table 18F-2 also includes other displays, beyond those required for the SPDS.

The evaluation of the SPDS against the requirements of Paragraph 3.8a of NUREG-0737, Supplement 1, and confirmation that the design meets all applicable criteria is a COL license information requirement (Subsection 18.8.4).

18.4.2.12 Fixed-Position Alarms

Fixed-position alarm tiles on the large display panel annunciate the key, plant-level alarm conditions that potentially affect plant availability or plant safety, or indicate the need for immediate operator action.

18.4.2.13 Alarm Processing Logic

Alarm prioritizing and filtering logic is employed in the ABWR design to enhance the presentation of meaningful alarm information to the operator and reduce the amount of information which the operators must absorb and process during abnormal events.

Alarm prioritizing is accomplished in the ABWR through the designation of three categories of alarm signals. The first of these is the important alarms. These are defined as those alarms which notify the operators of changes in plant status regarding safety and include those items which are to be checked in the event of accidents, principle events or transients. The important alarms are displayed on the fixed-position tiles discussed in Subsection 18.4.2.12.

The second category is the system-specific alarms which are provided to notify the operators of system-level abnormalities or non-normal system statuses. Examples of these are:

(1) Main pump trips caused by system process, power sources or control abnormalities

(2) Valve closures in cooling or supply lines

(3) Decreases in supply process values

(4) Loss of a backup system

(5) System isolation

(6) Safety systems are being bypassed

(7) Systems are undergoing testing

The system-specific alarms are also shown on the fixed-position tiles discussed in Subsection 18.4.2.12.

Equipment alarms make up the third category of alarms in the prioritizing scheme and are discussed in Subsection 18.4.2.14.

Alarm suppression in the ABWR is based upon the following concepts:

(1) **Suppression Based on the Operating Mode:** The plant operating mode is defined on the basis of the hardware or process status, and alarms which are not relevant to the current operating mode are suppressed. For example, alarms which are needed in the "RUN" mode but are unnecessary in the "SHUTDOWN" mode are suppressed.

(2) **Suppression of Subsidiary Alarms**: Alarms are suppressed if they are logically consequent to the state of operation of the hardware or to the process status. For example, scram initiation (a plant-level alarm condition announced with a fixed-position alarm tile on the large display panel) will logically lead to an FMCRD HCU scram accumulator low pressure (also an alarm condition). Such subsidiary alarms are suppressed if they simply signify logical consequences of the systems operation.

(3) **Suppression of Redundant Alarms**: When there are overlapping alarms, such as "high" and "high-high" or "low" and "low-low", only the more severe of the conditions is alarmed and the others are suppressed.

Operators may activate or deactivate the alarm suppression logic at any time.

18.4.2.14 Equipment Alarms

Alarms which are not indicated by fixed-position alarm tiles on the large display panel (i.e., those alarms of nominally lower level importance such as those related to specific equipment status) are displayed to the control room operating staff via the main control console VDUs. The supplemental alarm indications and supporting information regarding the plant-level alarms which are presented on the large display panel are also presented on the VDUs.

18.4.2.15 Control Room Arrangement

In the ABWR main control room arrangement, the main control console is located directly in front of the large display panel for optimum viewing efficiency by the plant operators seated at the main console. The shift supervisor's console is also placed in front of the large display panel, but at a somewhat greater distance than the main control console. The shift supervisor is, thus, in a position behind the control console operators. This arrangement allows all control room personnel to view the contents of the large panel displays.

18.4.3 Control Room HSI Technology

The ABWR main control room standard design features described in Subsection 18.4.2 include equipment which utilizes a variety of technologies to control and monitor the plant processes. This subsection provides a summary listing and description of the technologies which are utilized to support personnel execution of these control and monitoring functions. For this purpose, the term "technology" is taken to have the following definition:

> "the equipment, including both hardware and software, employed to directly accomplish the functions of control and monitoring of the plant processes."

Hardware such as consoles, panels, cabinets, control room lighting and HVAC and plant communication equipment which has a supporting role but is not directly involved in the control and monitoring processes is excluded.

The scope of this section is limited to the main control room and the remote shutdown station areas of the plant and includes all human-system interface (HSI) equipment technologies which may be applied, regardless of use in prior designs:

(1) Hardware switches such as multi-position rotary, push-button, rocker, toggle and pull-to-lock types.

(2) Soft switch, the functions of which may be changed through the execution of software functions

(3) Continuous adjustment controls, such as rotary controls and thumbwheels.

(4) Visual display units with full color screens, including large reverse projection screens, cathode ray tubes and flat panel display screens.

(5) On-screen control utilized with the cathode ray tubes and flat panel display devices.

(6) VDU screen formats such as large screen optical projection display formats; text displays, including menus and tabular information and graphical displays, including Trend Plots, 2-D Plots, P&IDs and other diagrams and pictorial information.

(7) Analog Meters which employ a hardware medium to pictorially or graphically present quantitative and qualitative information concerning plant process parameters. This includes analog meters using digitally controlled LEDs and digital readouts.

(8) Fixed-Position Digital Displays which present alphanumeric information in a hardware medium. These can be back-lit.

(9) Fixed-position hardware mimic displays which schematically represent plant systems and components and their relationships utilizing pictorial elements, labels and indicator lights.

(10) Fixed-Position alarm tiles which use light to indicate the alarm state.

(11) An Audio Signal system which is coordinated to the fixed-position alarm tiles and utilizes prioritization and alarm reduction logic and predefined setpoints to alert operators to plant status changes.

(12) Printers and Printer/Plotters used to provide hard copy output in the form of plots, logs and text.

(13) Keyboards which are composed of alphanumeric and/or assignable function keys and function as computer input devices.

18.5 Remote Shutdown System

The Remote Shutdown System (RSS) provides a means to safely shut down 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 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.

Evaluation of alternate design approaches for reliability and confirmation of the adequacy of the RSS design is COL license information requirement (Subsection 18.8.6).

18.6 Systems Integration

18.6.1 Safety-Related Systems

The operator interfaces with the safety-related systems through (1) dedicated hardware switches for system initiation and logic reset, (2) hardware switches for system mode changes, (3) safety-related VDUs for individual safety equipment control, status display and monitoring, (4) non-safety-related VDUs for additional safety system monitoring, and (5) the large fixed-position display for plant overview information. Instrumentation and control aspects of the microprocessor-based safety systems and logic control (SSLC) are described in Appendix 7A.

Divisional separation for control, alarm and display equipment is maintained. The SSLC processors provide alarm signals to their respective safety-related alarm processors and provide display information to the divisionally dedicated VDUs. The SSLC microprocessors communicate with their respective divisional VDU controllers through the Essential Multiplexing System (EMUX). The divisional VDUs have on-screen control capability.

SSLC also provides the plant safety-related systems status information (including alarms) to the plant non-safety-related communication network. Divisional isolation devices are provided between the safety-related systems and non-safety-related communication networks so that failures in the non-safety-related equipment will have no impact on the ability of the safety-related systems to perform their design functions. The non-safety-related communication network is part of the nonessential Multiplex System (NEMS) described in Subsection 7.7.1.9.

Selected operator control functions are performed through dedicated hardware control switches which are Class 1E qualified and divisionally separated on the main control console. These hardware switches communicate with the SSLC safety-related systems logic units through hardwire signal transmission lines (i.e., not multiplexed). Communication between the SSLC logic units and alarm panels and the safety-related fixed-position displays is through multiplexed data links.

The divisionally dedicated VDUs are classified as safety-related equipment. These VDUs provide control and display capabilities for individual safety-related systems if control of a system component is required. Normally, such control actions are performed for equipment surveillance purposes only, as the normal method of system control is through the mode-oriented master sequence switches.

18.6.2 Non-Safety-Related Systems

For non-safety-related systems, operation control is accomplished using master sequence switches, on-screen control via the non-safety VDUs. The hardware switches for non-safety-related equipment on the main control console communicate with the non-safety-related systems logic units through hardwire transmission lines.

The non-safety-related systems communicate with other equipment in the operator interface through the NEMS network. The non-safety-related portion of the large display panel fixed-position displays is driven by a controller separate from the process computer system. Alarm processing microprocessor units separate from the process computer perform alarm filtering and suppression and also drive dedicated alarm tiles on the large display panel. The alarms for entry conditions into the symptomatic emergency operating procedures are provided by the alarm processing units, both safety and non-safety-related. Equipment level alarm information is presented by the process computer on the main control console VDUs.

An additional set of non-safety-related on-screen control VDUs is provided on the main control console for control and display of non-safety systems. These VDUs are independent of the process computer system. In the unlikely event of loss of the process computer system, these independent VDUs, in conjunction with the large display panel safety-related displays, have sufficient information and control capability to allow the following operations to be performed:

(1) Steady-state power operation

(2) Power decrease

(3) Plant shutdown to hot standby conditions

(4) Plant shutdown to cold shutdown conditions

Without the plant process computer system, control is carried out through the master sequential switches and the process computer-independent, on-screen control VDUs. Monitoring is accomplished with the independent VDUs and the fixed-position display on the large display panel. Power increases cannot be performed in the absence of the process computer system because core thermal margin limit information provided by the process computer to the automated thermal limit monitor (Subsection 7.7.2.2) would not be available.

18.7 Detailed Design of the Operator Interface System

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

As part of the Appendix 18E discussion of the HSI design and implementation plan elements, 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 HFE 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-1 through 18F-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 HSI Design Implementation Process

The HSI Design Implementation Process as described in Appendix 18E is the responsibility of the COL applicant. In addition, the following specific COL license information is in effect.

18.8.2 Number of Operators Needing Controls Access

The number of operators needing access to the controls on the main control panel shall be evaluated and the ABWR control room staffing arrangement (Subsection 18.2, Item 1) shall be confirmed as adequate. In addition, the roles and responsibilities of the shift supervisor and assistant shift supervisor shall be specified. The results of the evaluation shall be placed in the HFE Issue Tracking System (Subsection II.2 of Table 18E-1).

18.8.3 Automation Strategies and Their Effect on Operator Reliability

Automation strategies for plant operation shall be evaluated for effects on operator reliability and the appropriateness of the ABWR automation design (Subsection 18.4.2.6.1) shall be confirmed. This evaluation shall be performed according to the criteria of Subsection II of Table 18E-1 and the results of the evaluation shall be placed in the HFE Issue Tracking System.

18.8.4 SPDS Integration With Related Emergency Response Capabilities

The design of the SPDS (Subsection 18.4.2.11) shall be evaluated against the requirements of Paragraph 3.8a of NUREG-0737, Supplement 1, and confirmed to be in compliance with all applicable criteria. The results of the evaluation shall be placed in the HFE Issue Tracking System.

18.8.5 Standard Design Features Design Validation

The design of each of the main control room standard design features (Subsection 18.4.2.1) shall be validated using the applicable criteria in Subsection VIII of Table 18E-1. The results of the validation shall be placed in the HFE Issue Tracking System.

18.8.6 Remote Shutdown System Design Evaluation

Digital versus analog design approaches for the Remote Shutdown System (RSS) shall be evaluated for reliability and the adequacy of the ABWR RSS design (Subsection 18.5) shall be confirmed. The results of the evaluation shall be placed in the HFE Issue Tracking System.

18.8.7 Local Valve Position Indication

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.

18.8.8 Operator Training

An operator training program which meets the requirements of 10CFR50 shall be established (Subsection II.1.c of Table 18E-1).

18.8.9 Safety System Status Monitoring

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 (Subsection 18.4.2.8).

18.8.10 PGCS Malfunction

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 (Subsection 18.4.2.6.1).

18.8.11 Local Control Stations

The COL applicant shall evaluate all operations at local control stations which are critical to plant safety, as defined in Paragraph V.1.c of Table 18E-1. The results of these evaluations shall be incorporated into the HFE Issue Tracking System.

18.8.12 As-Built Evaluation of MCR and RSS

The COL applicant shall prepare a report which documents that the as-built main control room (MCR) and remote shutdown station (RSS) conform to the certified and validated main control room and remote shutdown station configurations. Aspects of the as-built MCR and RSS to be considered in this report are the area and panel layouts, operator environment, alarms, displays, controls and general human-system interface characteristics.

18.8.13 Accident Monitoring Instrumentation

The COL applicant shall evaluate the instrumentation described in TMI Item II.F.1, “Additional Accident Monitoring Instrumentation”, with regard to the impact of the inclusion of that instrumentation in the MCR HSI on the potential for operator error. The results of this evaluation shall be placed in the HFE Issue Tracking System.

18.8.14 In-Core Cooling Instrumentation

The COL applicant shall evaluate the instrumentation described in TMI Item II.F.2, “Instrumentation For Detection of Inadequate Core-Cooling”, with regard to the impact of the inclusion of that instrumentation in the MCR HSI on the potential for operator error. The results of this evaluation shall be placed in the HFE Issue Tracking System.

18.8.15 Performance of Critical Tasks

The COL applicant shall evaluate the adequacy of the HSI with respect to providing the controls, displays and alarms necessary for timely performance of critical tasks. Critical tasks shall include, as a minimum, those operator actions which have significant impact on the PRA results, as presented in Section 19D.7, and the operator actions to isolate the reactor and inject water for the postulated event scenarios of a common-mode failure of the Safety System Logic and Control System and/or the Essential Multiplexing System concurrent with the design basis main steamline, feedwater line or shutdown cooling line break LOCA (Paragraph V.2.d of Table 18E-1). The results of this evaluation shall be placed in the HFE Issue Tracking System.

18.8.16 Plant Status and Post-Accident Monitoring

The main control instrumentation described in TMI Item I.D.5 (2), “Plant Status and Post-Accident Monitoring” shall be evaluated with regard to the impact of the inclusion of that instrumentation in the MCR HSI on the potential for operator error and the results of the evaluation shall be placed in the HFE Issue Tracking System.

18A Emergency Procedure Guidelines

This appendix contains the ABWR Emergency Procedure Guidelines (EPGs). The purposes of the ABWR EPGs are for human factors evaluation in support of the man-machine interface systems design in the main control room, to assure that the controls and displays required during emergency conditions are properly provided, and to provide the bases of operator actions for the probabilistic risk assessment (PRA).

The ABWR EPGs are developed based upon the U.S. BWR Owner's Group Emergency Procedure Guidelines, Revision 4, which have been approved by the NRC*, by deleting from the BWROG Guidelines inapplicable systems, design features, and strategies, and by applying ABWR systems, design features and strategies applicable for the ABWR. A list of differences, and basis for differences between the ABWR EPGs and the BWROG EPGs Revision 4 are provided in Appendix 18B. Operator instructions and strategies for utilization of design features to mitigate the consequence of severe accidents, such as the firewater addition system and the containment overpressure protection system have been incorporated. These instructions are beyond the scope of BWROG EPGs Revision 4. The bases for these instructions are given also in Appendix 18B. Appendix 18D contains the input parameters used for calculation of operation limits in the EPGs and the results of these calculations.

This set of EPGs is intended to be used for development of plant-specific technical guidelines for plants whose license applications reference the ABWR Standard Plant. The COL applicant is required to develop detailed plant-specific Emergency Operating Procedures (EOPs) in accordance with requirements of NUREG-0737, Supplement 1. The EOPs developed from the EPGs are to be used for verification and validation of the MCR system design using a simulator to be provided by the applicant referencing the ABWR design.

* NRC letter, A.C. Thadani to D. Grace, Safety Evaluation of "BWR Owner's Group-Emergency Procedure Guidelines, Revision 4," dated September 12, 1988 (NEDO-31331, March 1987).

18A.1 Table of Contents

TABLE OF CONTENTSPage

ABWR i

18A.2 Introduction

INTRODUCTION

The following generic symptomatic emergency procedure guidelines have been developed:

(1) RPV Control Guideline

(2) Primary Containment Control Guideline

(3) Secondary Containment Control Guideline

(4) Radioactivity Release Control Guideline

The RPV Control Guideline maintains adequate core cooling, shuts down the reactor, and cools down the RPV to cold shutdown conditions. This guideline is entered whenever low RPV water level, high RPV pressure, or high drywell pressure occurs, or whenever a condition which requires reactor scram exists and reactor power is above the APRM downscale trip or cannot be determined.

The Primary Containment Control Guideline maintains primary containment integrity, protects equipment in the primary containment, and limits radioactivity release from the primary containment with respect to the consequences of all mechanistic events including the consequences of severe accidents and hydrogen generation in the ABWR containment. This guideline is entered whenever suppression pool temperature, drywell temperature, drywell pressure, suppression pool water level, or primary containment hydrogen concentration is above its high operating limit or suppression pool water level is below its low operating limit.

The Secondary Containment Control Guideline protects the secondary containment, limits radioactivity release to the secondary containment, and either maintains secondary containment integrity or limits radioactivity release from the secondary containment. This guideline is entered whenever a secondary containment temperature, radiation level, or water level is above its maximum normal operating value or secondary containment differential pressure reaches zero.

The Radioactivity Release Control Guideline limits radioactivity release into areas outside the primary and secondary containments. This guideline is entered whenever offsite radioactivity release rate is above that which requires an Alert.

Table I is a list of the abbreviations used in the guidelines.

At various points throughout these guidelines, operator precautions are indicated by the symbol ☞ and a number referring to a numbered “Caution” contained in the Operator Precautions section. These "Cautions" are brief and succinct red flags for the operator.

Brackets [ ] indicate plant unique setpoints, design limits, pump shutoff pressures, etc, to be determined on a plant-specific basis, and the parentheses ( ) within brackets indicate the source or definition for the enclosed variable. At various points throughout these guidelines, limits for operations are specified. The basis and calculational methods for these limits are defined in the BWROG Emergency Procedure Guidelines, Revision 4, Appendices A and C, respectively. These limits are specified beyond which certain actions are required. While conservative, these limits are derived from engineering analyses utilizing best-estimate (as opposed to licensing) models. Consequently, these limits are generally not as conservative as the limits specified in a plant's Technical Specifications. This is not to imply that operation beyond the Technical Specifications is recommended in any emergency. Rather, such operation is required and is now permitted under certain degraded conditions in order to safely mitigate the consequences of those degraded conditions. The limits specified in the guidelines establish the boundaries within which continued safe operation of the plant can be assured. Therefore, conformance with the guidelines does not ensure strict conformance with a plant's Technical Specifications or other licensing bases.

At other points within these guidelines, defeating safety system interlocks and initiation logic is specified. This is also required in order to safely mitigate the consequences of degraded conditions, and it is generally specified only when conditions exist for which the interlock or logic was not designed. Bypassing other interlocks may also be required due to instrument failure, etc., but these interlocks cannot be identified in advance and are therefore not specified in the guidelines.

The entry conditions for these emergency procedure guidelines are symptomatic of both emergencies and events which may degrade into emergencies. The guidelines specify actions appropriate for both. Therefore, entry into procedures developed from these guidelines is not conclusive that an emergency has occurred.

Each procedure developed from these emergency procedure guidelines is entered whenever any of its entry conditions occurs, irrespective of whether that procedure has already been entered or is presently being executed. The procedure is exited and the operator returns to non-emergency procedures when either one of the exit conditions specified in the procedure is satisfied or it is determined that an emergency no longer exists. For example, the procedure developed from the RPV Control Guideline specifies cooldown to cold shutdown conditions by various methods and exit after the shutdown cooling interlocks have cleared, but entry into this procedure does not require any cooldown if it can be determined that an emergency no longer exists prior to establishing the conditions required to commence the cooldown as specified in the procedure. After a procedure developed from these guidelines has been entered, subsequent clearing of all entry conditions for that procedure is not, by itself, conclusive that an emergency no longer exists.

Procedures developed from these emergency procedure guidelines specify symptomatic operator actions which will maintain the reactor plant in a safe condition and optimize plant response and margin to safety irrespective of the initiating event. However, for certain specific events (e.g., earthquake, tornado, blackout, or fire), emergency response and recovery can be further enhanced by additional auxiliary event-specific operator actions which may be provided in supplemental event-specific procedures intended for use in conjunction with the symptomatic procedures. As with actions specified in any other procedure intended for use with the symptomatic procedures, these event-specific operator actions must not contradict or subvert the symptomatic operator actions specified in the symptomatic procedures and must not result in loss or unavailability of equipment the operation of which is specified in these procedures.

BWROG EPG step numbering is maintained in this document. Where an EPG step has been removed, the step number is left in place with an explanation in ( ) in order to maintain continuity of step sequence.

Water levels in this document have the following reference points:
RPV Water Level: 0 cm = Top of Active Fuel (TAF)
Suppression Pool and Primary Containment Water Level:
0 m = Bottom of Suppression Pool

The values for Table 1, Operating Values of Secondary Containment Parameters, are developed from the equipment environmental specification. The area water level Maximum Normal Operating Values were arbitrarily chosen at the hi alarm or 5 cm above the floor where visual inspection was the mode of detection. The areas in the secondary containment have sills to prevent movement of water from area to area. These sills are assumed to be 20 cm high. The area water level Maximum Safe Operating Values were developed based on the elevation of the bottom of pump motors in the area or greater than the top of the sill surrounding the area. The COL applicant will be required to re-evaluate these values as an “interface requirement” when plant specific installation details are completed.

TABLE I
ABWR EPG ABBREVIATIONS

ADS	—	Automatic Depressurization System
APRM	—	Average Power Range Monitor
ARI	—	Alternate Rod Insertion
CAMS	—	Containment Air Monitoring System
CRD	—	Control Rod Drive
CUW	—	Reactor Water Cleanup
ECCS	—	Emergency Core Cooling System
FAS	—	Firewater Addition System
FCS	—	Flammability Gas Control System
F/D	—	Filter/Demineralizer
FMCRD	—	Fine Motion Control Rod Drive
FPC	—	Fuel Pool Cooling
HCU	—	Hydrualic Control Unit
HPCF	—	High Pressure Core Flooder
HVAC	—	Heating, Ventilating and Air Conditioning
LCO	—	Limiting Condition for Operation
LPCF	—	Low Pressure Core Flooder mode of RHR System
MSIV	—	Main Steamline Isolation Valves
NPSH	—	Net Positive Suction Head
RBHVAC	—	Reactor Building HVAC
RCIC	—	Reactor Core Isolation System
RHR	—	Residual Heat Removal
RIP	—	Reactor Internal Pump
RPS	—	Reactor Protection System
RPV	—	Reactor Pressure Vessel
RSCS	—	Rod Sequence Control System

ABWR I-4

TABLE I
ABWR EPG ABBREVIATIONS (Continued)

RWM	—	Rod Worth Minimizer
SGTS	—	Standby Gas Treatment System
SLC	—	Standby Liquid Control
SPCU	—	Suppression Pool Cleanup
SRV	—	Safety Relief Valve
TIP	—	Transverse Incore Probe

ABWR I-4.1

18A.3 Operator Precautions

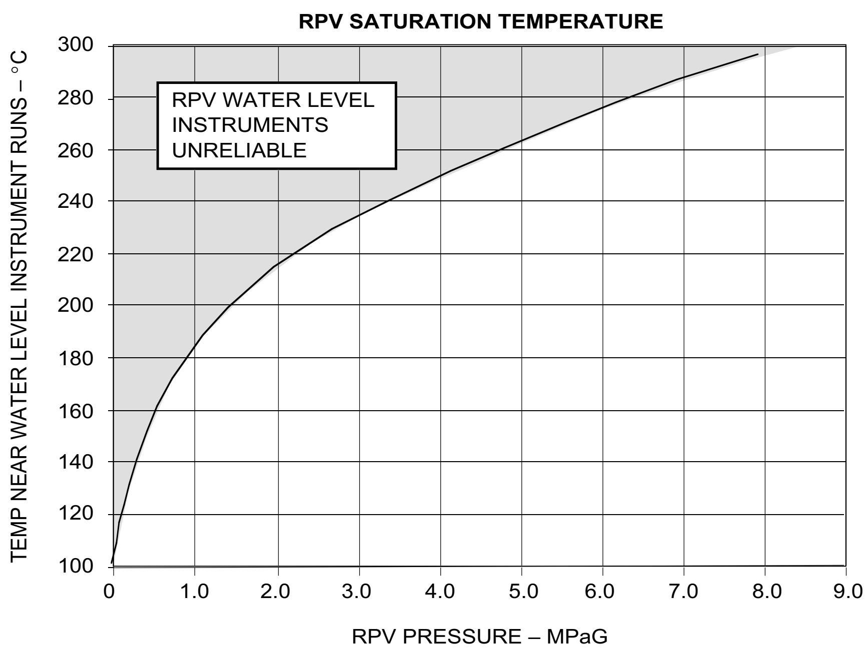
OPERATOR PRECAUTIONS

This section lists "Cautions" which are applicable at one or more specific points within the guidelines. Where a "Caution" is applicable, it is identified with the symbol, ☞, at the right side of a paragraph.

CAUTION #1

An RPV water level instrument may be used to determine RPV water level only when all the following conditions are satisfied for that instrument:

1. The temperatures near all the instrument runs are below the RPV Saturation Temperature.



ABWR I-5

2. For each of the following instruments, the instrument reads above the Minimum Indicated Level associated with the highest temperature near an instrument reference leg vertical run:

a. Narrow Range (355.5 to 508.0 cm)

Highest Drywell Run Temperature (°C) Between		Minimum Indicated
Low	High	Level (cm)
–	65.6	361.7
65.6	287.8	355.5

b. Shutdown Range (355.5 to 1282.5 cm)

Highest Drywell Run Temperature (°C) Between		Minimum Indicated
Low	High	Level (cm)
–	65.6	402.6
65.6	121.1	416.1
121.1	176.7	434.3
176.7	232.2	458.2
232.2	287.8	490.7

CAUTION #2

Deleted, not applicable to ABWR.

CAUTION #3

Operating RCIC turbine below [228 rad/s (minimum turbine speed limit per turbine vendor manual)] may result in unstable system operation and equipment damage.

ABWR I-6

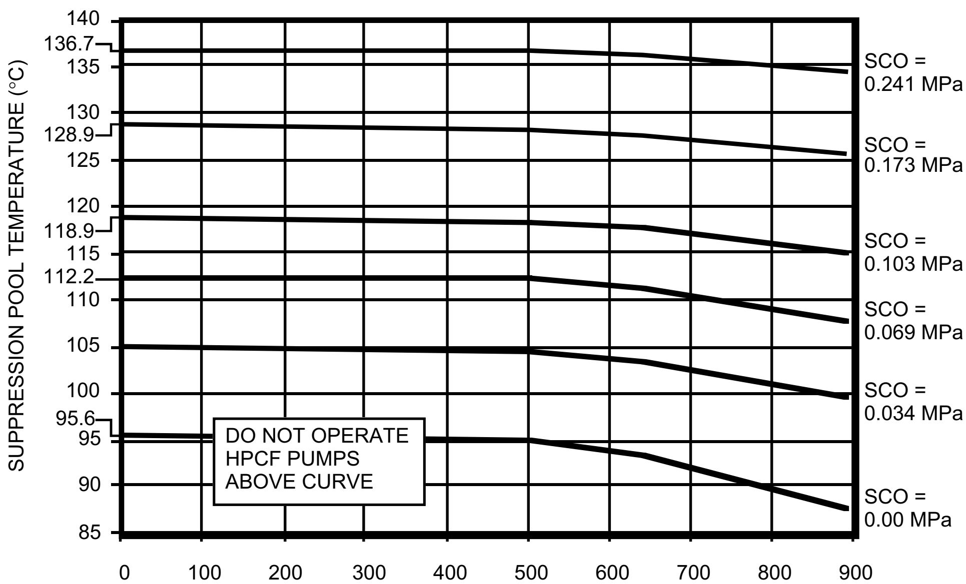
CAUTION #4

Elevated suppression chamber pressure may trip the RCIC turbine on high exhaust pressure.

CAUTION #5

If HPCF is taking suction from the suppression pool and suppression pool temperature exceeds the HPCF Pump NPSH Limit, the pump may be damaged and become inoperable.

HPCF PUMP NPSH



KEY: SUPPRESSION CHAMBER OVERPRESSURE (SCO) = SC AIRSPACE PRESSURE + WATER HEAD OVER SUCTION STRAINER

CAUTION #6

Cooldown rates above [55.6 °C/h (RPV cooldown rate LCO)] may be required to accomplish this step.

CAUTION #7

A rapid increase in injection into the RPV may induce a large power excursion and result in substantial core damage.

18A.4 RPV Control Guideline

RPV CONTROL GUIDELINE

PURPOSE

The purpose of this guideline is to:

- Maintain adequate core cooling,
- Shut down the reactor, and
- Cool down the RPV to cold shutdown conditions ([Avg. RPV water temperature £93.3 °C (cold shutdown conditions)]).

ENTRY CONDITIONS

The entry conditions for this guideline are any of the following:

- RPV water level below [380.8 cm (low level scram setpoint)]
- RPV pressure above [7.35 MPaG (high RPV pressure scram setpoint)]
- Drywell pressure above [0.012 MPaG (high drywell pressure scram setpoint)]
- A condition which requires reactor scram, and reactor power above [5% (APRM downscale trip)] or cannot be determined

OPERATOR ACTIONS

RC-1 If reactor scram has not been initiated, initiate reactor scram.

Irrespective of the entry conditions, execute [Steps RC/L, RC/P, and RC/Q] concurrently.

ABWR RC-1

RC/L Monitor and control RPV water level. ☞ #1

RC/L-1 Initiate each of the following which should have initiated but did not:

- lsolation
- ECCS
- Emergency diesel generator

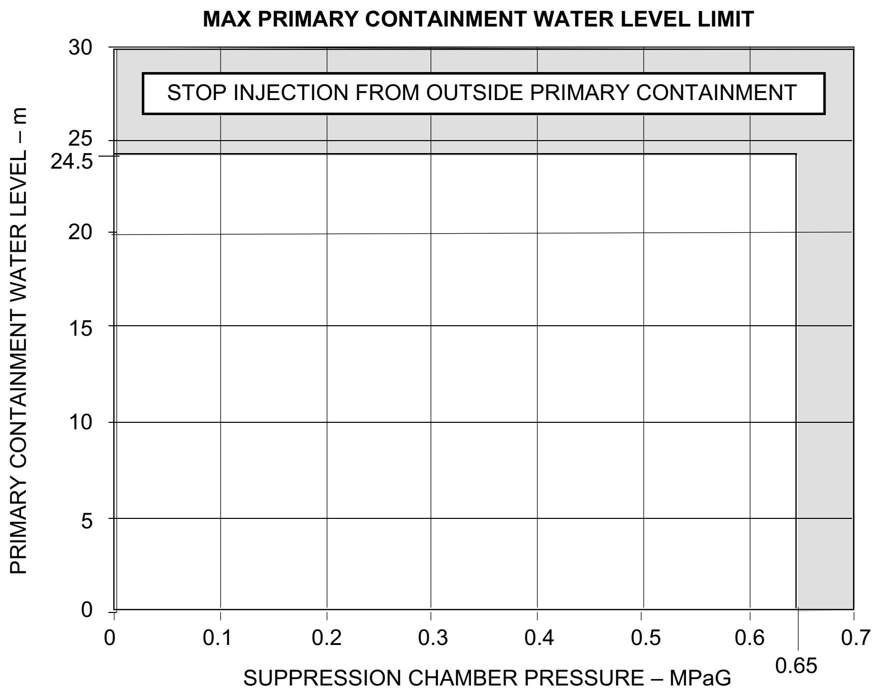
If while executing the following step:

- Any control rod cannot be determined to be inserted to or beyond [4.2%* (Maximum Subcritical Banked Withdrawal Position)] and it has not been determined that the reactor will remain shutdown under all conditions without boron, enter [procedure developed from Contingency #5].
- RPV water level cannot be determined, enter [procedure developed from Contingency #4].

* 0% = fully inserted

ABWR RC-2

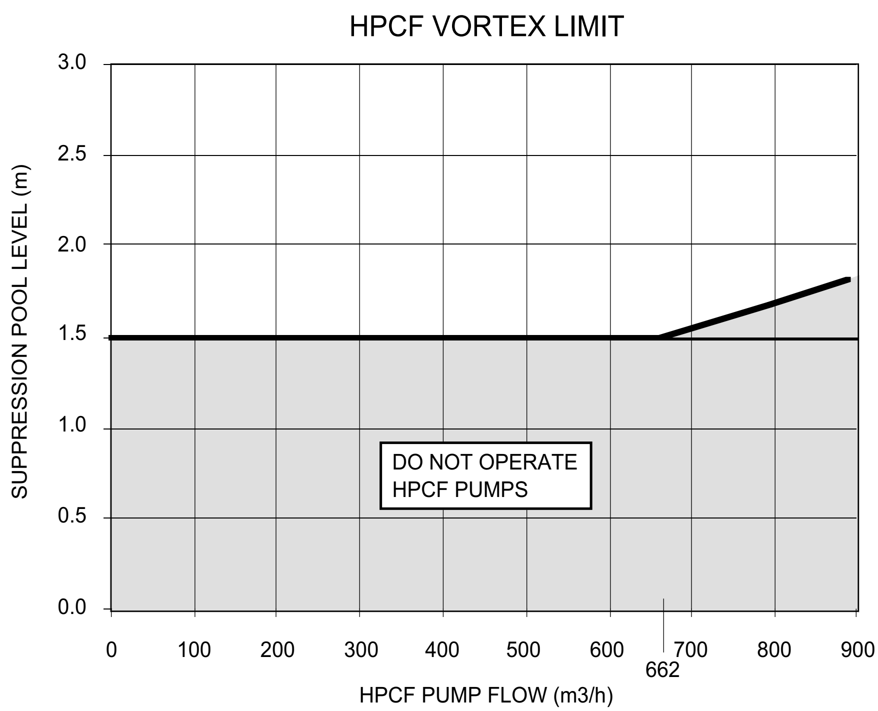
If while executing the following step primary containment water level and suppression chamber pressure cannot be maintained below the Maximum Primary Containment Water Level Limit, then irrespective of whether adequate core cooling is assured terminate injection into the primary containment from sources external to the primary containment until primary containment water level and suppression chamber pressure can be maintained below the Maximum Primary Containment Water Level Limit.



ABWR RC-3

RC/L-2 Restore and maintain RPV water level between [380.8 cm (low level scram setpoint or shutdown cooling RPV water level interlock, whichever is higher)] and [484.4 cm (high level trip setpoint)] with one or more of the following systems:

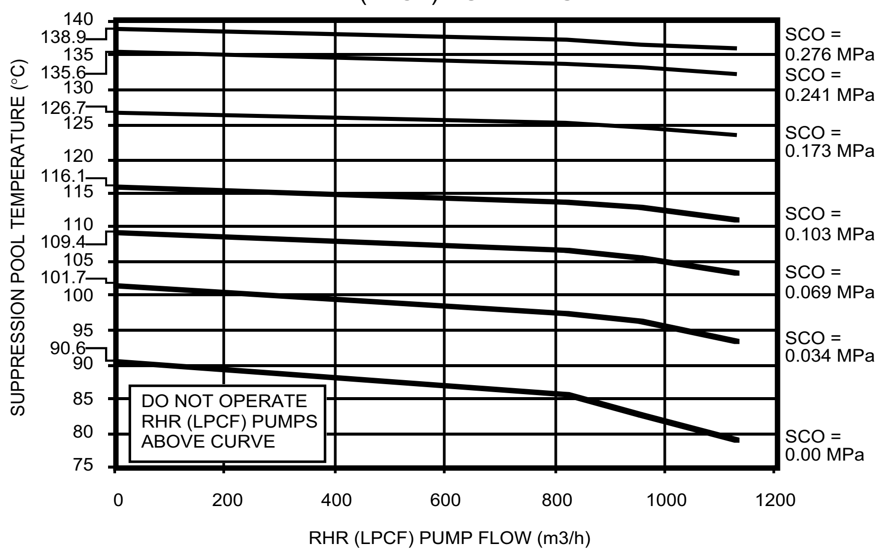
- Condensate/feedwater
- CRD
- RCIC with suction from the condensate storage pool, defeating low RPV pressure and area high temperature isolation interlocks and high suppression pool water level suction transfer logic if necessary. ☞ #3,4
- HPCF; control and maintain pump flow less than [the HPCF Vortex Limit]. ☞ #5



ABWR RC-4

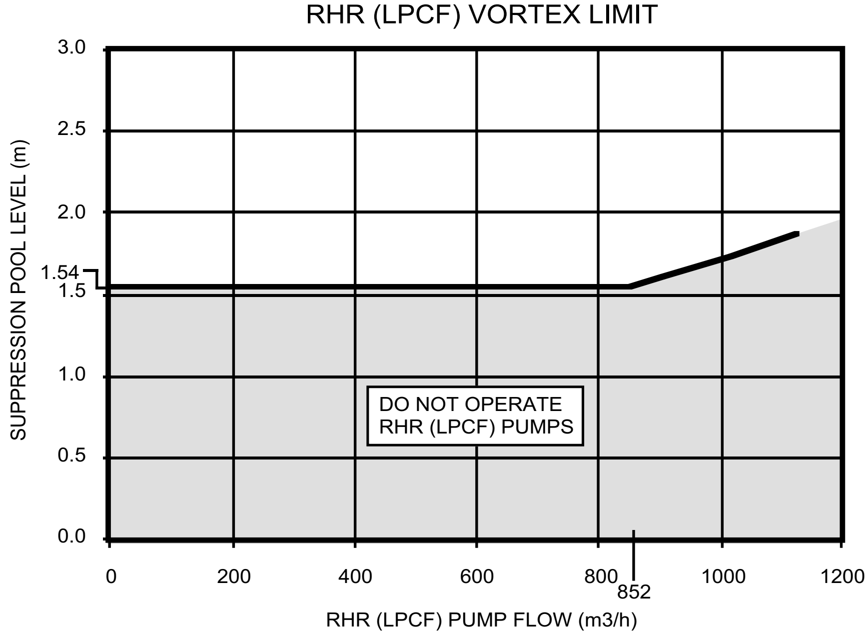
- RHR (LPCF); control and maintain pump flow less than the RHR Pump NPSH Limit and [the RHR Vortex Limit].

RHR (LPCF) PUMP NPSH



KEY: SUPPRESSION CHAMBER OVERPRESSURE (SCO) =
SC AIRSPACE PRESSURE + WATER HEAD OVER SUCTION STRAINER

RHR (LPCF) VORTEX LIMIT



ABWR RC-5

If RPV water level cannot be restored and maintained above [380.8 cm (low level scram setpoint or shutdown cooling RPV water level interlock, whichever is higher)], maintain RPV water level above [0 cm (top of active fuel)].

RPV water level control may be augmented by one or more of the following systems:

- Fire protection system and the firewater addition mode of RHR(C)
- [Interconnections with other units]
- ECCS keep-full systems:
  HPCF, RHR
- SLC (test tank)
- Condensate Makeup Water System

If RPV water level can be maintained above [0 cm (top of active fuel)] and the ADS timer has initiated, prevent automatic initiation of ADS.

> If RPV water level cannot be maintained above [0 cm (top of active fuel)], enter [procedure developed from Contingency #1].

RC/L-3 When [procedure for cooldown to cold shutdown conditions] is entered from [Step RC/P-5], proceed to cold shutdown in accordance with [procedure for cooldown to cold shutdown conditions].

RC/P Monitor and control RPV pressure.

If while executing the following steps:

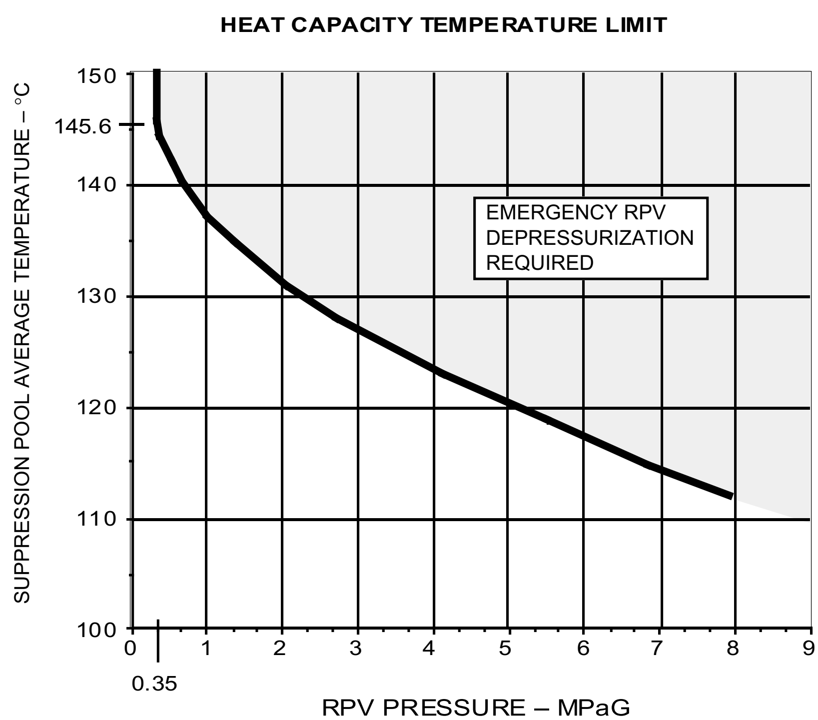
- A high drywell pressure ECCS initiation signal [0.012 MPaG (drywell pressure which initiates ECCS)] exists, prevent injection from those LPCF pumps not required to assure adequate core cooling prior to depressurizing below their maximum injection pressures.
- Emergency RPV Depressurization is anticipated and either all control rods are inserted to or beyond [4.2% (Maximum Subcritical Banked Withdrawal Position)] or it has been determined that the reactor will remain shutdown under all conditions without boron, rapidly depressurize the RPV with the main turbine bypass valves. ☞ #6
- Emergency RPV Depressurization is required and less than [8 (number of SRVs dedicated to ADS)] SRVs are open, enter [procedure developed from Contingency #2].
- RPV water level cannot be determined and less than [8 (number of SRVs dedicated to ADS)] SRVs are open, enter [procedure developed from Contingency #2].
- RPV water level cannot be determined and at least [8 (number of SRVs dedicated to ADS)] SRVs are open, enter [procedure developed from Contingency #4].

ABWR RC-7

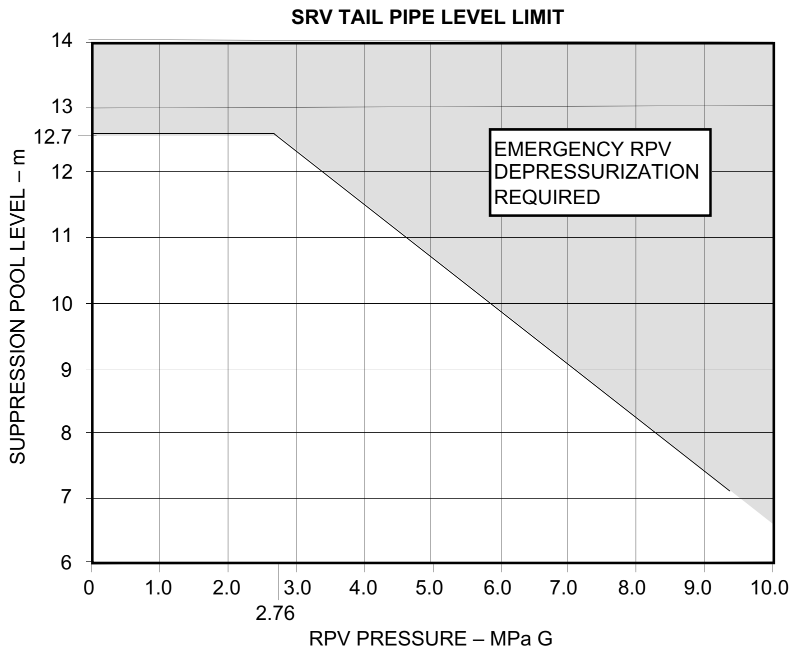
RC/P-1 If any SRV is cycling, manually open SRVs until RPV pressure drops to [6.70 MPaG (RPV pressure at which all turbine bypass valves are fully open)].

If while executing the following steps:

- Suppression pool temperature cannot be maintained below the Heat Capacity Temperature Limit, maintain RPV pressure below the Limit. ☞ #6



- Suppression pool water level cannot be maintained below the SRV Tail Pipe Level Limit, maintain RPV pressure below the Limit. ☞ #6



- Steam Cooling is required, enter [procedure developed from Contingency #3].

If while executing the following steps:

- Boron Injection is required, and
- The main condenser is available, and
- There has been no indication of gross fuel failure or steam line break,

open MSIVs, bypassing low RPV water level isolation interlocks if necessary, to re-establish the main condenser as a heat sink.

ABWR RC-9

RC/P-2 Stabilize RPV pressure at a pressure below [7.35 MPaG (high RPV pressure scram setpoint)] with the main turbine bypass valves.

RPV pressure control may be augmented by one or more of the following systems:

- SRVs only when suppression pool water level is above [2.291 m (elevation of top of SRV discharge device)]; open SRVs in the following sequence if possible: [Table (SRV opening sequence)]; if the continuous SRV pneumatic supply is or becomes unavailable, place the control switch for each SRV in the AUTO mode.

SRV Opening Sequence					
Sequence	Valve No.	Sequence	Valve No.	Sequence	Valve No.
1	C	7	H	13	B
2	L	8	R	14	M
3	F	9	D	15	E
4	T	10	K	16	U
5	A	11	G	17	J
6	N	12	S	18	P

- RCIC with suction from the condensate storage tank ☞ #3, 4

- [Other steam driven equipment]

- CUW (recirculation mode), bypassing regenerative heat exchangers and filter/demineralizers and, if necessary, defeating SLC and other isolation interlocks.

- Main steam line drains

- CUW (blowdown mode) if no boron has been injected into the RPV; refer to [sampling procedures] prior to initiating blowdown.

> If while executing the following steps the reactor is not shut down, return to [Step RC/P-2].

RC/P-3 When either:

- All control rods are inserted to or beyond [4.2% (Maximum Subcritical Banked Withdrawal Position)], or
- It has been determined that the reactor will remain shutdown under all conditions without boron, or
- [541.8 kg (Cold Shutdown Boron Weight)] of boron have been injected into the RPV, or
- The reactor is shutdown and no boron has been injected into the RPV,

depressurize the RPV and maintain cooldown rate below [55.6 °C/h (RPV cooldown rate LCO)].

If one or more SRVs are being used to depressurize the RPV and the continuous SRV pneumatic supply is or becomes unavailable, depressurize with sustained SRV opening.

RC/P-4 When the shutdown cooling RPV pressure interlock clears, initiate shutdown cooling using only those RHR subsytems not required to maintain RPV water level above [380.8 cm (RPV water level shutdown cooling interlock)] by operation in the LPCF mode.

If shutdown cooling cannot be established and further cooldown is required, continue to cool down using one or more of the systems used for depressurization.

RC/P-5 When either:

- All control rods are inserted to or beyond [4.2% (Maximum Subcritical Banked Withdrawal Position)], or
- It has been determined that the reactor will remain shutdown under all conditions without boron, or
- [541.8 kg (Cold Shutdown Boron Weight)] of boron have been injected into the RPV,

proceed to cold shutdown in accordance with [procedure for cooldown to cold shutdown conditions].

RC/Q Monitor and control reactor power.

If while executing the following steps:

- All control rods are inserted to or beyond [4.2% (Maximum Subcritical Banked Withdrawal Position)], terminate boron injection and enter [scram procedure].
- It has been determined that the reactor will remain shutdown under all conditions without boron, terminate boron injection and enter [scram procedure].
- The reactor is shutdown and no boron has been injected into the RPV, enter [scram procedure].

RC/Q-1 Confirm or place the reactor mode switch in SHUTDOWN.

RC/Q-2 If ARI has not initiated, initiate ARI.

RC/Q-3 If the main turbine-generator is on-line, confirm or initiate recirculation pump runback to minimum speed.

RC/Q-4 If reactor power is above [5% (APRM downscale trip)] or cannot be determined, trip the recirculation pumps.

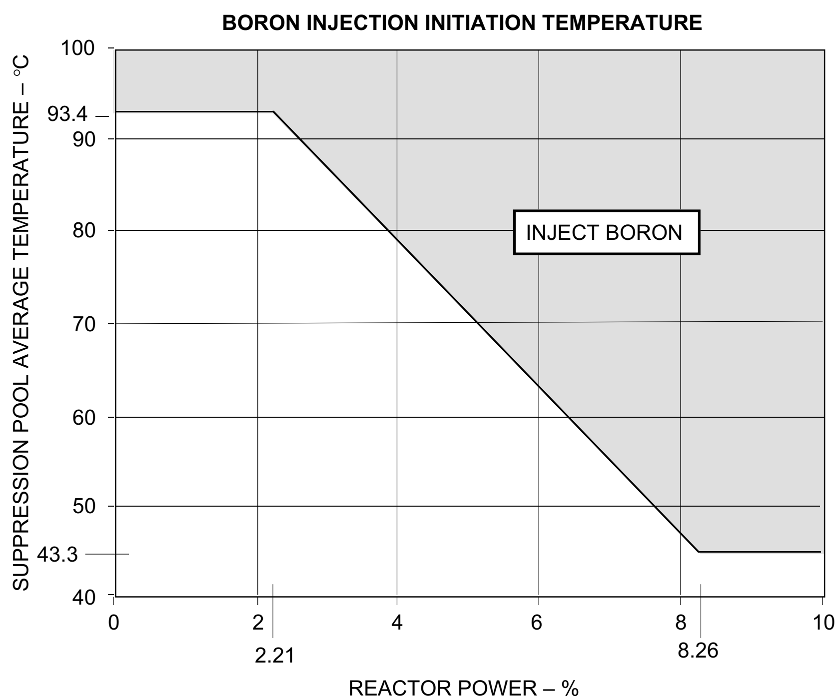
RC/Q-5 (Deleted, not applicable to ABWR.)

Execute [Steps RC/Q-6 and RC/Q-7] concurrently.

ABWR RC-13

RC/Q-6:

- When periodic neutron flux oscillations in excess of [25% (Large oscillation threshold)] peak-to-peak commence or continue, or
- Before suppression pool temperature reaches the[(Boron Injection Initiation Temperature)], BORON INJECTION IS REQUIRED; inject boron into the RPV with SLC and prevent automatic initiation of ADS.



If boron cannot be injected with SLC, inject boron into the RPV by one or more of the following alternative methods:

[• CRD]
[• HPCF]
[• CUW]
[• Feedwater]
[• RCIC]

ABWR RC-14

If while executing the following steps SLC tank water level drops to [0 m3 (low SLC tank water level)], manually trip the SLC pumps.

RC/Q-6.1 If boron is not being injected into the RPV by CUW and CUW is not isolated, bypass regenerative heat exchangers and filter/demineralizers.

RC/Q-6.2 Continue to inject boron until [541.8 kg (Cold Shutdown Boron Weight)] of boron have been injected into the RPV.

RC/Q-6.3 Enter [scram procedure].

RC/Q-7 Insert control rods as follows:

RC/Q-7.1 Reset ARI, bypassing ARI logic trips if necessary.

RC/Q-7.2 Insert control rods with one or more of the following methods:

- De-energize scram solenoids
- Vent the scram air header
- Reset the scram, bypassing RPS logic trips if necessary, and initiate a manual scram
- Open individual scram test switches
- Drive control rods, defeating RSCS and RWM interlocks if necessary

18A.5 Primary Containment Control Guideline

PRIMARY CONTAINMENT CONTROL GUIDELINE

PURPOSE

The purpose of this guideline is to:

- Maintain primary containment integrity,
- Protect equipment in the primary containment, and
- Limit radioactivity release from the primary containment.

ENTRY CONDITIONS

The entry conditions for this guideline are any of the following:

- Suppression pool temperature above [35.0 ºC (most limiting suppression pool temperature LCO)]]
- Drywell temperature above [57.2 ºC (drywell temperature LCO or maximum normal operating temperature, whichever is higher)]
- Drywell pressure above [0.012 MPaG (high drywell pressure scram setpoint)]
- Suppression pool water level above [7.1 m (maximum suppression pool water level LCO)]
- Suppression pool water level below [7.0 m (minimum suppression pool water level LCO)]
- Primary containment hydrogen concentration above [Hi Alarm (high hydrogen alarm setpoint)]

OPERATOR ACTIONS

Irrespective of the entry conditions, execute [Steps SP/T, DW/T, PC/P, SP/L, and PC/H] concurrently.

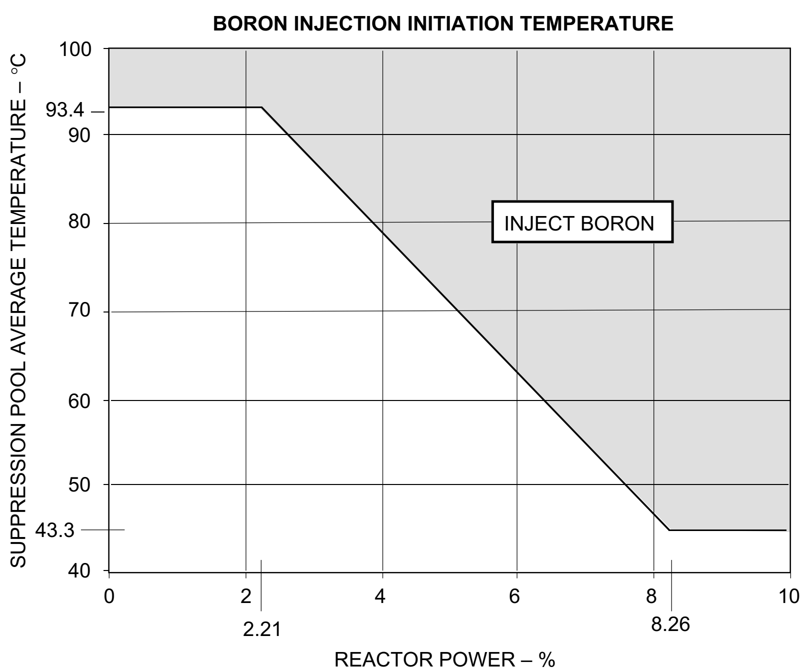
ABWR PC-1

SP/T Monitor and control suppression pool temperature below [35.0 °C (most limiting suppression pool temperature LCO)] using available suppression pool cooling.

When suppression pool temperature cannot be maintained below [35.0 ° C (most limiting suppression pool temperature LCO)]:

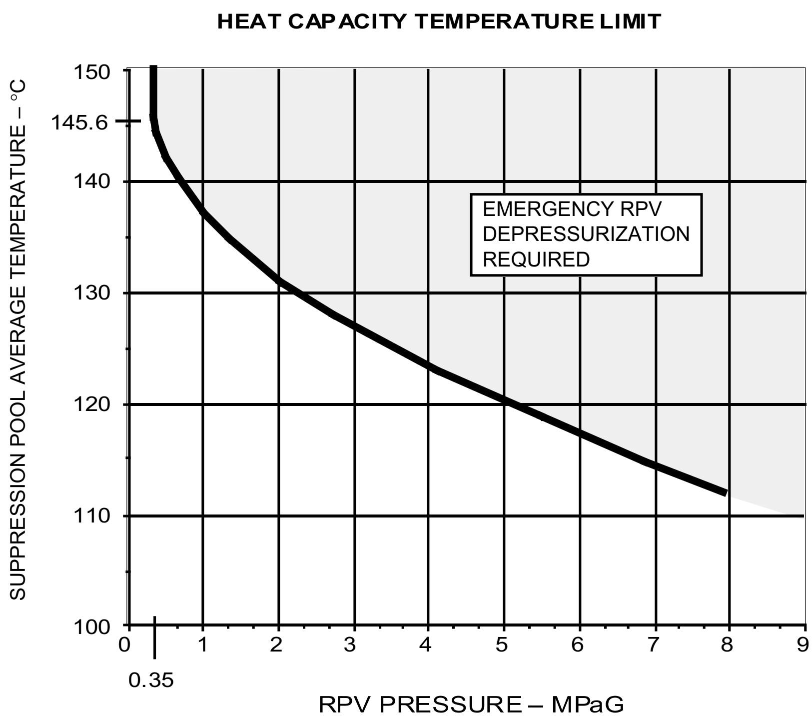
SP/T-1 Operate all available suppression pool cooling using only those RHR pumps not required to assure adequate core cooling by continuous operation in the LPCF mode.

SP/T-2 Before suppression pool temperature reaches the [(Boron Injection Initiation Temperature)], enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure.



ABWR PC-2

SP/T-3 When suppression pool temperature and RPV pressure cannot be maintained below the Heat Capacity Temperature Limit, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.



ABWR PC-3

DW/T Monitor and control drywell temperature below [57.2 ºC (drywell temperature LCO or maximum normal operating temperature, whichever is higher)] using available drywell cooling.

When drywell temperature cannot be maintained below [57.2 ºC (drywell temperature LCO or maximum normal operating temperature, whichever is higher)], shut down the reactor. ☞ #1

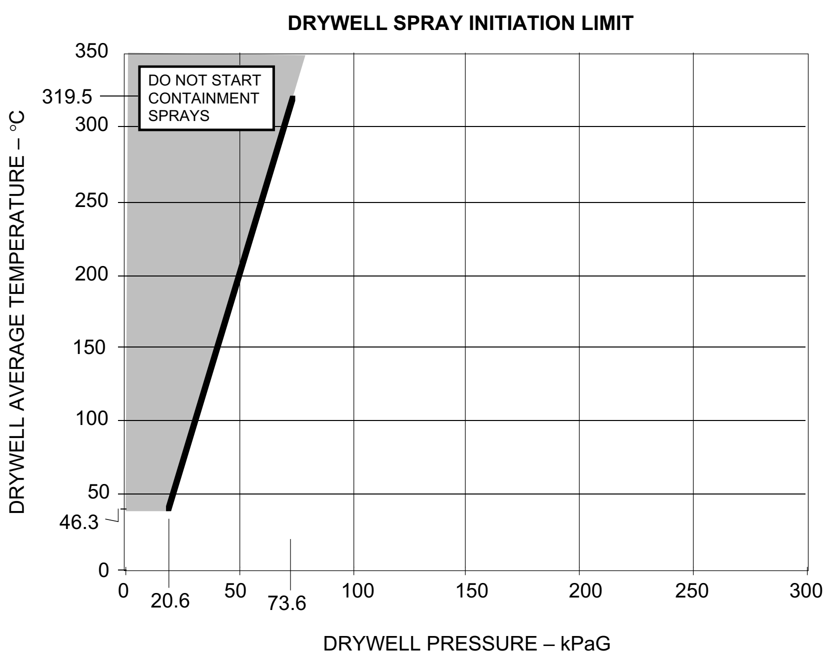
DW/T-1 Operate all available drywell cooling, defeating isolation interlocks if necessary.

When drywell temperature cannot be maintained below [103°C (Saturation temperature corresponding to high drywell pressure scram setpoint)], enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure.

> If while executing the following steps containment sprays have been initiated and suppression chamber or drywell pressure drops below [0.012 MPaG (high drywell pressure scram setpoint)], terminate containment sprays.

DW/T-2 Before drywell temperature reaches [171 °C (maximum temperature at which ADS qualified or drywell design temperature, whichever is lower)] but only if suppression pool water level is below [11.70 m (elevation of bottom of suppression pool-to-lower-drywell vent)] and drywell temperature and pressure are within the Drywell Spray Initiation Limit, shut down drywell cooling fans and initiate containment sprays using only those RHR subsystems (RHR(B), RHR(C)) not required to assure adequate core cooling by continuous operation in the LPCF mode.

If RHR(B) and RHR(C) are not available for containment sprays, initiate containment sprays using the fire protection system and firewater additon mode of RHR(C).



ABWR PC-5

DW/T-3 When drywell temperature cannot be maintained below [171 °C (maximum temperature at which ADS qualified or drywell design temperature, whichever is lower)], EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

ABWR PC-6

PC/P Monitor and control primary containment pressure below [0.012 MPaG (high drywell pressure scram setpoint)] using the ACS drywell bleed, SGTS and RBHVAC only if containment pressure is less than [0.014 MPaG (SGTS and RBHVAC design pressure)]; use [containment pressure control system operating procedures].

When primary containment pressure cannot be maintained below [0.012 MPaG (high drywell pressure scram setpoint)], or the offsite radioactivity release rate reaches the offsite release rate LCO, isolate the ACS drywell bleed.

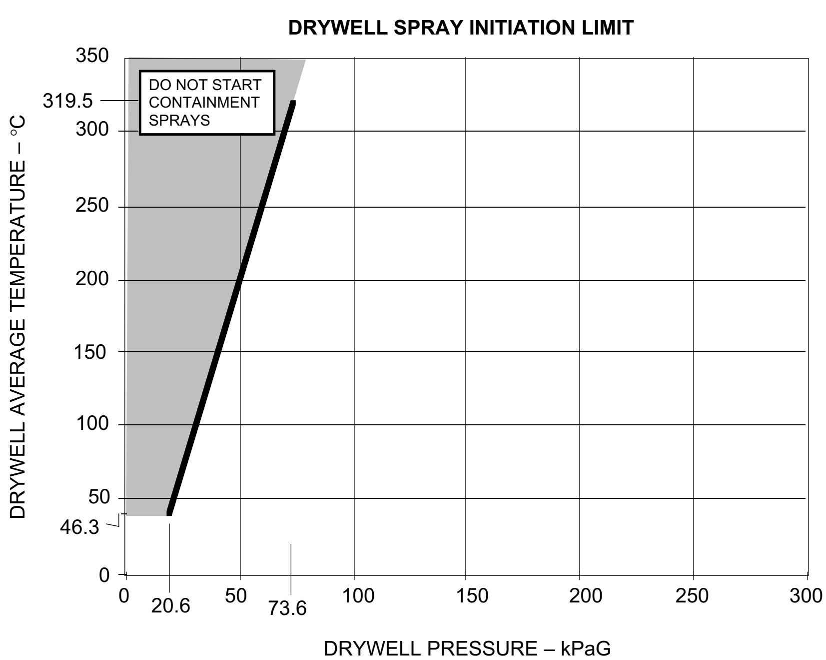
If while executing the following steps containment sprays have been initiated and suppression chamber or drywell pressure drops below [0.012 MPaG (high drywell pressure scram setpoint)], terminate containment sprays.

PC/P-1 (Deleted - not applicable to ABWR.)

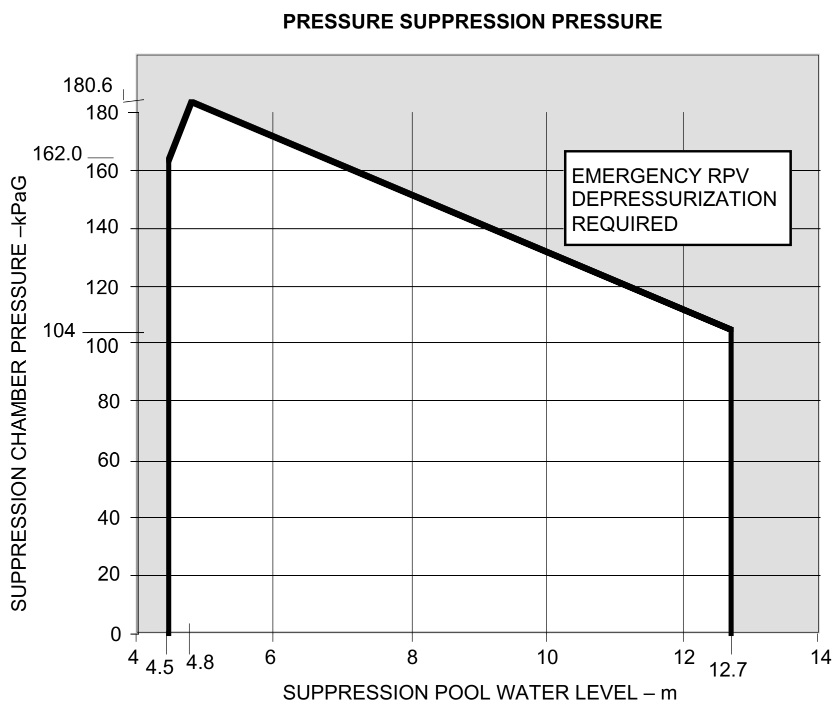
ABWR PC-7

PC/P-2 When suppression chamber pressure exceeds [0.072 MPaG (Suppression Chamber Spray Initiation Pressure)] but only if suppression pool water level is below [11.70 m (elevation of bottom of suppression pool-to-lower-drywell vent)] and drywell temperature and pressure are within the Drywell Spray lnitiation Limit, shutdown drywell cooling fans and initiate containment sprays using only those RHR subsystems (RHR(B), RHR(C)) not required to assure adequate core cooling by continuous operation in the LPCF mode.

If RHR(B) and RHR(C) are not available for containment sprays, initiate containment sprays using the fire protection system and the firewater addition mode of RHR(C).



PC/P-3 When suppression chamber pressure cannot be maintained below the Pressure Suppression Pressure, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.



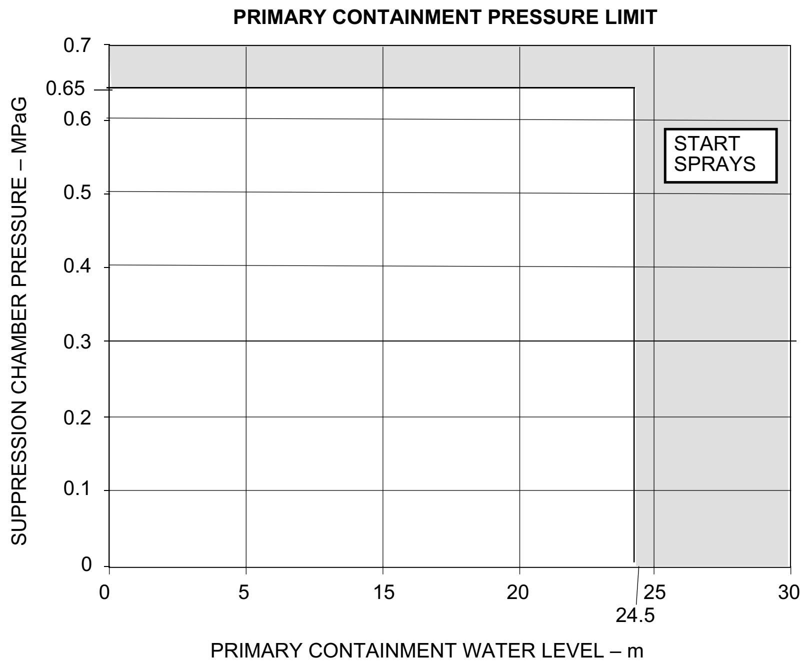
(PC/P-4 Deleted - not applicable to ABWR.)

ABWR PC-9

PC/P-5 When primary containment pressure reaches the range of [0.59 - 0.65 MPaG (Rupture diaphragm pressure range)] and the rupture diaphragms are actuated, do not isolate the containment vent path until directed by [procedure developed for post accident recovery].

ABWR PC-9.1

PC/P-6 When suppression chamber pressure cannot be maintained below [(the Primary Containment Pressure Limit)], then irrespective of whether adequate core cooling is assured:



If suppression pool water level is below [11.70 m (elevation of bottom of suppression pool-to-lower-drywell vent) and drywell temperature and pressure are within the Drywell Spray Initiation Limit, shut down drywell cooling fans and initiate containment sprays. Containment spray may be augmented by the fire protection system and the firewater addition mode of RHR(C) only when suppression chamber pressure is below [0.65 MPaG (pressure capability of the containment)] and primary containment water level is below [24.5 m (elevation of the main steamline penetration centerline)].

ABWR PC-10

SP/L Monitor and control suppression pool water level.

If while executing the following steps Primary Containment Flooding is required, enter [procedure developed from Contingency #6].

SP/L-1 Maintain suppression pool water level between [7.1 m (maximum suppression pool water level LCO)] and [7.0 m (minimum suppression pool water level LCO)]; refer to [sampling procedure] prior to discharging water. If suppression pool water level cannot be maintained above [7.0 m (minimum suppression pool water level LCO)], enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with step [SP/L-2].

- Use the following systems to makeup to the suppression pool:
  - SPCU
  - RCIC
  - HPCF
  - Fire protection system and firewater addition mode of RHR(C).
- Use the following systems to reject water from the suppression pool:
  - RHR

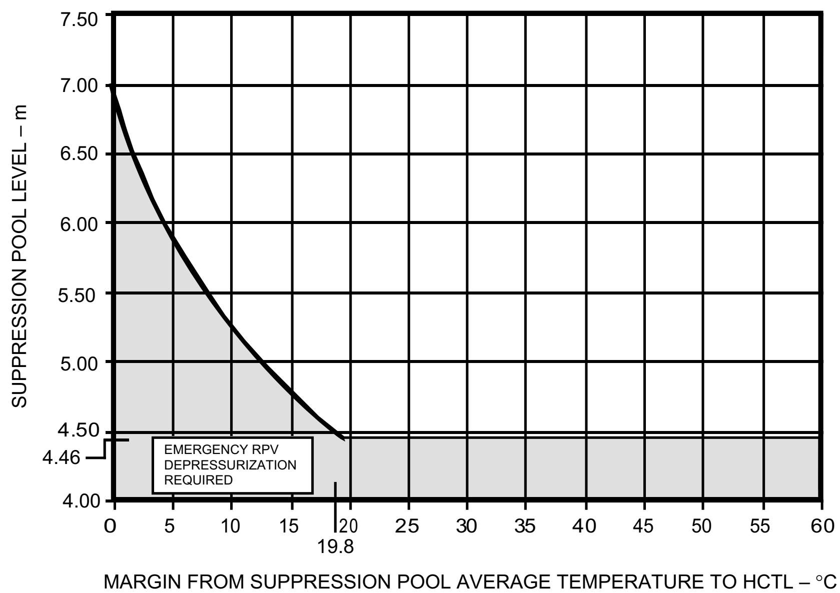
If suppression pool water level cannot be maintained above [7.0 m (minimum suppression pool water level LCO)], execute [Step SP/L-2].

If suppression pool water level cannot be maintained below [7.1 m (maximum suppression pool water level LCO)], execute [Step SP/L-3].

SP/L-2 SUPPRESSION POOL WATER LEVEL BELOW
[7.0 m (minimum suppression pool water level LCO)]

SP/L-2.1 Maintain suppression pool water level above the Heat Capacity Level Limit.

HEAT CAPACITY LEVEL LIMIT



where HCTL Margin = Heat Capacity Temperature Limit
- Suppression pool temperature.

If suppression pool water level cannot be maintained above the Heat Capacity Level Limit, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

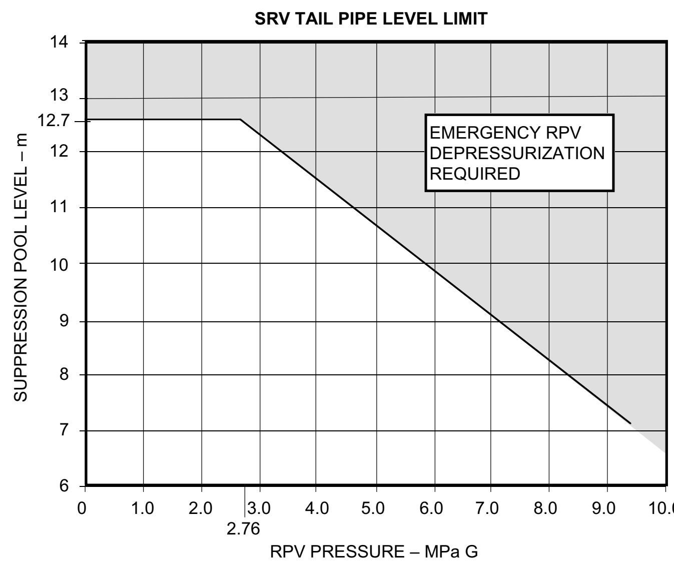
(SP/L-2.2 Deleted – not applicable to ABWR)

ABWR PC-12

SP/L-3 SUPPRESSION POOL WATER LEVEL ABOVE [7.1 m (maximum suppression pool water level LCO)]

Execute [Steps SP/L-3.1, SP/L-3.2, and SP/L-3.3] concurrently.

SP/L-3.1 Maintain suppression pool water level below the SRV Tail Pipe Level Limit.



If suppression pool water level cannot be maintained below the SRV Tail Pipe Level Limit, enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure.

If suppression pool water level and RPV pressure cannot be maintained below the SRV Tail Pipe Level Limit but only if adequate core cooling is assured, terminate injection into the primary containment from sources external to the primary containment except from boron injection systems and CRD.

If suppression pool water level and RPV pressure cannot be restored and maintained below the SRV Tail Pipe Level Limit, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

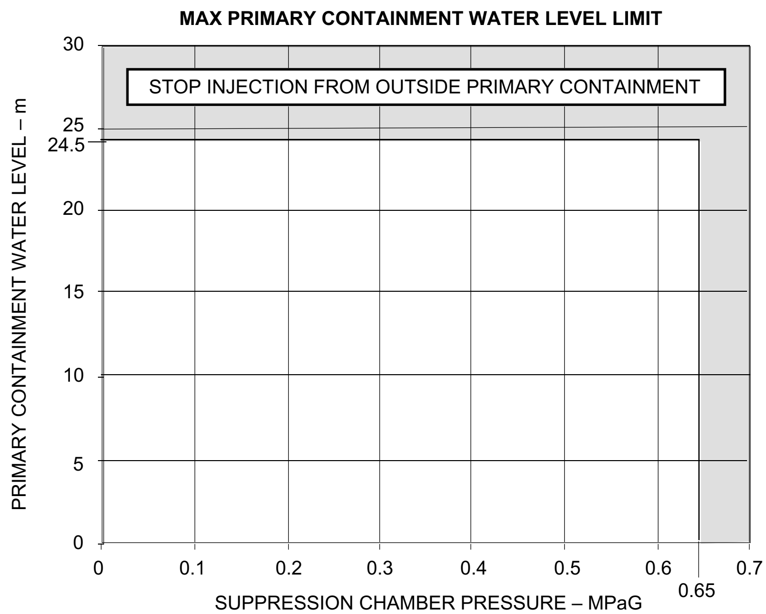
ABWR PC-13

SP/L–3.2 Maintain suppression pool water level below 11.70 m (elevation of the bottom of suppression pool-to-lower drywell vent)].

lf suppression pool water level cannot be maintained below [11.70 m (elevation of the bottom of suppression pool-to-lower drywell vent)]:

- Terminate containment sprays.
- If adequate core cooling is assured, terminate injection into the primary containment from sources external to the primary containment except from boron injection systems and CRD.

SP/L-3.3 Maintain primary containment water level below the Maximum Primary Containment Water Level Limit.



If primary containment water level cannot be maintained below the Maximum Primary Containment Water Level Limit, terminate injection into the primary containment from sources external to the primary containment irrespective of whether adequate core cooling is assured.

PC/H Monitor and control hydrogen and oxygen concentrations

If while executing the following steps:

- The hydrogen or oxygen monitoring system is or becomes unavailable, sample the drywell and suppression chamber for hydrogen and oxygen in accordance with [sampling procedure].
- Drywell or suppression chamber hydrogen concentration cannot be determined to be below 6% and drywell or suppression chamber oxygen concentration cannot be determined to be below 5%, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED; enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure; secure and prevent operation of the FCS and, initiate containment sprays in accordance with [Step PC/H-4] until drywell and suppression chamber hydrogen concentrations can be determined to be below 6% or drywell and suppression chamber oxygen concentrations can be determined to be below 5%.

PC/H-1 When drywell or suppression chamber hydrogen concentration reaches [0.1% (minimum detectable hydrogen concentration)], but only if the offsite radioactivity release rate is expected to remain below the offsite release rate LCO and primary containment pressure is below [0.014 MPaG (SGTS and RBHVAC design pressure)], vent and purge the primary containment, bypassing isolation interlocks (except drywell pressure and radiation interlocks) if necessary, to restore and maintain drywell and suppression chamber hydrogen concentrations below [0.1% (minimum detectable hydrogen concentration)] as follows:

If while executing the following steps the offsite radioactivity release rate reaches the offsite release rate LCO, or primary containment pressure exceeds [0.014 MPaG (SGTS and RBHVAC design pressure)], isolate the primary containment vent and purge.

ABWR PC-16

PC/H-1.1 Refer to [sampling procedure].

PC/H-1.2 Vent the primary containment using the ACS bleed line, SGTS and RBHVAC and purge the primary containment with nitrogen in accordance with [procedure for primary containment venting and purging].

PC/H-1.3 (Deleted)

Execute [Steps PC/H-2 and PC/H-3] concurrently.

PC/H-2 Monitor and control hydrogen and oxygen concentrations in the drywell.

PC/H-2.1 When drywell hydrogen concentration reaches [0.5% (minimum hydrogen concentration for recombiner operation or minimum detectable hydrogen concentration, whichever is higher)] but only if drywell hydrogen concentration is below [6% (maximum hydrogen concentration for recombiner operation or 6%, whichever is lower)] or drywell oxygen concentration is below [5% (maximum oxygen concentration for recombiner operation or 5%, whichever is lower)], and only if suppression pool level is below [11.70 m (elevation of bottom of suppression pool-to-lower drywell vent)], place FCS in service and enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure.

PC/H-2.2 When drywell hydrogen concentration reaches [6% (maximum hydrogen concentration for recombiner operation or 6%, whichever is lower)] and drywell oxygen concentration reaches [5% (maximum oxygen concentration for recombiner operation or 5%, whichever is lower)], secure FCS operation.

PC/H-2.3 Continue in this procedure at [Step PC/H-4].

PC/H-3 Monitor and control hydrogen and oxygen concentrations in the suppression chamber.

PC/H-3.1 When suppression chamber hydrogen concentration reaches [0.5% (minimum hydrogen concentration for recombiner operation or minimum detectable hydrogen concentration, whichever is higher)], but only if suppression pool level is below [11.70 m (elevation of bottom of suppression pool-to-lower drywell vent)], and only if drywell hydrogen concentration is below [6% (maximum hydrogen concentration for recombiner operation or 6%, whichever is lower)] or drywell oxygen concentration is below [5% (maximum oxygen concentration for recombiner operation or 5%, whichever is lower)], place FCS in service and enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure.

(PC/H-3.2 Deleted, not applicable to ABWR.)

PC/H-4 When drywell or suppression chamber hydrogen concentration reaches 6% and drywell or suppression chamber oxygen concentration is above 5%, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

> If while executing the following steps containment sprays have been initiated and suppression chamber or drywell pressure pressure drops below [0.012 MPaG (high drywell pressure scram setpoint)], terminate containment sprays.

PC/H-4.1 (Deleted - not applicable to ABWR.)

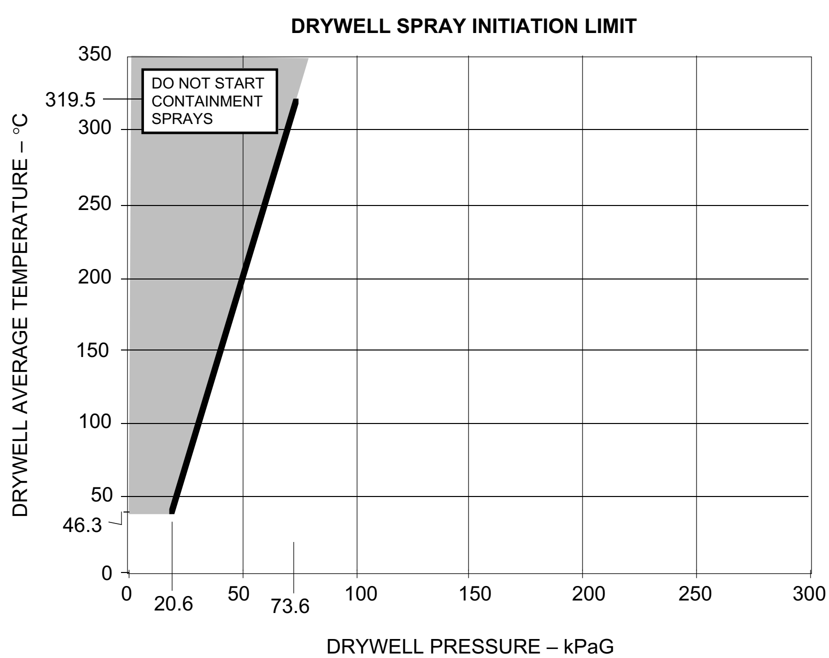
ABWR PC-20

PC/H-4.2 (Deleted - not applicable to ABWR.)

PC/H-4.3 (Deleted - not applicable to ABWR.)

PC/H-4.4 If suppression pool water level is below [11.70 m (elevation of bottom of suppression pool-to-lower-drywell vent)] and drywell temperature, and pressure are within the Drywell Spray lnitiation Limit, shut down drywell cooling fans and initiate containment sprays using only those RHR subsystems (RHR(B), RHR(C)) not required to assure adequate core cooling by continuous operation in the LPCF mode.

If RHR(B) and RHR(C) are not available for containment sprays, initiate containment sprays using the fire protection system and the firewater addition mode of RHR(C).



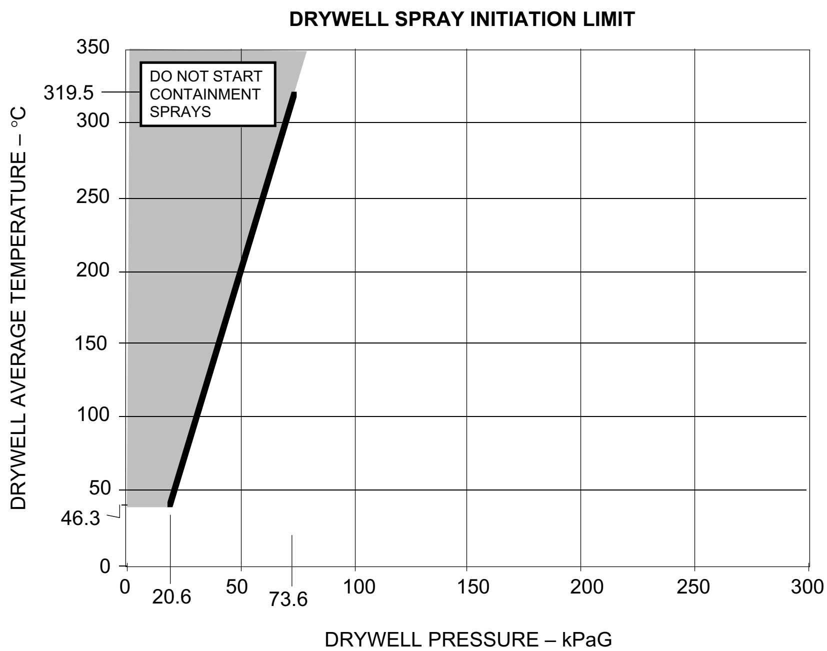
ABWR PC-21

PC/H-5 When drywell or suppression chamber hydrogen concentration cannot be restored and maintained below 6% and drywell or suppression chamber oxygen concentration cannot be restored and maintained below 5%, then irrespective of whether adequate core cooling is assured:

> If while executing the following steps containment sprays have been initiated and suppression chamber or drywell pressure drops below [0.012 MPaG (high drywell pressure scram setpoint)], terminate containment sprays.

PC/H-5.1 (Deleted - not applicable to ABWR.)

PC/H-5.2 If suppression pool water level is below [11.70 m (elevation of bottom of suppression pool-to-lower-drywell vent)] and drywell temperature and pressure are within the Drywell Spray Initiation Limit, shut down drywell cooling fans and initiate containment sprays.



ABWR PC-23

18A.6 Secondary Containment Control Guideline

SECONDARY CONTAINMENT CONTROL GUIDELINE

PURPOSE

The purpose of this guideline is to:

- Protect equipment in the secondary containment,
- Limit radioactivity release to the secondary containment, and either:
- Maintain secondary containment integrity, or
- Limit radioactivity release from the secondary containment.

ENTRY CONDITIONS

The entry conditions for this guideline are any of the following secondary containment conditions:

- Differential pressure at or above 0 mm of water
- An area temperature above the maximum normal operating temperature
- A HVAC cooler differential temperature above the maximum normal operating differential temperature
- A HVAC exhaust radiation level above the maximum normal operating radiation level
- An area radiation level above the maximum normal operating radiation level
- A floor drain sump water level above the maximum normal operating water level
- An area water level above the maximum normal operating water level

OPERATOR ACTIONS

If while executing the following steps secondary containment HVAC exhaust radiation level exceeds [2 μGy/h Reactor Building or 20 μGy/h Fuel Handling Area (secondary containment HVAC isolation setpoint)]:

- Confirm or manually initiate isolation of secondary containment HVAC, and
- Confirm initiation of or manually initiate SGTS.

If while executing the following steps:

- Secondary containment HVAC isolates, and,
- Secondary containment HVAC exhaust radiation level is below [2 μGy/h Reactor Building or 20 μGy/h Fuel Handling Area (secondary containment HVAC isolation setpoint)],

restart secondary containment HVAC, defeating high drywell pressure and low RPV water level isolation interlocks if necessary.

Irrespective of the entry condition, execute [Steps SC/T, SC/R and SC/L] concurrently.

SC/T Monitor and control secondary containment temperatures.

SC/T-1 Operate available area coolers.

SC/T-2 If secondary containment HVAC exhaust radiation level is below [2 µGy/h Reactor Building or 20 µGy/h Fuel Handling Area (secondary containment HVAC isolation setpoint)], operate available secondary containment HVAC.

SC/T-3 When an area temperature exceeds its maximum normal operating temperature, isolate all systems that are discharging into the area except systems required to shut down the reactor, assure adequate core cooling, protect primary containment integrity, or suppress a fire. ☞ #1

Execute [Steps SC/T-4 and SC/T-5] concurrently.

SC/T-4 If a primary system is discharging into secondary containment:

SC/T-4.1 Before any area temperature reaches its maximum safe operating temperature, enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure.

SC/T-4.2 When an area temperature exceeds its maximum safe operating temperature in more than one area, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

SC/T-5 When an area temperature exceeds its maximum safe operating temperature in more than one area, shut down the reactor.

SC/R Monitor and control secondary containment radiation levels.

SC/R-1 When an area radiation level exceeds its maximum normal operating radiation level, isolate all systems that are discharging into the area except systems required to shut down the reactor, assure adequate core cooling, protect primary containment integrity, or suppress a fire.

Execute [Steps SC/R-2 and SC/R-3] concurrently.

SC/R-2 If a primary system is discharging into secondary containment:

SC/R-2.1 Before any area tradiation level reaches its maximum safe operating radiation level, enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure.

SC/R-2.2 When an area radiation level exceeds its maximum safe operating radiation level in more than one area, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

SC/R-3 When an area radiation level exceeds its maximum safe operating radiation level in more than one area, shut down the reactor.

SC/L Monitor and control secondary containment water levels.

SC/L-1 When a floor drain sump or area water level is above its maximum normal operating water level, operate available sump pumps to restore and maintain it below its maximum normal operating water level.

If any floor drain sump or area water level cannot be restored and maintained below its maximum normal operating water level, isolate all systems that are discharging water into the sump or area except systems required to shut down the reactor, assure adequate core cooling, protect primary containment integrity, or suppress a fire.

Execute [Steps SC/L-2 and SC/L-3] concurrently.

SC/L-2 If a primary system is discharging into secondary containment:

SC/L-2.1 Before any area water level reaches its maximum safe operating water level, enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure.

SC/L-2.2 When an area water level exceeds its maximum safe operating water level in more than one area, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

SC/R-3 When an area water level exceeds its maximum safe operating water level in more than one area, shut down the reactor.

Table 1
Operating Values of Secondary Containment Parameters
(Cont.)

Secondary Containment Parameter	Maximum Normal Operating Value	Maximum Safe Operating Value
Area Temperature	°C	°C
El. -8200 T.M.S.L. (Floor 100-B3F)		
• HCU Area - 0°	40100	
• RHR(A) Pump & Hx Room65100		
• RCIC Room65100		
• HPCF(C) Pump Room65100		
• RHR(C) Pump & Hx Room65100		
• CRD Pump Room40100		
• HCU Area - 180°	40100	
• RHR(B) Pump & Hx Room65100		
• HPCF(B) Pump Room65100		
• CUW Non-Regen. Hx Room50100		
• CUW Pump Area40100		
El. -1700 T.M.S.L. (Floor 200-B2F)		
• TIP Area40100		
• ECCS Pump Maintenance Area40100		
• Valve Room A40100		
• Valve Room C40100		
• FMCRD & RIP Maintenance Area40100		
• Valve Room B40100		
• CUW Regen. Hx & Valve Area50100		
• CUW F/D Valve Area40100		
El. 4800 T.M.S.L. (Floor 300-B1F)		
• RPV Instrument Area 1 & 340100		
• RPV Instrument Area 2 & 440100		
• CUW/FPC F/D Area40100		
El. 12300 T.M.S.L. (Floor 400-1F)		
• Valve Room A40100		
• Valve Room C40100		
• FCS Area65100		
• Valve Room B40100		
• CUW Valve Area40100		
El. 18100 T.M.S.L. (Floor 500-2F)		
• Main Steam/FW Tunnel55171		
• FPC Area		
- Hx Area40100		
- Pump Area65100		
- Valve Area40100		

ABWRSC-6

Table 1
Operating Values of Secondary Containment Parameters
(Cont.)

Secondary Containment Parameter	Maximum Normal Operating Value	Maximum Safe Operating Value
Area Temperature	°C	°C
El. 23500 T.M.S.L. (Floor 600-3F)		
• SRV/MSIV Maintenance Room40100		
• SLC Area40100		
• SGTS Area		
- Fan Area65100		
- Filter Train Area40100		
El. 31700 T.M.S.L. (Floor 800-4F)		
• Dryer/Separator Area40100		
• Reactor Well Area40100		
• Spent Fuel Storage Area40100		

ABWRSC-7

Table 1
Operating Values of Secondary Containment Parameters
(Cont.)

Secondary Containment Parameter	Maximum Normal Operating Value	Maximum Safe Operating Value
<u>HVAC Cooler Differential Temperature</u>	℃	
RHR(A) Pump RoomHi	AlarmN/A	
RHR(B) Pump RoomHi	AlarmN/A	
RHR(C) Pump RoomHi	AlarmN/A	
HPCF(B) Pump RoomHi	AlarmN/A	
HPCF(C) Pump RoomHi	AlarmN/A	
RCIC Pump/Turbine RoomHi	AlarmN/A	
FPC(A)Hi	AlarmN/A	
FPC(B)Hi	AlarmN/A	
SGTS(B) i	AlarmN/A	
SGTS(C) i	AlarmN/A	
CAMS(A)Hi AlarmN/A		
CAMS(B)Hi AlarmN/A		
Main Steam/FW TunnelHi AlarmN/A		
FCS(B)Ii	AlarmN/A	
FCS(C)Ii	AlarmN/A	
RIP Handling Machine Control Room AHi AlarmN/A		
RIP Handling Machine Control Room BHi	AlarmN/A	
CRD Auto Exchanger Control Room AHi AlarmN/A		
CRD Auto Exchanger Control Room BHi AlarmN/A		
ISI Room AHi	AlarmN/A	
ISI Room BHi	AlarmN/A	
Primary Containment L/T Measurement RoomHi AlarmN/A		
Plant Outage Workers RoomHi AlarmN/A		
Refueling Machine Control RoomHi AlarmN/A		
CUW Non-Regen. Hx AreaHi	AlarmN/A	
CUW Regen. Hx AreaHi	AlarmN/A	
CUW Valve RoomHi AlarmN/A		

ABWRSC-8

Table 1
Operating Values of Secondary Containment Parameters
(Cont.)

Secondary Containment Parameter	Maximum Normal Operating Value	Maximum Safe Operating Value
HVAC Exhaust Radiation Level	10^{-5} Gy/h	
Reactor building0.1N/A		
Refuel floor (Fuel Handling Area)1N/A		
Area Radiation Level	10^{-5} Gy/h	10^{-5} Gy/h
El. -8200 T.M.S.L. (Floor 100-B3F)		
• HCU Area - 0°	5____	
• RHR(A) Pump & Hx Room30____		
• RCIC Room200____		
• HPCF(C) Pump Room5____		
• RHR(C) Pump & Hx Room30____		
• CRD Pump Room5____		
• HCU Area - 180°	5____	
• RHR(B) Pump & Hx Room30____		
• HPCF(B) Pump Room5____		
• CUW Non-Regen. Hx Room	20,000	____
• CUW Pump Area500____		
El. -1700 T.M.S.L. (Floor 200-B2F)		
• TIP Area5		____
• ECCS Pump Maintenance Area5		____
• Valve Room A5		____
• Valve Room C5		____
• FMCRD & RIP Maintenance Area5		____
• Valve Room B5		____
• CUW Regen. Hx & Valve Area	20,000	____
• CUW F/D Valve Area5		____
El. 4800 T.M.S.L. (Floor 300-B1F)		
•RPV Instrument Area 1 & 35____		
•RPV Instrument Area 2 & 45____		
• CUW/FPC F/D Area5____		
El. 12300 T.M.S.L. (Floor 400-1F)		
• Valve Room A5		____
• Valve Room C5		____
• FCS Area5____		
• Valve Room B5		____
• CUW Valve Area5		____

ABWRSC-9

Table 1
Operating Values of Secondary Containment Parameters
(Cont.)

Secondary Containment Parameter	Maximum Normal Operating Value	Maximum Safe Operating Value
Area Radiation Level	10^{-5} Gy/h	10^{-5} Gy/h
El. 18100 T.M.S.L. (Floor 500-2F)		
■ Main Steam/FW Tunnel	5000	___
■ FPC Area		
– Hx Area	5	___
– Pump Area	5	___
– Valve Area	5	___
El. 23500 T.M.S.L. (Floor 600-3F)		
■ SRV/MSIV Maintenance Room	5	___
■ SLC Area	5	___
■ SGTS Area		
– Fan Area	5	___
– Filter Train Area	5	___
El. 31700 T.M.S.L. (Floor 800-4F)		
■ Dryer/Separator Area	5	___
■ Reactor Well Area	5	___
■ Spent Fuel Storage Area	5	___

ABWR SC-10

Table 1
Operating Values of Secondary Containment Parameters
(Cont.)

Secondary Containment Parameter	Maximum Normal Operating Value	Maximum Safe Operating Value
Floor Drain Sump Water Level	cm	
Sump HCU Area - 0°	Hi Hi Alarm	N/A
Sump RHR(A) & RCIC AreaHi Hi AlarmN/A		
Sump RHR(C) & HPCF(C) AreaHi Hi AlarmN/A		
Sump HCU Area - 180°	Hi Hi Alarm	N/A
Sump RHR(B) & HPCF(B) AreaHi Hi AlarmN/A		
Area Water Level	cm	cm
El. -8200 T.M.S.L. (Floor 100-B3F)		
• HCU Area - 0°	5127	
• RHR(A) Pump & Hx Room5213		
• RCIC Room5140		
• HPCF(C) Pump Room5288		
• RHR(C) Pump & Hx Room5213		
• CRD Pump Room570		
• HCU Area - 180°	5127	
• RHR(B) Pump & Hx Room5213		
• HPCF(B) Pump Room5288		
• CUW Non-Regen. Hx Room5>20		
• CUW Pump Area585		
El. -1700 T.M.S.L. (Floor 200-B2F)		
• TIP Area5>20		
• ECCS Pump Maintenance Area5>20		
• Valve Room A5*		
• Valve Room C5>20		
• FMCRD & RIP Maintenance Area5>20		
• Valve Room B5>20		
• CUW Regen. Hx & Valve Area5>20		
• CUW F/D Valve Area5>20		
El. 4800 T.M.S.L. (Floor 300-B1F)		
• RPV Instrument Area 1 & 35>20		
• RPV Instrument Area 2 & 45>20		
• CUW/FPC F/D Area5>20		
* Level of detail not available; should be bottom of MOV elevation.		

ABWRSC-11

Table 1
Operating Values of Secondary Containment Parameters
(Cont.)

Secondary Containment Parameter	Maximum Normal Operating Value	Maximum Safe Operating Value
Area Water Level	cm	cm
El. 12300 T.M.S.L. (Floor 400-1F)		
• Valve Room A5>20		
• Valve Room C5>20		
• FCS Area5>20		
• Valve Room B5>20		
• CUW Valve Area5>20		
El. 18100 T.M.S.L. (Floor 500-2F)		
• Main Steam/FW Tunnel5400		
• FPC Area		
- Hx Area5>20		
- Pump Area5100		
- Valve Area5>20		
El. 23500 T.M.S.L. (Floor 600-3F)		
• SRV/MSIV Maintenance Room5>20		
• SLC Area546		
• SGTS Area		
- Fan Area5>20		
- Filter Train Area5>20		

ABWRSC-12

18A.7 Radioactivity Release Control Guideline

RADIOACTIVITY RELEASE CONTROL GUIDELINE

PURPOSE

The purpose of this guideline is to limit radioactivity release into areas outside the primary and secondary containments

ENTRY CONDITIONS

The entry conditions for this guideline is

- Offsite radioactivity release rate above the offsite release rate which requires an Alert.

OPERATOR ACTIONS

If while executing the following steps turbine building HVAC is shutdown restart turbine building HVAC.

RR-1 Isolate all primary systems that are discharging into areas outside the primary and secondary containments except systems required to assure adequate core cooling or shut down the reactor.

If the radioactivity release rate continues to increase enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure.

RR-2 When offsite radioactivity release rate approaches or exceeds the offsite release rate which requires a General Emergency but only if a primary system is discharging into an area outside the primary and secondary containments, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED.

ABWR RR-1

18A.8 Contingency #1, Alternative Level Control

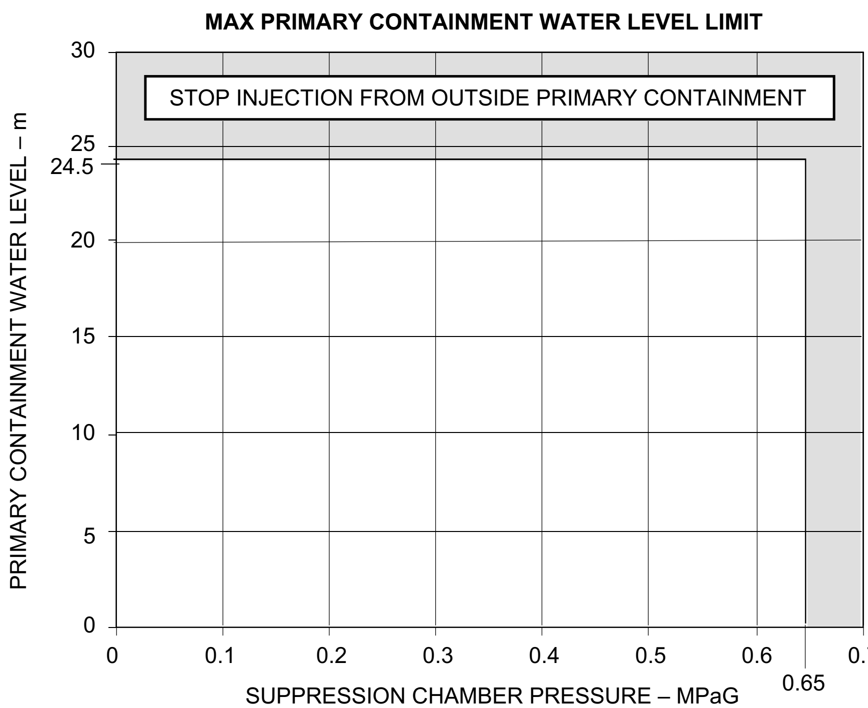
CONTINGENCY#1
ALTERNATIVE LEVEL CONTROL

If while executing the following steps:

- Any control rod cannot be determined to be inserted to or beyond 4.2% (Maximum Subcritical Banked Withdrawal Position)] and it has not been determined that the reactor will remain shutdown under all conditions without boron, enter [procedure developed from Contingency #5].
- RPV water level cannot be determined, enter [procedure developed from Contingency #4].
- RPV water level is increasing, enter [procedure developed from the RPV Control Guideline] at [Step RC/L].
- RPV water level drops below [34.7 cm (ADS initiation setpoint)], prevent automatic initiation of ADS.

ABWR C1-1

If while executing the following steps primary containment water level and suppression chamber pressure cannot be maintained below the Maximum Primary Containment Water Level Limit, then irrespective of whether adequate core cooling is assured terminate injection into the primary containment from sources external to the primary containment until primary containment water level and suppression chamber pressure can be maintained below the Maximum Primary Containment Water Level Limit.



ABWR C1-2

(C1-1 Deleted -- not applicable to ABWR)

C1-2 Line up for injection, start pumps, and irrespective of pump NPSH and vortex limits, increase injection flow to the maximum with 2 or more of the following injection subsystems:

- Feedwater / Condensate
- HPCF(B)
- HPCF(C)
- RHR-A (LPCF)
- RHR-B (LPCF)
- RHR-C (LPCF)

If less than 2 of the injection subsystems can be lined up, commence lining up as many of the following alternate injection subsystems as possible:

- Fire protection system and the firewater addition mode of RHR(C)
- [Interconnections with other units]
- ECCS keep-full systems:
  HPCF, RHR
- SLC (test tank)
- Condensate Makeup Water System

C1-3 If RPV pressure is above [1.37 MPaG (highest RPV pressure at which the shutoff head of a low-water-quality alternate injection subsystem (excluding SLC) is reached)]:

> If while executing the following steps RPV pressure drops below [1.37 MPaG (highest RPV pressure at which the shutoff head of a low-water-quality alternate injection subsystem (excluding SLC) is reached)], continue in this procedure at [Step C1-4].

C1-3.1 If no injection subsystem is lined up for injection with at least one pump running, start pumps in alternate injection subsystems which are lined up for injection.

C1-3.2 When RPV water level drops to [0 cm (top of active fuel)]:

- If any system, injection subsystem or alternate injection subsystem is lined up with at least one pump running, EMERGENCY RPV DEPRESSURIZATION lS REQUIRED.
- If no system, injection subsystem or alternate injection subsystem is lined up with at least one pump running, STEAM COOLING IS REQUIRED.

C1-4 When RPV pressure drops below [1.37 MPaG (highest RPV pressure at which the shutoff head of a low-water-quality alternate injection subsystem (excluding SLC) is reached)]:

C1-4.1 Line up for injection, start pumps, and irrespective of pump NPSH and vortex limits, increase injection flow to the maximum with all systems and injection subsystems.

ABWR C1-4

C1-4.2 When RPV water level drops to [0 cm (top of active fuel)], EMERGENCY RPV DEPRESSURIZATION IS REQUIRED; line up for injection, start pumps, and increase injection flow to the maximum with all alternate injection subsystems.

If RPV water level cannot be restored and maintained above [0 cm (top of active fuel)], PRIMARY CONTAINMENT FLOODING IS REQUIRED; enter [procedure developed from Contingency #6].

18A.9 Contingency #2, Emergency RPV Depressurization

CONTINGENCY#2
EMERGENCY RPV DEPRESSURIZATION

C2-1 When either: ☞ #6

- All control rods are inserted to or beyond [4.2% (Maximum Subcritical Banked Withdrawal Position)], or
- It has been determined that the reactor will remain shutdown under all conditions without boron, or
- All injection into the RPV except from boron injection systems, CRD, and RCIC has been terminated and prevented,

C2-1.1 If a high drywell pressure ECCS initiation signal [0.012 MPaG (drywell pressure which initiates ECCS)] exists, prevent injection from those RHR pumps not required to assure adequate core cooling.

(C2-1.2 Deleted -- Not applicable to ABWR)

C2-1.3 If suppression pool water level is above [2.291 m (elevation of top of SRV discharge device)]:

- Open all ADS valves.
- If any ADS valve cannot be opened, open other SRVs until

  [8 (number of SRVs dedicated to ADS)] valves are open.

ABWR C2-1

Execute Step [C2-1.4] and [Step C2-1.5] concurrently.

C2-1.4 If [8 (number of SRVs dedicated to ADS)] SRVs cannot be opened, open the ADS valves using nitrogen stored in bottles of the High Pressure Nitrogen Gas Supply system using [procedure for opening ADS SRVs with nitrogen bottles].

C2-1.5 If less than [6 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs are open, rapidly depressurize the RPV, defeating isolation interlocks if necessary, using one or more of the following:

- Main condenser
- Main steam line drains
- RCIC steam line
- Head vent
- [Other steam driven equipment]

If RPV water level cannot be determined, enter [procedure developed from Contingency #4].

C2-2 When either:

- All control rods are inserted to or beyond [4.2% (Maximum Subcritical Banked Withdrawal Position)], or
- It has been determined that the reactor will remain shutdown under all conditions without boron, or
- [541.8 kg (Cold Shutdown Boron Weight)] of boron have been injected into the RPV, or
- The reactor is shutdown and no boron has been injected into the RPV,

enter [procedure developed from the RPV Control Guideline] at [Step RC/P-4].

18A.10 Contingency #3, Steam Cooling

CONTINGENCY#3
STEAM COOLING

C3-1Perform steam cooling operation as follows:

> If while executing this step Emergency RPV Depressurization is required, RPV water level cannot be determined, or any system, injection subsystem, or alternate injection subsystem is lined up for injection with at least one pump running, enter [procedure developed from Contingency #2].

When RPV water level drops to [-111.2 cm (Minimum Zero-lnjection RPV Water Level)] enter [procedure developed from Contingency #2].

ABWRC3-1

18A.11 Contingency #4, RPV Flooding

CONTINGENCY#4
RPV FLOODING

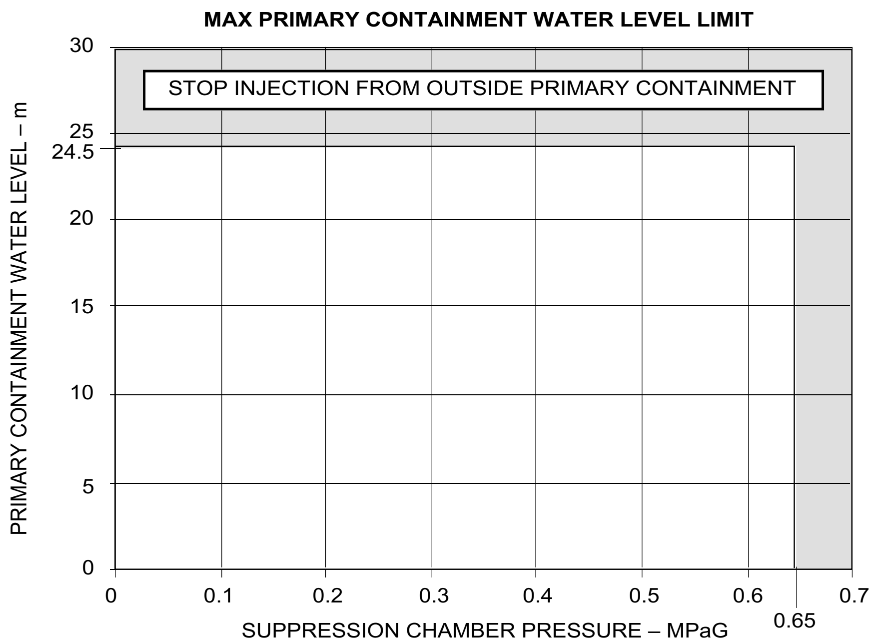
If while executing the following steps RPV water level can be determined:

- If any control rod cannot be determined to be inserted to or beyond [4.2% (Maximum Subcritical Banked Withdrawal Position)] and it has not been determined that the reactor will remain shutdown under all conditions without boron, enter [procedure developed from Contingency #5] and [procedure developed from RPV Control Guideline] at [Step RC/P-4] and execute these procedures concurrently.

- If all control rods are inserted to or beyond [4.2% (Maximum Subcritical Banked Withdrawal Position)] or it has been determined that the reactor with remain shutdown under all conditions without boron, enter [procedure developed from the RPV Control Guideline] at [Steps RC/L and RC/P-4] and execute these steps concurrently.

ABWR C4-1

If while executing the following steps primary containment water level and suppression chamber pressure cannot be maintained below the Maximum Primary Containment Water Level Limit, then irrespective of whether adequate core cooling is assured terminate injection into the primary containment from sources external to the primary containment until primary containment water level and suppression chamber pressure can be maintained below the Maximum Primary Containment Water Level Limit.



ABWR C4-2

C4-1 If any control rod cannot be determined to be inserted to or beyond [4.2% (Maximum Subcritical Banked Withdrawal Position)] and it has not been determined that the reactor will remain shutdown under all conditions without boron, flood the RPV as follows:

If while executing the following steps either all control rods are inserted to or beyond [4.2% (Maximum Subcritical Banked Withdrawal Position)] or it has be been determined that the reactor will remain shutdown under all conditions without boron but RPV water level cannot be determined, continue in this procedure at [Step C4-2].

C4-1.1 Terminate and prevent all injection into the RPV except from boron injection systems and CRD until RPV pressure is below the Minimum Alternate RPV Flooding Pressure.

Number of open SRVs	Minimum Alternate RPV Flooding Pressure (MPaG)
8 or more	0.93
7	1.08
6	1.27
5	1.55
4	1.96
3	2.65
2	4.02

If less than [2 (minimum number of SRVs for which the Minimum Alternate RPV Flooding Pressure is below the lowest SRV lifting pressure)] SRVs can be opened, continue in this procedure.

C4-1.2 If at least [6 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs can be opened, close the MSIVs, main steam line drain valves,and RClC isolation valves.

C4-1.3 Commence and, irrespective of pump NPSH and vortex limits, slowly increase injection into the RPV with the following systems until at least [2 (minimum number of SRVs for which the Minimum Alternate RPV Flooding Pressure is below the lowest SRV lifting pressure)] SRVs are open and RPV pressure is above the Minimum Alternate RPV Flooding Pressure: ☞ #7

- Motor driven feedwater pumps, defeating high RPV water level isolation interlocks if necessary.
- Condensate pumps
- CRD
- RHR (LPCF)

If less than [2 (minimum number of SRVs for which the Minimum Alternate RPV Flooding Pressure is below the lowest SRV lifting pressure)] SRVs are open or RPV pressure cannot be increased to above the Minimum Alternate RPV Flooding Pressure, commence and, irrespective of pump NPSH and vortex limits, slowly increase injection into the RPV with the following systems until at least [2 (minimum number of SRVs for which the Minimum Alternate RPV Flooding Pressure is below the lowest SRV lifting pressure)] SRVs are open and RPV pressure is above the Minimum Alternate RPV Flooding Pressure:

- HPCF, defeating high RPV water level isolation interlocks if necessary.
- Fire protection system and the firewater addition mode of RHR(C)
- ECCS keep-full systems
  HPCF, RHR
- Condensate Makeup Water System

If less than [2 (minimum number of SRVs for which the Minimum Alternate RPV Flooding Pressure is below the lowest SRV lifting pressure)] SRVs are open or RPV pressure cannot be increased to above the Minimum Alternate RPV Flooding Pressure, PRIMARY CONTAINMENT FLOODING IS REQUIRED; enter [procedure developed from Contingency #6] and [procedure developed from the RPV Control Guideline] at [Step RC/P-4] and execute these procedures concurrently.

C4-1.4 When at least [2 (minimum number of SRVs for which the Minimum Alternate RPV Flooding Pressure is below the lowest SRV lifting pressure)] SRVs are open and RPV pressure is above the Minimum Alternate RPV Flooding Pressure, control injection to maintain at least [2 (minimum number of SRVs for which the Minimum Alternate RPV Flooding Pressure is below the lowest SRV lifting pressure)] SRVs open and RPV pressure above the Minimum Alternate RPV Flooding Pressure but as low as practicable.

C4-1.5 When all control rods are inserted to or beyond [4.2% (Maximum Subcritical Banked Withdrawal Position)] or it has been determined that the reactor will remain shutdown under all conditions without boron, continue in this procedure.

C4-2 If at least [6 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs can be opened or if a HPCF or motor driven feedwater pump is available for injection, close the MSIVs, main steam line drain valves, and RCIC isolation valves.

ABWR C4-5

C4-3 Flood the RPV as follows:

C4-3.1 Commence and, irrespective of pump NPSH and vortex limits, increase injection into the RPV with the following systems until at least [6 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs are open and RPV pressure is not decreasing and is [0.354 MPaG (Minimum RPV Flooding Pressure)] or more above suppression chamber pressure:

- HPCF, defeating high RPV water level isolation interlocks if necessary.
- Motor driven feedwater pumps, defeating high RPV water level isolation interlocks if necessary.
- RHR (LPCF)
- Condensate pumps
- CRD
- Fire protection system and firewater addition mode of RHR(C)
- [Interconnections with other units]
- ECCS keep-full systems
  HPCF, RHR
- SLC (test tank)
- Condensate Makeup Water System

lf less than [6 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs are open or RPV pressure cannot be maintained at least [0.354 MPaG (Minimum RPV Flooding Pressure)] above suppression chamber pressure, PRIMARY CONTAINMENT FLOODING IS REQUIRED; enter [procedure developed from Contingency #6] and [procedure developed from the RPV Control Guideline] at [Step RC/P-4] and execute these procedures concurrently.

C4-3.2 When at least [6 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs are open and RPV pressure can be maintained at least [0.354 MPaG (Minimum RPV Flooding Pressure)] above suppression chamber pressure, control injection to maintain at least [6 (Minimum Number of SRVs Required for Emergency Depressurization)] SRVs open and RPV pressure at least [0.354 MPaG (Minimum RPV Flooding Pressure)] above suppression chamber pressure but as low as practicable.

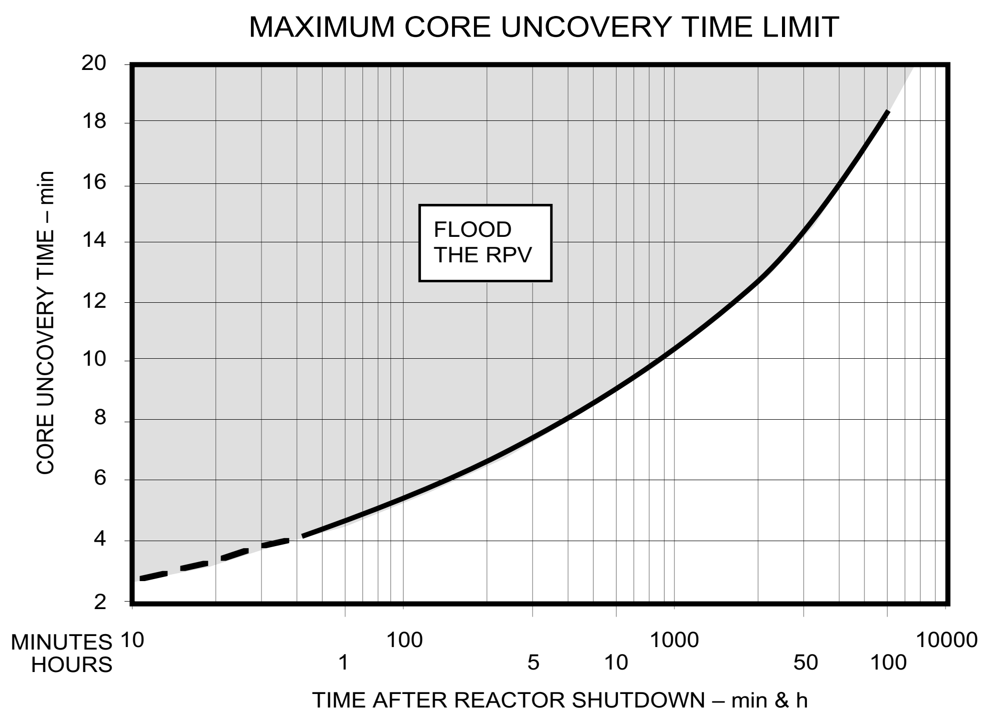
C4-4 When:

- RPV water level instrumentation is available, and
- Temperature[s] [near the cold reference leg instrument vertical runs] are below 100° C, and
- RPV pressure has remained at least [0.354 MPaG (Minimum RPV Flooding Pressure)] above suppression chamber pressure for at least [the Minimum Core Flooding Interval]

Number of open SRVs	Minimum Core Flooding Interval (Min)
8 or more	43.5
7	59.4
6	84.3

Terminate all injection into the RPV and reduce RPV water level until RPV water level indication is restored.

If RPV water level indication is not restored within the Maximum Core Uncovery Time Limit after commencing termination of injection into the RPV, return to [Step C4-3.1].



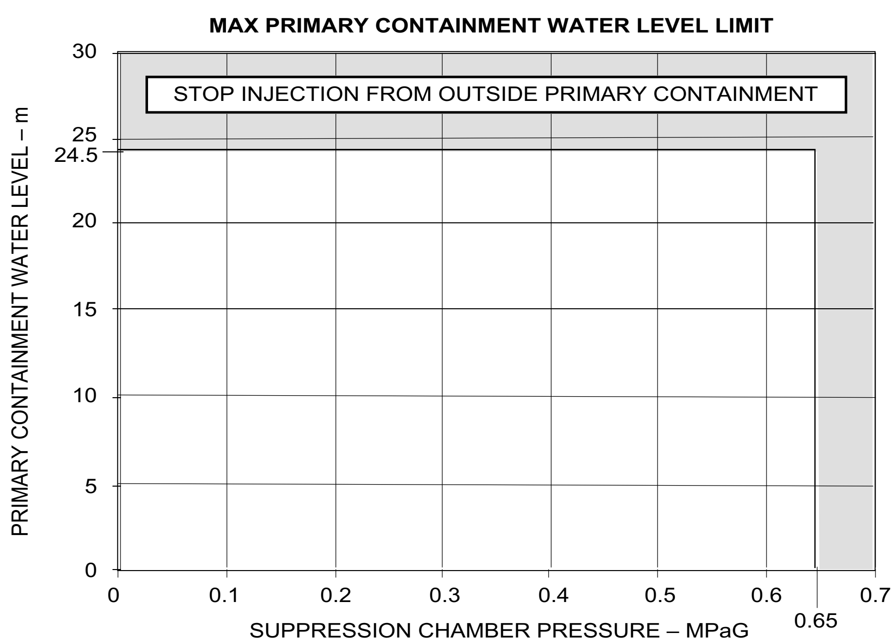
C4-5 Enter [procedure developed from the RPV Control Guideline] at [Steps RC/L and RC/P-4] and execute these steps concurrently.

18A.12 Contingency #5, Level/Power Control

CONTINGENCY#5
LEVEL POWER CONTROL

If while executing the following steps:

- RPV water level cannot be determined, enter [procedure developed from Contingency #4].
- All control rods are inserted to or beyond [4.2% (Maximum Subcritical Banked Withdrawal Position)] or it has been determined that the reactor will remain shutdown under all conditions without boron, enter [procedure developed from the RPV Control Guideline] at [Step RC/L].
- Primary containment water level and suppression chamber pressure cannot be maintained below the Maximum Primary Containment Water Level Limit, then irrespective of whether adequate core cooling is assured terminate injection into the primary containment from sources external to the primary containment until primary containment water level and suppression chamber pressure can be maintained below the Maximum Primary Containment Water Level Limit.



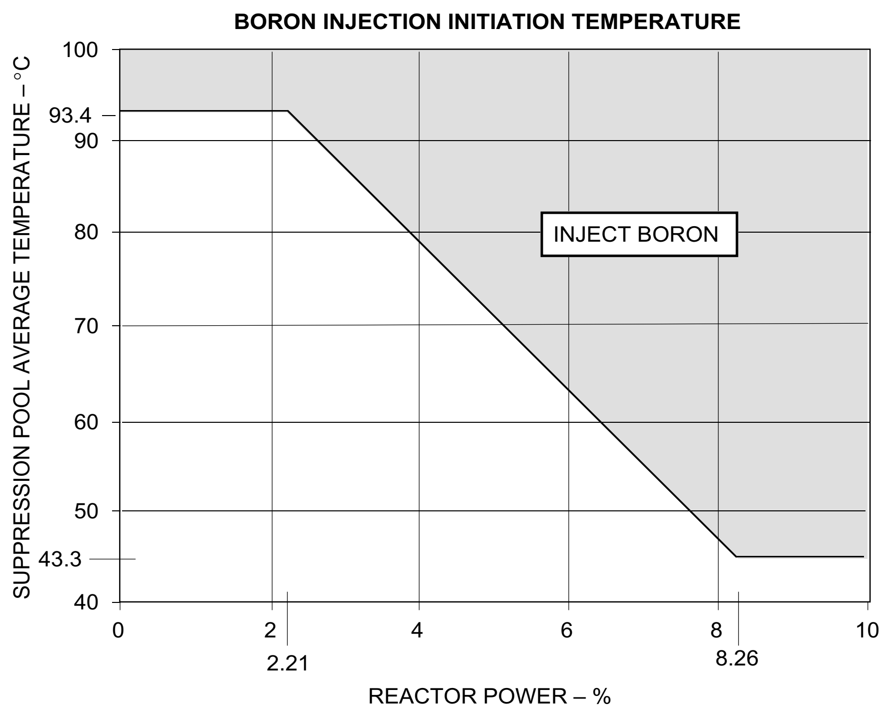
ABWR C5-1

C5-1 Prevent automatic initiation of ADS.

C5-2 If any MSL is not isolated, bypass low RPV water level interlocks to maintain the main Condenser as a heat sink.

C5-3 If:

- Reactor power is above [5% (APRM downscale trip)] or cannot be determined, and
- Suppression pool temperature is above the Boron Injection Initiation Temperature, and



- Either an SRV is open or opens or drywell pressure is above [0.012 MPaG (high drywell pressure scram setpoint)],

ABWR C5-2

C5-3 (continued)

Then:

- Lower RPV water level, irrespective of any reactor power or RPV water level oscillations, by terminating and preventing all injection into the RPV except from boron injection systems and CRD until either:
  - Reactor power drops below [5% (APRM downscale trip)], or
  - RPV water level reaches [0 cm (top of active fuel)], or
  - All SRVs remain closed and drywell pressure remains below [0.012 MPaG (high drywell pressure scram setpoint)].

ABWR C5-2.1

If while executing the following steps Emergency RPV Depressurization is required, continue in this procedure at [Step C5-5.1].

If while executing the following step:

- Reactor power is above [5% (APRM downscale trip)] or cannot be determined, and
- RPV water level is above [0 cm (top of active fuel)], and
- Suppression pool temperature is above [the Boron Injection lnitiation Temperature], and
- Either an SRV is open or opens or drywell pressure is above [0.012 MPaG (high drywell pressure scram setpoint)],

return to [Step C5-3].

C5-4 If RPV water level is above [164.9 cm (Maximum Power Control RPV Water Level)] and the reactor is not shutdown:

- Lower RPV water level to below [164.9 cm (Maximum Power Control RPV Water Level)] by terminating and preventing all injection into the RPV except from boron injection systems and CRD.

C5-5 Maintain RPV water level between [-79.5cm (Minimum Steam Cooling RPV Water Level)] and either: ☞ #7

- If RPV water level was deliberately lowered in [Step C5-3 or C5-4], the level to which it was lowered, or
- If RPV water level was not deliberately lowered in [Step C5-3 or C5-4], [484.4 cm (high level trip setpoint)], with the following systems:
  - Condensate/feedwater
  - CRD

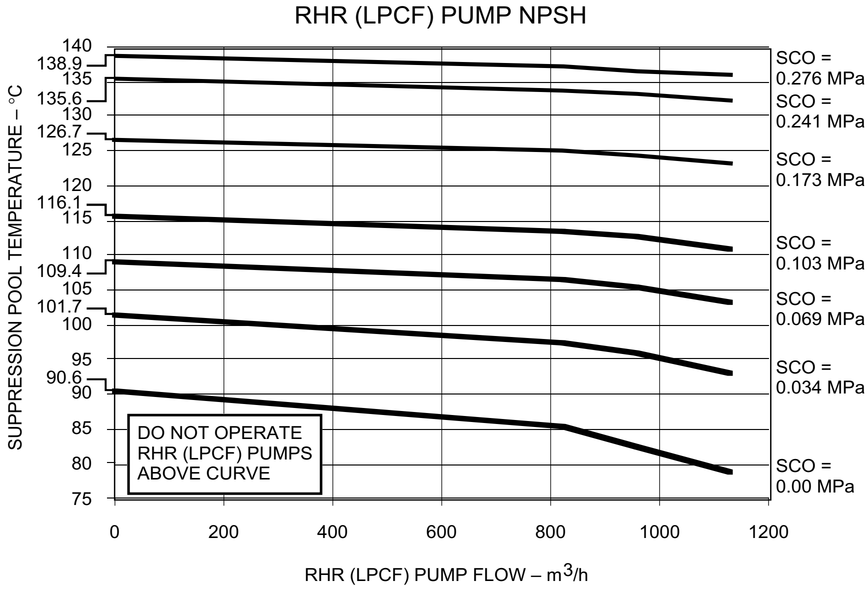
ABWR C5-3

- RCIC with suction from the condensate storage tank, bypassing low RPV pressure and area high temperature isolation interlocks and high suppression pool water level suction transfer logic if necessary. ☞ #3,4

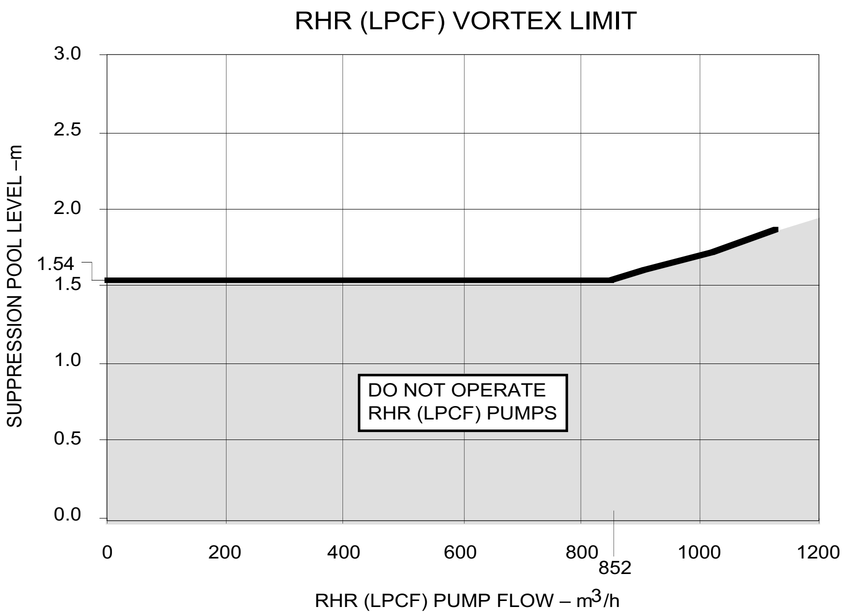
- RHR (LPCF)

ABWR C5 3.1

- RHR (LPCF); control and maintain pump flow less than the RHR Pump NPSH Limit and the RHR Vortex Limit.



KEY: SUPPRESSION CHAMBER OVERPRESSURE (SCO) = SC AIRSPACE PRESSURE + WATER HEAD OVER SUCTION STRAINER



ABWR C5-4

If RPV water level cannot be maintained above [-79.5 cm (Minimum Steam Cooling RPV Water Level)], EMERGENCY RPV DEPRESSURIZATION IS REQUIRED:

C5-5.1 Terminate and prevent all injection into the RPV except from boron injection systems, CRD, and RCIC until RPV pressure is below the Minimum Alternate RPV Flooding Pressure.

Number of open SRVs	Minimum Alternate RPV Flooding Pressure (MPaG)
8or more	0.93
7	1.08
6	1.27
5	1.55
4	1.96
3	2.65
2	4.02

If less than [2 (minimum number of SRVs for which the Minimum Alternate RPV Flooding Pressure is below the lowest SRV lifting pressure)] SRVs can be opened, continue in this procedure.

C5-5.2 Commence and, irrespective of pump NPSH and vortex limits, slowly increase injection into the RPV with the following systems to restore and maintain RPV water level above [-79.5 cm (Minimum Steam Cooling RPV Water Level)]: ☞#7

- Condensate/feedwater
- CRD
- RCIC with suction from the condensate storage pool, defeating low RPV pressure isolation and area high temperature interlocks and high suppression pool water level suction transfer logic if necessary.
- RHR (LPCF)

If RPV water level cannot be restored and maintained above [-79.5 cm (Minimum Steam Cooling RPV Water Level)], commence and, irrespective of pump NPSH and vortex limits, slowly increase injection into the RPV with the following systems to restore and maintain RPV water level above [-79.5 cm (Minimum Steam Cooling RPV Water Level)]:

- HPCF
- Fire protection system and firewater addition mode of RHR(C)
- ECCS keep-full systems:
  HPCF, RHR
- Condensate Makeup Water System

If RPV water level cannot be restored and maintained above [-79.5 cm (Minimum Steam Cooling RPV Water Level)], PRIMARY CONTAINMENT FLOODING IS REQUIRED; enter [procedure developed from Contingency #6].

C5-5.3 When RPV water level can be maintained above [-79.5 cm (Minimum Steam Cooling RPV Water Level)], return to [Step C5-3].

ABWR C5-6

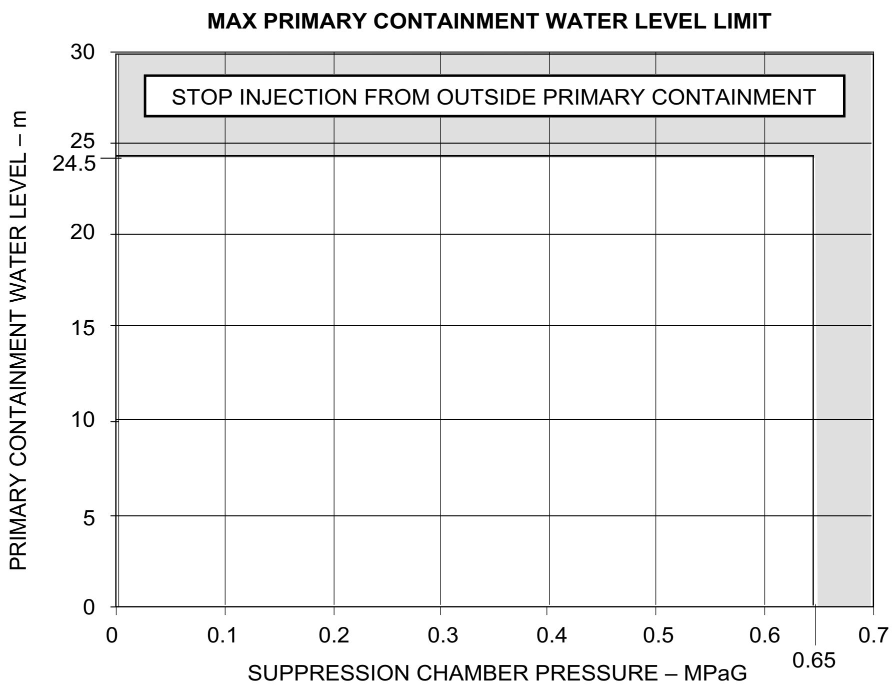
C5-6 When [procedure for cooldown to cold shutdown conditions] is entered from [procedure developed from the RPV Control Guideline] at [Step RC/P-5], proceed to cold shutdown in accordance with [procedure for cooldown to cold shutdown conditions].

18A.13 Contingency #6, Primary Containment Flooding

CONTINGENCY#6
PRIMARY CONTAINMENT FLOODING

If while executing the following steps:

- Primary containment water level and suppression chamber pressure cannot be maintained below the Maximum Primary Containment Water Level Limit, then irrespective of whether adequate core cooloing is assured terminate injection into the primary containment from sources external to the primary containment until primary containment water level and suppression chamber pressure can be maintained below the Maximum Primary Containment Water Level Limit.



- RPV water level can be restored and maintained above [0 cm (top of active fuel)] enter [procedure developed from the RPV Control Guideline] at [Step RC/L].

ABWR C6-1

(C6-1 Deleted -- not applicable to ABWR)

> If while executing the following step:
>
> Containment radiation is greater than [(Core Damage Radiation Level)], and RPV water level is below [0 cm (top of active fuel)] or cannot be determined, terminate all injection into the primary containment when drywell water level reaches [12.87 m (elevation of the bottom of the RPV)].

C6-2 Operate the following systems:

- HPCF with suction from the condensate storage tank when available
- Feedwater / Condensate
- CRD
- SPCU with suction from the condensate storage tank
- RCIC with suction from the condensate storage tank only, defeating low RPV pressure isolation interlocks and high suppression pool water level suction transfer logic if necessary
- Fire protection system and firewater addition mode of RHR(C), injecting into the RPV
- ECCS keep-full systems:
  HPCF, RHR
- [lnterconnections with other units]
- [Other primary containment fill systems].
- Condensate Makeup Water System

> Execute [Steps C6-3 and C6-4] concurrently, only if containment radiation is below [(Core Damage Radiation Level)] or cannot be determined.

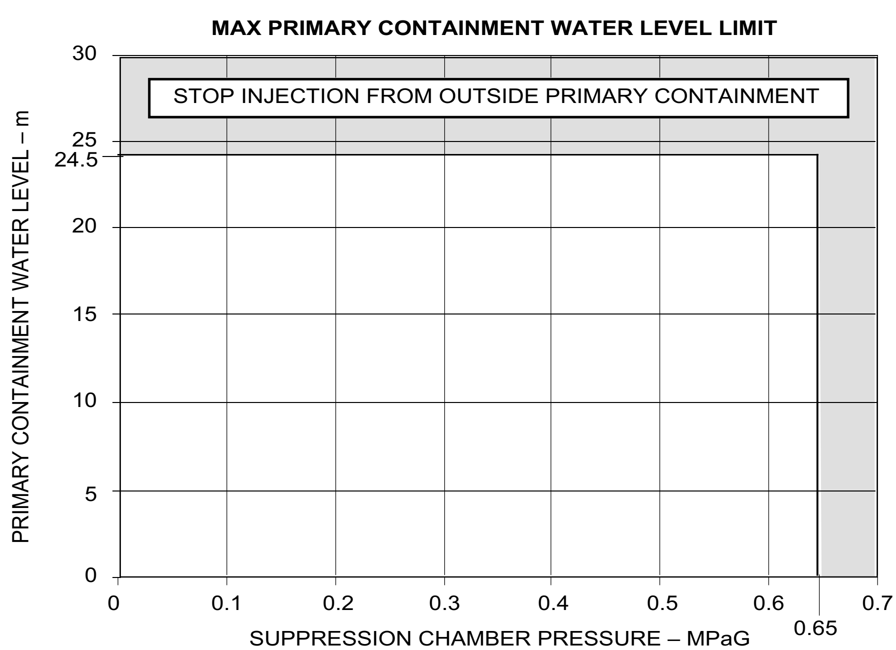
C6-3 When primary containment water level reaches [12.87 m (elevation of the bottom of the RPV)], then irrespective of the offsite radioactivity release rate vent the RPV, bypassing isolation interlocks if necessary, until RPV water level reaches [0 cm (top of active fuel)] with one or more of the following:

- MSIVs,
- Main steam line drain,
- RCIC steam line.

ABWR C6-2

C6-4 When primary containment water level reaches [22.2 m (elevation of top of active fuel)], maintain primary containment water level between [22.2 m (elevation of top of active fuel)] and the Maximum Primary Containment Water Level Limit with the following systems taking suction from sources external to the primary containment only when required:

- HPCF
- Feedwater/condensate
- CRD
- SPCU
- RHR (LPCF)
- Head spray
- Fire protection system and firewater addition mode of RHR(C), injecting into the RPV
- ECCS keep-full systems:HPCF, RHR
- [lnterconnections with other units],
- [Other primary containment fill systems]
- Condensate Makeup Water System



ABWR C6-3

18B Differences Between BWROG EPG Revision 4 and ABWR EPG

18B.1 Introduction

Appendix 18B presents the differences and bases for the differences between the NRC approved BWROG EPG Revision 4 document* and the ABWR EPGs. For a given difference identified, the ABWR EPG step, BWROG EPG Revision 4 step, and the basis for the difference is given. The numbers used for the ABWR EPG steps correspond to those of the ABWR EPG Guidelines given in Appendix 18A.

* NRC letter, A. C. Thadani to D. Grace, Safety Evaluation of "BWR Owner's Group-Emergency Procedure Guidelines, Revision 4", dated September 12,1988 (NEDO-31331, March 1987).

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
Caution #1	Caution #1	• Fuel zone and wide range instruments are deleted from item number 2 and 3, respectively.	• ABWR RPV water level instrumentation for the fuel zone and the wide range instruments have instrument leg temperature sensors and, along with reactor pressure signal, are used for compensating for instrument leg water density variations due to temperature variations both inside the drywell and in the secondary containment. The compensation algorithm also accounts for differences in reference leg and instrument leg vertical drops both inside the drywell and in the secondary containment. The compensated outputs are displayed to the operator in the control room. In addition, the instrument runs inside the drywell are required to have specified parallel slopes and approximately equal vertical drops to further minimize the effect on indicated level due to drywell temperature variations. The narrow range and shutdown range instruments have no such temperature compensation. However, instrument leg runs inside the drywell have similar requirements as those of the fuel zone and wide range instruments. The effect of temperature on indicated water level is expected to be small, but is to be evaluated on plant-specific basis based upon the actual installation details, and therefore is retained in the Caution statement.
Caution #2	Caution #2	• Deleted	• ABWR does not have reactor water level instrumentation with heated reference legs.
Caution #3	Caution #3	• Deleted HPCI from the caution.	• ABWR does not have the steam-driven high pressure injection system HPCI.
Caution #5	Caution #5	• Changed HPCS to HPCF.	• The ABWR high pressure ECCS injection system is HPCF.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
RC/L-2 Override Statement	RC/L-2 Override Statement	• Changed the word “RPV” in the phrase “…terminate injection into the RPV from sources external to the primary containment…“, to “primary containment”.	• A system is injecting water into the primary containment if all the following criteria are satisfied: (1) The suction source of the system is outside the primary containment. (2) The system penetrates the primary containment. (3) The system discharge is adding to the primary containment water inventory (i. e., a system is injecting into the RPV and either the RPV has an unisolated leak inside the primary containment or the safety/relief valves are open to the primary containment. The function of the Primary Containment Water Limit is to preclude containment failure. A systems that injects into the RPV is a subset of those systems that can inject into the primary containment. It has always been the intent of the existing wording to direct the termination of all injection into the primary containment from sources external to the primary containment. The new wording of the injection termination statement is also intended to allow RPV injection to continue if no water is leaving the RPV into the primary containment.
RC/L–2	RC/L–2	• Deleted HPCI from list of systems. • Specified the high pressure ECCS as HPCF. • Deleted LPCS from the list of systems.	• The ABWR does not have the steam-driven HPCI System. • In the ABWR, the high pressure ECCS injection system consists of two separate loops, HPCF(B) and HPCF(C); both inject inside the shroud in the RPV. • The ABWR does not have LPCS.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
		• Deleted phrase, "LPCI with injection through the heat exchangers as soon as possible", and changed LPCI to RHR and throughout this document.	• The ABWR RHR System consists of three separate subsystems. The low pressure injection mode is a mode of the RHR System. RHR(A) injects water from the suppression pool to the RPV through a feedwater line. RHR(B) and RHR(C) inject water from the suppression pool to the RPV outside of the shroud in the RPV. For all three subsystems, the heat exchangers are normally in the flow path. There is no timer to keep the heat exchanger bypass valves from closing as in a typical BWR/6 design, and hence the phrase, "with injection through the heat exchangers as soon as possible", is not necessary.
		• Added bypass of RCIC area high temperature isolation interlock.	• Isolation of RCIC due to high area temperature can be caused by loss of ventilation as well as process leaks. If area temperature is high enough to cause an isolation and RCIC is still needed for core cooling, it is appropriate also to bypass this isolation function. Adequate instructions are provided in Secondary Containment Control to isolate unnecessary systems which may be injecting into the RCIC room. If RCIC is needed for core cooling, Secondary Containment Control allows its continued use; otherwise, it is to be isolated.
		• Deleted RHR service water crosstie from the list of systems.	• The ABWR does not have RHR service water crosstie.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
RC/L–2 (continued)	RC/L–2 (continued)	• Changed the phrase, “prevent automatic RPV depressurization by resetting the ADS timer”, to “prevent automatic initiation of ADS”.	• In the ABWR ADS design, there are no timer reset switches comparable to those in some operating plants. Two ADS inhibit switches are available to override automatic initiation of ADS. There are two sets of conditions that will automatically initiate ADS: (a) after a time delay of 29 seconds upon receipt of high drywell pressure and low RPV water level signals, and (b) upon receipt of low RPV water level signals after an eight-minute time delay plus an additional delay of 29 seconds. These automatic ADS initiations can be inhibited by actuating two ADS inhibit switches on the main control console if actuated within the stated time delays. The instruction for such action is to be specified in plant-specific emergency procedures.
		• Specified the firewater addition system, ECCS keep-full systems and SLC (test tank) as alternate injection systems.	• Use of the Fire Protection System and the firewater addition mode of RHR(C) is described in Subsection 5.4.7.1.1.I0. Water can be injected into the RPV via piping connection to RHR(C) header. Fire water addition using the Fire Protection System backed up by an external connection outside of the reactor building at ground level for connecting portable water injection sources (such as a fire truck). The ABWR RCIC System does not have a line fill pump that can take water from the suppression pool or the condensate storage tank and therefore is not included in the list of ECCS keep-full systems. The SLC test tank is a source of water that can be aligned to inject into the RPV with the SLC pumps, with makeup to the tank provided by a makeup water system.
RC/P Override Statement	RC/P Override Statement	• Deleted LPCS, and	• The ABWR does not have a LPCS.
		• Changed LPCI to LPCF.	• See basis under RC/L-2 above.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
RC/P-2 Override, second box statement	RC/P-2 Override, second box statement	• Changed phrase, “open MSIVs, bypassing pneumatic system and low RPV water level isolation interlocks if necessary’, to read as follows: “open MSIVs, bypassing low RPV water level isolation interlocks if necessary.”	• The ABWR pneumatic supply to the MSIVs is not isolated by a containment isolation signal (low RPV water level or high drywell pressure) as in some operating plants.
RC/P-1	RC/P-1	• Deleted IC from step	• ABWR does not have isolation condensers.
RC/P-2	RC/P-2	• Deleted IC and HPCI	• ABWR does not have these systems.
RC/P-4	RC/P-4	• Changed LPCI to LPCF mode of the RHR system.	• See basis under RC/L-2 above.
RC/Q-2	RC/Q-2	• ARI is specified in this step instead of RC/Q-5.	• Initiation of ARI will open scram header valves (separate from those actuated by the Reactor Protection System, RPS), and initiate the FMCRD Run-In function. Two dedicated switches on the operator’s control console are used for ARI initiation as a backup to the automatic ARI initiation based on an ATWS signal. ARI logic is separate from that of RPS.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
RC/Q-3	RC/Q-3	• Deleted phrase, “and the MSIVs are open”.	• In the ABWR, a turbine trip is initiated when the MSIVs are closed and hence this phrase is superfluous, since the turbine-generator cannot be online with the MSIVs closed.
		• Changed phrase “Confirm or initiate recirculation flow runback to minimum”, to “Confirm or initiate recirculation pump runback to minimum speed”.	• New phrase is a more explicit instruction to reduce recirculation flow by runback of the internal recirculation pumps to their minimum speeds.
RC/Q-5	RC/Q-5	• Deleted step.	• ARI is specified in Step RC/Q-2 because ARI initiation will not trip recirculation pumps with a potential for tripping of the main turbine at high RPV water level (Level 8)
RC/Q-6	RC/Q-6	• Added as an alternate condition for boron injection: “Either: When periodic neutron flux oscillations in excess of [25% (Large Oscillation Threshold)] peak-to peak commence and continue, or”	• This symptom is indicative of a power instability and becomes a condition for boron injection to eliminate any threat to fuel clad integrity during such oscillations during a failure to scram condition.
		• Deleted: “but only if the reactor cannot be shutdown” as a condition for boron injection when suppression pool temperature approaches the Boron Injection Initiation Temperature.	• In the absence of power oscillations fuel and RPV integrity are not directly challenged, even under failure to scram conditions, as long as the core is submerged. However, suppression pool heatup can challenge the containment and remains the second condition for boron injection. Since failure to scram conditions may present severe plant safety consequences, the requirement to initiate boron injection is independent of any anticipated success of control rod insertions.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
RC/Q-6	RC/Q-6	• Deleted HPCI and Hydro pump from second paragraph.	• The ABWR does not have these systems.
RC/Q-6.1 Override	RC/Q-6.1 Override	• Delete “confirm automatic trip of or”.	• ABWR does not have automatic trip of pump on low SLC tank level. Level indication only.
RC/Q-7.2	RC/Q-7.2	• Deleted the following phrases: “drain the scram discharge volume”, “Increase CRD cooling water differential pressure”, and “Vent control rod drive overpiston volumes”.	• These steps are applicable to the conventional hydraulic locking-piston drives and are not applicable to the ABWR FMCRDs.
Primary Containment Control Entry Conditions	Primary Containment Control Entry Conditions	• Deleted the phrase: “Containment temperature above [90°F(containment temperature LCO)]”.	• This entry condition is applicable only to BWRs with Mark III containments. Refer to basis for deleting the CN/T subsection given below.
—	CN/T	• Deleted entire section.	• The control functions specified in this section, operation of containment cooling, initiation of suppression pool sprays, and preforming an RPV depressurization when containment temperature cannot be maintained below a prescribed limit, are control functions that are already specified in subsection SP/T of the ABWR EPGs. Subsection CN/T of the BWROG EPGs is developed specifically for the BWR/6 Mark III containment where temperature can be controlled by the previously stated control functions. The ABWR containment, although it incorporates the concept of a Mark III suppression pool, is analogous to a Mark II BWR containment for the purpose of controlling the wetwell space temperature.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
DW/T, DW/T-1	DW/T, DW/T-1	• Added phrase: "shutdown the reactor" at the end of Step DW/T, and added a second part to DW/T-1, "When drywell temperature cannot be maintained below [103°C (Saturation temperature corresponding to high drywell pressure scram setpoint)], enter [procedure developed from the RPV Control Guideline] at [Step RC-1 and execute it concurrently with this procedure".	• The BWROG EPGs assumed that other plant procedure steps will shut down the plant at the Technical Specification LCO limit. Adding the instruction to shut down the reactor allows shutdown by running back the recirculation pumps and inserting control rods, and then proceed to scram the reactor as specified in the second paragraph of Step DW/T-1. Adding these steps does not change the intent of the EPGs and makes DW/T consistent with the other primary containment sections.
DW/T-2	DW/T-2	• Replaced "drywell sprays" with "containment sprays". • Replaced phrase, "elevation of bottom of internal suppression chamber to drywell vacuum breakers less vacuum breaker opening pressure in feet of water", with the phrase, "elevation of the bottom of suppression pool-to-lower-drywell vent".	• In the ABWR, drywell and suppression pool sprays are initiated simultaneously. They may not be independently operated. • In the ABWR containment, vents are provided connecting the upper drywell to the lower drywell. When the wetwell-to-drywell vacuum breakers open, flow is from the wetwell to the lower drywell and then from the lower drywell to the upper drywell through these vents. The vacuum breakers are located above the vents. It is appropriate to preserve the operability of the vacuum breaker function and spray the containment only when suppression pool water level is below the bottom of the suppression pool to lower drywell vents to preclude drywell differential pressure capability to be exceeded.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
DW/T-2 (continued)	DW/T-2 (continued)	• Deleted phrase “recirculation pumps” from instruction to shutoff recirculation pumps and drywell cooling fans prior to containment spray initiation.	• The ABWR has internal recirculation pumps, driven by motors located below the RPV in the lower portion of the drywell. Containment sprays can not spray the internal recirculation pumps. An explicit instruction to shut down the recirculation pumps is not required.
		• Specify RHR pumps used for containment spray as “RHR subsystems B and C”.	• RHR subsystems B and C provide simultaneous drywell and suppression pool spray capability. Initiation of containment sprays is by manual control action. It is possible to initiate spray when RHR B or C is operating in other modes by opening spray valves.
		• Specified the use of the Firewater Addition System if RHR(B) and RHR(C) are not available for containment sprays.	• The firewater addition system is described in Subsection 5.4.7.1.1.10. The specific purpose of the Fire Addition System is to provide makeup to the RPV to extend the station blackout capability of the ABWR, but it can be used for drywell and wetwell sprays if no other systems are available for sprays.
DW/T-3	DW/T-3	• Deleted phrase: “enter [procedure developed from the RPV Control Guideline] at [Step RC-1 and execute it concurrently with this procedure”.	• This phrase has been moved to Step DW/T-1. Reactor scram is specified under the same instruction in DW/T-1 prior to reaching the temperature as stated in Step DW/T-2.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
PC/P	PC/P	• Added instruction to permit venting via the ACS drywell bleed, exhausting through SGTS and RBHVAC only if containment pressure is less than the design pressure of these systems. Also, venting through these systems is to be terminated if containment pressure exceeds the design pressure of these systems or if offsite release rate exceeds the release rate LCO.	• Normal containment pressure control venting is performed using the small ACS drywell bleed line only if containment pressure is less than the design pressure of these “soft vent” systems to preclude damage to these system equipment, and venting through these system for pressure control is allowed if radioactivity release rate is less than the LCO limit.
		• Combined overrides to terminate sprays based on suppression chamber or drywell pressure.	• See basis for Step PC/P-1
PC/P-l	PC/P-1	• Deleted entire step.	• In the ABWR, drywell and suppression pool sprays are initiated simultaneously. They may not be independently operated. The containment spray initiation instruction is contained in Step PC/P-2 which follows.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
PC/P-2	PC/P-2	• Replaced “drywell” sprays with “containment” sprays. • Replaced phrase, “elevation of bottom of internal suppression chamber to drywell vacuum breakers less vacuum breaker opening pressure in feet of water”, with the phrase, “elevation of the bottom of suppression pool-to-lower-drywell vent”. • Deleted phrase “recirculation pumps” from instruction to shutoff recirculation pumps and drywell cooling fans prior to containment spray initiation. • Specified RHR pumps used for containment spray as “RHR subsystems B and C” and specified using the Firewater Addition System for sprays if RHR B & C are not available for sprays.	• See bases for DW/T-2 above. • See bases for DW/T-2 above. • See bases for DW/T-2 above. • See bases for DW/T-2 above.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
PC/P-4	PC/P-4	• Deleted entire step.	• In the ABWR, primary containment venting for pressure control is not to be performed. Primary containment overpressure protection is provided by blowout diaphragms (Subsection 6.2.5.2.6). The blowout diaphragms are chosen to actuate in the range of 0.59 to 0.65 MPaG, prior to reaching the service Level C pressure of 0.67 MPaG for the primary containment. Venting is not performed so that radioactivity release to the environment can be minimized.
PC/P-5	PC/P-5	• Revised entire step to read as follows: "When primary containment pressure reaches the range of [0.59 to 0.65 MPaG (Rupture diaphragm pressure range)] and the rupture diaphragms are actuated, do not isolate the containment vent path until directed by [procedure developed for post accident recovery]".	• The rupture diaphragm pressure actuation pressure is in the range of 0.59 to 0.65 MPaG. When the rupture diaphragms are actuated, the vent path is not to be isolated until directed by post-accident recovery procedure. If isolation of the vent path is specified after the rupture diaphragms are actuated, potential exists for the need for subsequent re-opening should containment pressure increase. Failure to open valves in the vent path for any reason can lead to containment failure. If the vent paths are isolated after rupture diaphragm actuation, subsequent containment spray initiation has the potential for containment implosion because most of the non-condensable gases would have been released during the initial burst, and the containment would be saturated with steam. Although instructions are specified to terminate sprays when containment pressure drops to the high drywell scram setpoint value, the risk of containment implosion outweighs the benefit of isolating the vent paths. In addition, with the vent path open, any radioactivity release after the initial burst when the rupture diaphragms actuate is expected to be small. For these reasons, isolation of vent path is best specified in post-accident recovery procedures.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
PC/P-6	PC/P-6	• Combined suppression pool and drywell spray initiation steps into one step. • Specified that containment sprays may be augmented by the Firewater Addition System within specified containment pressure and level limits.	• In the ABWR, drywell and suppression pool sprays are initiated simultaneously. They may not be independently operated. The lower of the elevation of the bottom of suppression pool-to-lower-drywell vent (11.70m) and the elevation of the suppression pool spray nozzles (18.90m) is used as the allowable pool water elevation for containment spray initiation. • In the ABWR, venting the containment is not to be performed, since containment integrity is assured by the rupture diaphragms as discussed above under basis for PC/P-4. The Firewater Addition System may be aligned to spray the wetwell and the drywell. The limits are imposed for consistency with the MPCWLL specified in Step SP/L-3.3 which requires termination of injection from sources external to containment above these limits.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
SP/L-1	SP/L-1	• Deleted all references to Suppression Pool Makeup System (SPMS). • Added phrase: “If suppression pool water level cannot be maintained above [7.0 m (minimum suppression pool water level LCO)], enter [procedure developed from the RPV Control Guideline] at [Step RC-1 and execute it concurrently with this procedure”. • Specified RCIC, HPCF, SPCU, and Fire Protection System and the Firewater Addition mode of RHR(C) as systems that can makeup to the suppression pool, and RHR for rejecting water from the suppression pool.	• ABWR does not have SPMS which dumps water from the containment pools to the suppression pool in a BWR/6. ABWR uses the SPCU as the normal system for makeup to the suppression pool from the condensate storage tank. • This step is added for scramming the reactor when suppression pool water level cannot be maintained above the low level LCO limit. The BWROG EPGs assumed that other plant procedure steps will require a scram. Specifying this step here does not change the intent of the EPGs and makes it consistent with other sections of the Primary Containment Control Guidelines. Scramming the reactor at this point will allow the operator to use the turbine bypass valves to depressurize the reactor and will make the transient less severe in the subsequent depressurization required in Step SP/L-2. • More explicit information is provided on the systems that can be used to control suppression pool water level. SPCU is the normal system that can be aligned to take suction from the condensate storage tank and add water to the suppression pool.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
SP/L-2	SP/L-2	• Deleted phrase: "enter [procedure developed from the RPV Control Guideline] at [Step RC-1 and execute it concurrently with this procedure".	• This phrase has been moved to Step SP/L-1 as discussed above under Step SP/L-1.
SP/L-2.2	SP/L-2.2	• Deleted entire step on maintaining pool level above HPCI exhaust line and instruction to execute concurrently with Step SP/L-2.1.	• ABWR does not have the steam-driven HPCI system.
SP/L-3	SP/L-3	• Deleted references to SPMS.	• ABWR does not have SPMS.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
SP/L-3.1	SP/L-3.1	• Replaced the phrase “terminate injection into the RPV from sources external to the primary containment: with the phrase, “terminate injection into the primary containment from sources external to the primary containment”.	• A system is injecting water into the primary containment if all the following criteria are satisfied: (1) The suction source of the system is outside the primary containment. (2) The system penetrates the primary containment. (3) The system discharge is adding to the primary containment water inventory (i.e., a system is injecting into the RPV and either the RPV has an unisolated leak inside the primary containment or the safety/relief valves are open to the primary containment). • The function of the Primary Containment Water Limit is to preclude containment failure. Systems that inject into the RPV is a subset of those systems that can inject into the primary containment. It has always been the intent of the existing wording to direct the termination of all injection into the primary containment. The new wording of the injection termination statement is also intended to allow RPV injection to continue if no water is leaving the RPV into the primary containment.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
SP/L-3.2	SP/L-3.2	• Replaced phrase, “elevation of bottom of internal suppression chamber to drywell vacuum breakers less vacuum breaker opening pressure in feet of water”, with the phrase, “elevation of the bottom of suppression pool-to-lower-drywell vent”. • Replaced the phrase “terminate injection into the RPV from sources external to the primary containment” with the phrase, “terminate injection into the primary containment form sources external to the primary containment”.	• For the ABWR, it is appropriate to control suppression pool water level below the suppression pool-to-lower drywell vents to maintain operability of the wetwell vacuum breaking function. Refer to discussion of basis for step DW/T-2. • See basis for SP/L-3.1 above.
SP/L-3.3	SP/L-3.3	• Replaced the phrase “terminate injection into the RPV from sources external to the primary containment” with the phrase, “terminate injection into the primary containment from sources external to the primary containment”.	• See basis for SP/L-3.1 above.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
PC/H-1 Override, second bullet item	PC/H-1 Override, second bullet item	• Deleted phrase, “hydrogen mixing systems and” throughout this document. • Deleted instruction to vent the containment.	• The ABWR Flammability Gas Control System does not have hydrogen mixing systems. • Containment venting is not to be performed in the ABWR because containment integrity is assured by the rupture diaphragms as discussed under basis for PC/P-4.
PC/H-1	PC/H-1	• Added instruction not to bypass the high radiation isolation and high drywell pressure isolation interlocks.	• It is required by this step to maintain offsite radioactivity release rates below the LCO. Therefore, the radiation isolation interlocks (which typically have setpoints which are less than or equal to the LCO) should remain operable. The instruction not to bypass the high radiation isolation interlock is consistent with the instruction given in the override statement of Steps PC/H-1.1 to PC/H-1.2 to isolate the primary containment vent and purge when offsite release rate reaches the LCO. The basis for the instruction to not bypass the high drywell pressure isolation interlock is given under the basis for the override statement of Steps PC/H-1.1 to PC/H-1.2 in this table.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
PC/H-1.1 to 1.2 Override	PC/H-1.1 to 1.2 Override	• Added instruction to isolate containment venting if containment pressure exceeds the design pressure of SGTS and RBHVAC Systems.	• Containment venting at relatively low containment pressure is permitted only if containment pressure is less than the design pressure of these “soft vent” systems (RBHVAC, SGTS) to preclude structural damage to these system equipment. The vent path is automatically isolated on high containment pressure. Bypassing this isolation interlock and opening the vent path for venting and purging will defeat the purpose of the rupture disks. At such low hydrogen concentration (0.1%), it is inappropriate to bypass the high containment pressure isolation and open the vent path which can damage plant equipment that may be needed later for post-accident recovery. If hydrogen concentration reaches 0.5%, the hydrogen recombiners are placed into operation. In case there is a LOCA and ECCS is available, boiling in the reactor is suppressed by the injection of cold water into the reactor, stopping hydrogen generation by radiolysis. Even if the containment is isolated on high pressure, hydrogen concentration is expected to not exceed 0.5%, precluding the need for vent and purge. If no pumps are available after a LOCA, containment pressure will increase to a pressure that will actuate the rupture disks in about 24 hours, prior to reaching an explosive mixture, assuming the hydrogen recombiners are not available. In severe accident scenarios with core damage, the containment vent paths will be automatically isolated by a high radiation signal. According to the BWROG EPGs, venting at low hydrogen concentration is not allowed in the presence of high radiation.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
PC/H-1.2	PC/H-1.2	• Changed the step to read as follows: “Vent the primary containment using the ACS bleed line and purge the primary containment with nitrogen in accordance with [procedure for primary containment purging].”	• Nitrogen purge flow is established in order to lower the containment hydrogen concentration. Venting of the containment is restricted to the use of the small drywell bleed line. The use of nitrogen only for the purging operation will maintain the existing inerted atmosphere. Detailed instructions for conducting the purging is beyond the scope of the EPGs and thus the identification of a plant-specific procedure is enclosed in brackets.
PC/H-1.3	PC/H-1.3	• Deleted step.	• Since venting is restricted to using the drywell bleed line, purging with the ACS using air (by means of the large air purge lines) is not appropriate.
PC/H-2.1	PC/H-2.1	• Replaced phrase, “place hydrogen recombiners in service taking suction directly on the drywell and operate the drywell hydrogen mixing system”, with the phrase, “place FCS in service”.	• The Flammability Gas Control System (FCS) is described in Section 6.2.5. The system equipment is located outside of the drywell. It consists of two blowers that only take suction on the drywell and two hydrogen recombiners. Flow is discharged to the wetwell. An explicit instruction to take suction directly from the drywell is redundant. Instruction is given to place the FCS into service rather than to start the hydrogen recombiners because in the FCS, pushing the FCS Start control switch will start the blower, heater, and recombiner, and align valves.
		Added phrase, “and only if suppression pool water level is below [11.70 m(elevation of the suppression pool-to-lower drywell vent)]”, as a condition for initiating FCS.	• • When the recombiners discharge into the wetwell, the vacuum breakers open to allow flow into the lower drywell, through the suppression pool-to-lower drywell vents to the upper drywell. This flow path can only be established if the vents are not covered by water.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
		• Added phrase, “enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure”.	• Step RC-1 requires a reactor scram. Scramming the reactor at this point will make the depressurization (as required in Step PC/H-4) transient less severe and is consistent with the strategies in other sections of the Primary Containment Control Guidelines.
PC/H-2.2	PC/H-2.2	• Replaced the phrase, “secure any hydrogen recombiner taking suction on the drywell”, with the phrase, “secure FCS operation”.	• See basis for PC/H-2.1 above.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
PC/H-3.1	PC/H-3.1	• Deleted phrase, "but only if suppression chamber hydrogen …" in the first paragraph through "…directly on the suppression chamber" in the second paragraph. In the second paragraph, replaced "taking suction indirectly on the suppression chamber by way of the drywell" with "place FCS in service". • Added instruction to operate the FCS only if suppression pool water level is below the suppression pool-to-lower-drywell vent. • Added phrase, "enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure".	• The ABWR hydrogen recombiners only take suction directly on the drywell. They take suction indirectly on the suppression pool chamber by way of the drywell in conjunction with operation of the blowers of FCS and the vacuum breakers and through the suppression pool-to-lower-drywell vents. • Operation of the FCS will purge the wetwell through the vacuum breakers. The purge flow is mixed with the drywell atmosphere. Recombination takes place in the recombiners located outside of the drywell. Operation of FCS is contingent upon suppression pool water level being below the pool-to-lower drywell vents to allow mixing of the drywell and wetwell atmosphere through these vents. See also discussion of basis for step DW/T-2. • Step RC-1 requires a reactor scram. Scramming the reactor at this point will make the depressurization (as required in Step PC/H-4) transient less severe and is consistent with the strategies in other sections of the Primary Containment Control Guidelines.
PC/H-3.2	PC/H-3.2	• Deleted step.	• The ABWR does not have recombiners that take suction directly on the suppression chamber.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
PC/H-4	PC/H-4	• Deleted instruction for vent and purging of the primary containment when oxygen and hydrogen concentrations reaches the level specified in this step. • Deleted phrase, “enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure”. • Combined overrides to terminate sprays based on suppression chamber or drywell pressure.	• Venting at this step through SGTS and RBHVAC (“soft vents”) with high oxygen and hydrogen concentrations is not to be performed to preclude potential structural damage to these equipment due to combustion or explosions. • This phrase has been moved to Step PC/H-2.1. Refer to the bases for Step PC/H-2.1. • See bases for Step PC/H-4.1.
PC/H-4.1	PC/H-4.1	• Deleted step.	• In the ABWR, drywell and suppression pool sprays are initiated simultaneously. They may not be independently operated. The containment spray initiation instruction is contained in Step PC/H-4.4.
PC/H-4.2	PC/H-4.2	• Deleted step.	• Venting is not to be performed as discussed above under basis for Step PC/H-4.
PC/H-4.3	PC/H-4.3	• Deleted step.	• Purging is not applicable because the venting instructions have been deleted.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
PC/H-4.4	PC/H-4.4	• Deleted reference to recirculation pumps and specified RHR pumps used for containment spray as RHR subsystems B and C; added instruction to use FAS if RHR B and C are not available. • Replaced phrase, “elevation of bottom of internal suppression chamber to drywell vacuum breakers less vacuum breaker opening pressure in feet of water”, with the phrase, “elevation of the bottom of suppression pool-to-lower-drywell vent”.	• See discussion for step DW/T-2. • See discussion for step DW/T-2.
PC/H-5	PC/H-5	• Combined overrides to terminate sprays based on suppression chamber or drywell pressure.	• See bases for Step PC/H-5.1
PC/H-5.1	PC/H-5.1	• Deleted step.	• In the ABWR, drywell and suppression chamber sprays are initiated simultaneously. They may not be independently operated. The containment spray initiation instruction is contained in Step PC/H-5.2.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
PC/H-5.2	PC/H-5.2	• Deleted reference to recirculation pumps. • Replaced phrase, “elevation of bottom of internal suppression chamber to drywell vacuum breakers less vacuum breaker opening pressure in feet of water”, with the phrase, “elevation of the bottom of suppression pool-to-lower-drywell vent”. • Changed “drywell” sprays to “containment” sprays.	• See discussion of basis for step DW/T-2. • See discussion of basis for step DW/T-2. • See bases for Step PC/H-5.1

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
SC/T-3, SC/R-1, SC/L-1	SC/T-3, SC/R-1, SC/L-1	• Added phrase, “protect primary containment integrity”, to each of these three steps.	• The existing steps in BWROG EPGs SC/T-3, SC/R-1, and SC/L-1 already prioritize the secondary containment’s importance with respect to the reactor core. By requiring the isolation of only those systems not required to assure adequate core cooling, regardless of their current effect on the secondary containment, the EPGs have set the protection of the reactor core ahead of secondary containment. When a decision between the possible loss of adequate core cooling and a loss of primary containment integrity must be made, the EPGs choose to maintain primary containment integrity. Therefore, it directly follows that the primary containment takes precedence over the secondary containment. Those systems that are required to protect primary containment integrity must not be isolated in Secondary Containment Control.
RR-1 Override Statement	RR-1 Override Statement	• Deleted phrases, “or isolated due to high radiation,” and “defeating isolation interlocks if necessary.”	• The Turbine Building HVAC has no high radiation interlock.
RR-1	RR-1	• Added phrase, “If the radioactivity release rate continues to increase, enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure”.	• If offsite release continues to increase, it is appropriate to scram the reactor [at RC-1]. This will also allow the operator to use the turbine bypass valves to depressurize the reactor, making the depressurization as required in RR-2 a less severe transient.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
RR-2	RR-2	• Deleted phrase, “enter [procedure developed from the RPV Control Guideline] at [Step RC-1] and execute it concurrently with this procedure”.	• This phrase has been moved to Step RR-1 as discussed above.
C1 second Override Statement	C1 second Override Statement	• Changed the word “RPV” in the phrase “... terminate injection into the RPV from sources external to the primary containment...”, to “primary containment”.	• A system is injecting water into the primary containment if all the following criteria are satisfied: (1) The suction source of the system is outside the primary containment. (2) The system penetrates the primary containment. (3) The system discharge is adding to the primary containment water inventory (i.e., a system is injecting into the RPV and either the RPV has an unisolated leak inside the primary containment or the safety/relief valves are open to the primary containment). The function of the Primary Containment Water Limit is to preclude containment failure. Systems that inject into the RPV are a subset of those systems that can inject into the primary containment. It has always been the intent of the existing wording to direct the termination of all injection into the primary containment from sources external to the primary containment. The new wording of the injection termination statement is also intended to allow RPV injection to continue if no water is leaving the RPV into the primary containment.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C1-1	C1-1	• Deleted step.	• ABWR does not have isolation condensers.
C1-2	C1-2	• Added Feedwater to list of systems. • HPCS specified as HPCF(B) and HPCF(C). • Deleted phrase, “with injection through the heat exchangers as soon as possible”. • Deleted LPCS and RHR service water crosstie. • Specified the Firewater Addition System, ECCS keep-full systems and SLC (test tank) as alternate injection systems.	• ABWR has three motor-driven feedpumps and hence the feedwater system is added to the list of motor-driven injection subsystems. • In ABWR, the high pressure ECCS injection system is termed High Pressure Core Flooder(HPCF), having two separate loops B & C. • In the ABWR design, the RHR heat exchangers are normally in the flow path for all modes of operation. There are no timers to keep the heat exchanger bypass valves from closing as in a typical BWR/6 design. Therefore, it is not necessary to retain the phrase, “with injection through the heat exchangers as soon as possible”. • ABWR does not have LPCS or RHR service water crosstie. • See basis RC/L-2.
C2-1.1	C2-1.1	• Deleted LPCS.	• ABWR does not have LPCS.
C2-1.2	C2-1.2	• Deleted step.	• ABWR does not have isolation condensers.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C2-1	C2-1	• Revised conditional steps to read as follows: • All control rods are inserted to or beyond [4.2%(Maximum Subcritical Banked Withdrawal Position)], or, • It has been determined that the reactor will remain shutdown under all conditions without boron, or • All injection into the RPV except from boron injection systems, CRD, and RCIC has been terminated and prevented.	• The restructuring of this step simplifies the original wording and improves operator understanding. The logic for operator actions is unchanged by this restructuring of the original conditional statements in the BWROG EPGs, Step C2-1.
C2-1.4	–	• Added instruction to execute steps C2-1.4 and C2-1.5 concurrently.	• The ABWR ADS valves can be opened using nitrogen in stored bottles. Local manual action would be required to align the stored nitrogen to open the ADS valves. This action should be taken concurrently with other actions to depressurize the reactor as specified in Step C2-1.5. Refer Section 6.7 for a description of the ADS capability using nitrogen bottles.
C2-1.5	C2-1.4	• Renumbered as C2-1.5 in ABWR EPG. • Deleted RHR steam condensing mode, HPCI steamline, & IC tube side vent. • Deleted [and RPV... pressure]	• Renumbered due to addition of C2-1.4 in ABWR EPG. • ABWR does not have RHR steam condensing mode, HPCI, or isolation condensers. • SRVs are direct acting and have a reopening pressure of 0 MPaG.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C3-1	C3-1	• Deleted references to IC.	• ABWR does not have isolation condensers.
C4 second Override Statement	C4 second Override Statement	• Change the word “RPV” in the phrase “... terminate injection into the RPV from sources external to the primary containment...”, to “primary containment”.	• A system is injecting water into the primary containment if all the following criteria are satisfied: (1) The suction source of the system is outside the primary containment, and (2) The system penetrates the primary containment, and (3) The system discharge is adding to the primary containment water inventory (i.e., a system is injecting into the RPV and either the RPV has an unisolated leak inside the primary containment or the safety relief valves are open to the primary containment. The function of the Primary Containment Water Limit is to preclude containment failure. Systems that inject into the RPV is a subset of those systems that can inject into the primary containment. It has always been the intent of the existing wording to direct the termination of all injection into the primary containment. The new wording of the injection termination statement is also intended to allow RPV injection to continue if no water is leaving the RPV into the primary containment.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C4-1.2	C4-1.2	• Deleted IC and RHR steam condensing from step.	• ABWR does not have isolation condensers and RHR steam condensing mode.
C4-1.3	C4-1.3	• Deleted phrase, “LPCI with injection through the heat exchangers as soon as possible”, and added RHR to list of systems in the first part of the step.	• In the ABWR design, the RHR heat exchangers are normally in the flow path for all modes of operation. There are no timers to keep the heat exchanger bypass valves from closing as in a typical BWR/6 design. Therefore, it is not necessary to retain the phrase, “with injection through the heat exchangers as soon as possible.” In addition, the ABWR LPCF mode of RHR(A) injects into a feedwater line, and RHR(B) and RHR(C) injects outside of the shroud in the RPV, and hence, are suitable systems to be used in this step for systems injecting outside of the shroud.
		• Defined HPCS as HPCF(B) and HPCF(C).	• In the ABWR, the high pressure ECCS injection system consists of two separate loops, HPCF(B) and HPCF(C); both inject inside the shroud in the RPV.
		• Deleted LPCS and RHR service water crosstie from the list of systems used in the second part of this step.	• The ABWR does not have LPCS or RHR service water crosstie.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C4-1.3	C4-1.3	• Inserted the phrase, “PRIMARY CONTAINMENT FLOODING IS REQUIRED”, prior to the phrase, “enter [procedure developed from Contingency #6]”.	• EPG Steps C1-4.2, C4-1.3, C4-3.1, and C5-3.2 establish requirements for flooding the primary containment to assure adequate core cooling. When flooding of the containment is required, operator actions for controlling suppression pool water level are transferred to Contingency #6. As the status or condition of a specific parameter degrades and either approaches or exceeds limiting values, control of that parameter may be transferred from one contingency to another. This is accomplished by identifying the requirement for a contingency action, denoting this in capital letters, and then effecting the transfer of control explicit direction in the appropriate guideline sections and contingencies that address the affected parameter(s). Step C1-4.2 presently includes the upper case phrase, “PRIMARY CONTAINMENT FLOODING IS REQUIRED”. Steps C4-1.3, C4-3.1, and C5-3.2 are made consistent with the stated approach and with Step C1-4.2 by the inserted phrase “PRIMARY CONTAINMENT FLOODING IS REQUIRED”.
C4-2	C4-2	• Changed HPCS to HPCF and throughout the remainder of this document. • Deleted IC and RHR steam condensing from step.	• In the ABWR, the high pressure ECCS injection system consists of two separate loops, HPCF(B) and HPCF(C), both inject inside the shroud in the RPV. • ABWR does not have isolation condensers and RHR steam condensing mode.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C4-3.1	C4-3.1	• Defined HPCS as HPCF(B) and HPCF(C).	• See C4-1.3 basis above.
		• Deleted LPCS and RHR service water crosstie from the list of systems.	• See C4-1.3 basis above.
		• Deleted phrase, “LPCI with injection through the heat exchangers as soon as possible”, and added RHR to list of systems.	• See C4-1.3 basis above.
C4-3.2 Override Statement	C4-3.2 Override Statement	• Inserted phrase, “PRIMARY CONTAINMENT FLOODING IS REQUIRED”, prior to instruction to enter C6.	• See basis for C4-1.3 above.
C-5 Override Statement, third bullet item	C-5 Override Statement, third bullet item	• Changed the word “RPV” in the phrase “... terminate injection into the RPV from sources external to the primary containment... “, to “primary containment”.	• Refer to basis for RC/L-2 Override statement.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C5-2	C5-2	• Changed the phrase, “if any MSIV is open, bypass low RPV water level pneumatic system and MSIV isolation interlocks and restore the pneumatic supply to the containment, and,” to read as follows: “if any MSL is not isolated, bypass low RPV water level interlocks to maintain the main condenser as a heat sink”. • Part of Rev. 4 Step C5-2 moved and added as a separate step: “If any MSL is not isolated, bypass low RPV water level interlocks to maintain the main condenser as a heat sink.” • Subsequent steps and references to them are renumbered for consistency with the added Step C5-2.	• The pneumatic system supply to the MSIVs in the ABWR has no low RPV water isolation and no high drywell pressure isolation and, therefore, the instruction to bypass isolation interlocks and restore the pneumatic supplies (having been isolated) is not appropriate. • RPV water level is lowered in subsequent steps to minimize both reactor power and core inlet subcooling. Bypassing low RPV water level interlocks is specified to avoid RPV depressurization that could be required as a result of loss of the main condenser. Increased emphasis is placed on maintaining the main condenser as a heat sink to address mitigation of ATWS.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C5-3	C5-2	• Moved the instruction: “If any MSIV is open, bypass RPV low water level ... [to the containment], and “ to Step C5-2 with changes noted above.	• This instruction was specified previously as the new Step C5-2 and becomes unnecessary in this step.
C5-4	C5-4	• Entire C5-4 step and the “If while executing...” phrase above the step are deleted.	• This step is only applicable for plants with SLC injecting into the bottom of the RPV. The ABWR SLC injects via HPCF(B) into the core. Therefore, this step is not applicable to the ABWR.
	—	• Step added: “If RPV water level is above [164.9 cm (Maximum Power Control RPV Water Level)] and the reactor is not shutdown: Lower RPV water level to below [164.9 cm (Maximum Power Control RPV Water Level)] by terminating and preventing all injection into the RPV except from boron injection systems and CRD.	• Reducing RPV water level to the Maximum Power Control RPV Water Level assures that water injected through the feedwater sparger will fall a sufficient distance through a steam environment such that its subcooling will be significantly reduced by the time it reaches the RPV water level surface. Raising the enthalpy of the water entering the lower plenum and core inlet is expected to prevent or mitigate large periodic oscillations induced by neutronic /thermal-hydraulic instabilities.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C5-5	C5-3	• Added bypass of RCIC area high temperature isolation interlock.	• See basis for RC/L-2.
		• HPCI is deleted.	• The ABWR does not have the HPCI system.
		• The phrase, “LPCI with injection through the heat exchangers as soon as possible”, is deleted, and added RHR (LPCF) to the list of systems.	• In the ABWR design, the RHR heat exchangers are normally in the flow path for all modes of operation. There are no timers to keep the heat exchanger bypass valves from closing as in a typical BWR/6 design. Therefore, it is not necessary to retain the phrase, “with injection through the heat exchangers as soon as possible.” In addition, the ABWR LPCF mode of RHR(A) injects into a feedwater line, and RHR(B) and RHR(C) injects outside of the shroud in the RPV and, hence, are suitable systems to be used in this step for systems injecting outside of the shroud.
		• This step was restructured and reworded for control of water level as part of the change package to address ATWS/ stability concerns for the ABWR. The control bands specified are: (a) if level was deliber- ately lowered in Step C5-3 or C5-4, control between the Minimum Steam Cooling RPV Water Level (MSCRWL) and the lowered level or (b) if level was not	• These changes provide for control of RPV water level in three different ranges: (1) between MSCRWL and lowered level from Step C5-3, (2) between MSCRWL the Maximum Power Control RPV Water Level from Step C5-4, or (3) between MSCRWL and the high level trip setpoint if the water level was not lowered in either Step C5-3 or Step C5-4. Range (1) allows power reduction, range (2) provides power reduction and prevents or mitigates power oscillations, and range (3) provides the maximum possible band for water level control in the absence of power oscillations.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C5-5 (continued)	C5-3 (continued)	deliberately lowered, control between MSCRWL and the high level setpoint. In contrast, the previous control bands were respectively: (a) between MSCRWL and the lowered level and (b) between top of active fuel and the high level trip setpoint. Specific changes to address power instabilities are listed as follows: • After “Maintain RPV water level”, added: “between [-79.5 cm (Minimum Steam Cooling RPV Water Level)] and”. • After “If RPV water level was deliberately lowered in Step [C5-”, change the “2” to “3 or C5-4” and delete “between [-79.5 cm (Minimum Steam Cooling RPV Water Level)] and”. • After “If RPV water level was not deliberately lowered in Step [C5-”, changes the “2” to “3 or C5-4” and delete “between	

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C5-5 (continued)	C5-3 (continued)	[0 cm(top of active fuel)] and". • Delete: "If RPV water level was not deliberately lowered in [Step C5-2] and RPV water level cannot be maintained above [0 cm(top of active fuel)], maintain RPV water level between [-79.5 cm (Minimum Steam Cooling RPV Water Level)] and [484.4 cm (high level trip setpoint)]. • Specified HPCF.	
C5-5.2	C5-3.2		• The systems given are systems that inject inside the shroud. The ABWR HPCF systems inject inside the shroud and thus are appropriate in this step.
		• Deleted LPCS, and	• The ABWR does not have LPCS.
		• Deleted RHR service water crosstie.	• The ABWR does not have RHR service water crosstie.
		• Inserted phrase, "PRIMARY CONTAINMENT FLOODING IS REQUIRED", prior to instruction to enter C6.	• See basis for C4-1.3 above.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C5-5.2 (continued)	C5-3.2 (continued)	• After "....maintain RPV water level above", deleted: "[0 cm (top of active fuel)]", and added: "[-79.5 cm (Minimum Steam Cooling RPV Water Level)]". • Delete: "If RPV water level cannot be restored and maintained above [0 cm(top of active fuel)], restore and maintain RPV water level above [-79.5 cm (Minimum Steam Cooling RPV Water Level)]".	• See basis for C4-1.3 above. • See basis for C4-1.3 above.
C6-1	C6-1	• Step deleted.	• ABWR does not have Suppression Pool Makeup System (SPMS).

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C6-2 Override Statement	–	• Override statement is added for Step C6-2 to terminate containment flooding when drywell water level reaches the bottom of the RPV, if RPV water level is below TAF and containment radiation level indicates that substantial core damage has occurred.	• Containment flooding is terminated when the drywell water level reaches the bottom of the RPV during severe accident conditions when most of the core has melted and dropped to the lower drywell. Flooding is terminated to avoid covering the wetwell vent path which has the containment rupture diaphragms. This will avoid potential discharging of water through the containment vent path should the rupture diaphragms actuate. Flooding of the lower drywell under these conditions provides sufficient scrubbing. The wetwell vent is located at an elevation above the bottom of the RPV. The bottom of the RPV is chosen for flooding termination because it provides a convenient reference. The Core Damage Radiation Level (CDRL) is set at a level which will distinguish between an accident which has led to the melting of most of the fuel, and an accident which results in damage of a few fuel pins. Therefore, if the core is still mostly intact in the reactor pressure vessel but all the fuel pins have a failure, the CDRL will not be reached, and subsequent steps in this Contingency will direct flooding of the containment to a level above TAF. Since the goal of this Contingency is to flood the containment to prevent core damage, and not to prevent further core damage once core damage has started, it is appropriate to minimize radiation release after core damage has occurred. (Continued on next page.)

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C6-2 Override Statement (continued)	–		(continued) If the core has melted sufficiently to fail the vessel, and corium has fallen to the floor of the lower drywell, then most of the core will have been molten, and the noble gases and most of the volatile fission products will have been released. This will lead to the CDRL being reached. Under these conditions, there will be little additional release of fission products from the fuel remaining in the vessel. On the other hand, there will be a high concentration of fission products on the upper vessel internals. These will slowly be revaporized due to self-heating. Therefore, if a vent is opened in the vessel (necessary if containment is to be flooded to TAF), the release of fission products from the containment would be very similar to that if all of the fuel had melted and relocated to the lower drywell. Thus, it is not desirable to vent the RPV under these conditions.
C6-2	C6-2	• Changed HPCS to HPCF. • LPCS deleted. • LPCI deleted. • SPCU added. • RHR service water crosstie deleted. • The Firewater Addition system is specified.	• See basis in Step C4-2. • ABWR does not have LPCS. • LPCI mode of RHR cannot take suction from sources external to the primary containment. • Suppression Pool Cleanup System can be aligned to take suction from the CST and inject into the suppression pool. • ABWR does not have RHR service water crosstie. • The FAS can be aligned to inject into the RPV, providing some core cooling capability.

Table 18B-1 Differences Between BWROG EPG Revision 4 and ABWR EPG (Continued)

ABWR EPG Step	BWROG EPG Rev. 4 Step	Differences from BWROG Rev. 4 EPG	Basis for Differences
C6-3 & C6-4 Override Statement	C6-3 & C6-4 Override Statement	• Added phrase "only if containment radiation is below Core Damage Radiation Level or cannot be determined."	• See bases for C6-2 Override above.
C6-3	C6-3	• Deleted phrase "lowest recirculation piping", and added "RPV", and deleted phrase "then irrespective of the offsite radioactivity release rate".	• ABWR does not have external recirculation system. The recirculation pumps are internal to the RPV and, thus, when primary containment water level reaches the bottom of the RPV, it is appropriate to vent the RPV as elevation of the bottom of the RPV is the lowest point that can be postulated to have a break. Venting of the RPV is permitted only if the containment radiation level is below that indicative of core damage to preclude releasing radioactivity outside of the primary containment.
		• Deleted "Flood vent valves", "HPCI steam line", "IC tube side vents".	• ABWR does not have flood vent valves, HPCI system, and isolation condensers.
		• Deleted "RHR" from the list of systems for venting of the RPV.	• ABWR RHR System does not have a steam condensing mode and therefore is not suitable for venting the RPV.
C6-4	C6-4	• Changed HPCS to HPCF.	• See basis in Step C4-2.
		• LPCS was deleted.	• ABWR does not have LPCS.
		• RHR service water crosstie was deleted.	• ABWR does not have RHR service water crosstie.
		• The Firewater Addition system is specified.	• The FAS can inject into the RPV and flood the containment from an external water source, if required to maintain the specified water level band.

18C Operator Interface Equipment Characterization

This Appendix contains a characterization of one operator interface system which has been designed to meet the control room standard design features as specified in Section 18.4. The key features of the design are discussed. The design characterized in this appendix does not necessarily represent the final design. The final design must be established based upon the requirements of Section 18.7, which is the responsibility of the COL applicant.

18C.1 Control Room Arrangement

The conceptual main control room contains the main control console, the large display panel, the supervisor’s console, the assistant shift supervisor’s desk, a large table and various other desks, peripheral equipment and storage space. The arrangement of these items of equipment and furniture is shown in Figure 18C-1. The spatial arrangement of the main control console, large display panel and supervisor’s console is a standard design feature, as discussed in Subsection 18.4.2.15. Figure 18C-1 illustrates this standard arrangement.

18C.2 Main Control Room Configuration

The conceptual main control panel is configured as shown in a plan view in Figure 18C-2. As shown in Figure 18C-2, the configuration is that of a shallow, truncated V with desk space attachments at the ends of both wings. The dimensions are such that two operators can comfortably work at the console at all times.

A cross-sectional view of the main console is shown in Figure 18C-3. This is a cross-section at points A-A, indicated in Figure 18C-2. This view gives an indication of the console height and the depth of the console desk surface. The dashed lines indicate the position of the computer driven VDUs, which, in this concept, are CRTs.

A second cross-sectional view, at points B-B, as indicated in Figure 18C-2, is shown in Figure 18C-4. This view shows the cross-sectional shape of the console in the desk areas.

Figure 18C-4 shows a larger, more detailed version of the schematic shown in Figure 18C-2. This detail includes the identification and arrangement of the equipment installed on the main control console. This equipment includes computer-driven CRTs, flat panel display devices, panels of dedicated function switches and analog displays for selected equipment (e.g., Standby Liquid Control System and the main generator). The flat panel display devices are driven by dedicated microprocessors and, thus, are independent of the process computer.

In general, the conceptual equipment arrangement on the main console is (1) safety-related and NSS on the left, (2) overall plant supervision in the center and (3) balance of plant on the right.

The flat panel displays on the left side of the console are divisionally dedicated. These flat panels are qualified to Class 1E standards and are used to monitor and control the divisional safety systems.

The flat panels on the center and right panels of the main console support monitoring and control of non-safety NSS and BOP systems.

The CRTs and flat panel display devices on the main control console are fitted with touch screens. In addition to the control capabilities provided by the touch screens on the CRTs and flat panels, there are panels of dedicated switches implemented in hardware and located on the main control console. Dedicated switches are discussed in Subsection 18.4.2.5.

18C.3 Large Display Panel Configuration

The conceptual large display panel is approximately 3 meters high and 10.5 meters wide. In conformance with the standard design feature discussed in Subsection 18.4.2.7, it has three major components; the fixed-position (mimic) display, the top-level alarm display and the large VDU. There are also fixed-position alarm tiles positioned in the top portion of the fixed-mimic display. All displays on the large display panel are positioned to be viewed by the operators from a sitting position behind the main control console as shown in Figure 18C-6.

The fixed-position displays occupy the central portion of the large display panel and is discussed in Subsection 18.4.2.8. The fixed-position displays are driven by controllers that are independent of the process computer so that the fixed-position displays will continue to function normally in the event of process computer failure. Figure 18C-7 illustrates an implementation of a fixed-position display design.

The plant-level alarm display panel is at the left of the fixed-position displays as you face the large display panel. To the right of the fixed-position displays on the panel is the large VDU.

18C.4 Systems Integration

A characterization of the plant instrumentation and control systems architecture which supports the control room operator interface is illustrated in Figure 18C-8. As shown in Figure 18C-8, display and control capability for both safety-related and non-safety-related systems are driven by microprocessors which are independent of the redundant process computer. This assures the ability to safely shut down the plant in the unlikely event of computer failure. In the case of the safety-related systems, the microprocessors are divisionally dedicated and are each electrically isolated from the rest of the system.

The plant-wide, fiber-optic Essential Multiplexing System (EMUX) provides the communications network for the system. This multiplexing system is actually a series of data acquisition and control networks, separate networks being provided for safety-related and non-safety-related plant systems.

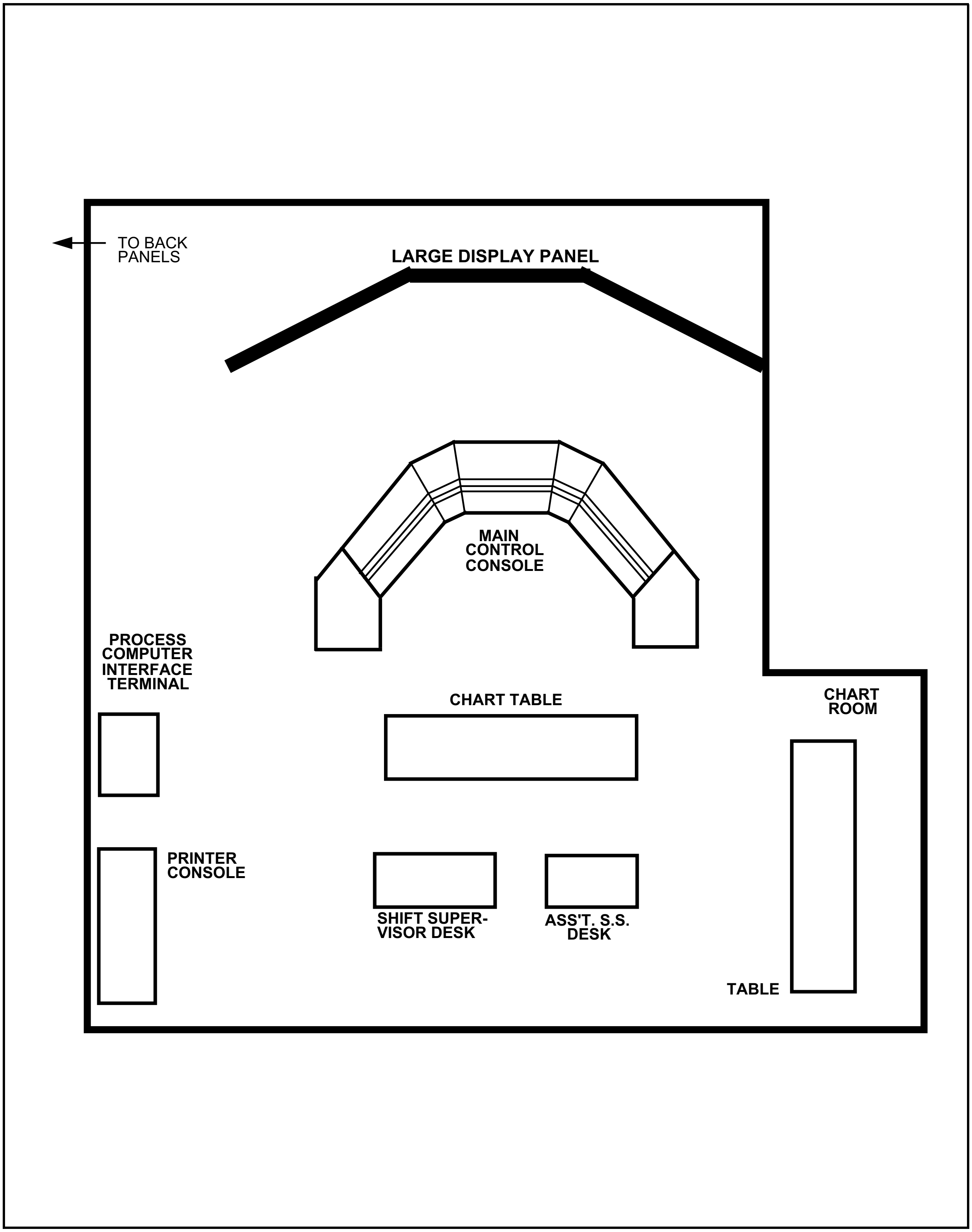


Figure 18C-1 Control Room Arrangement

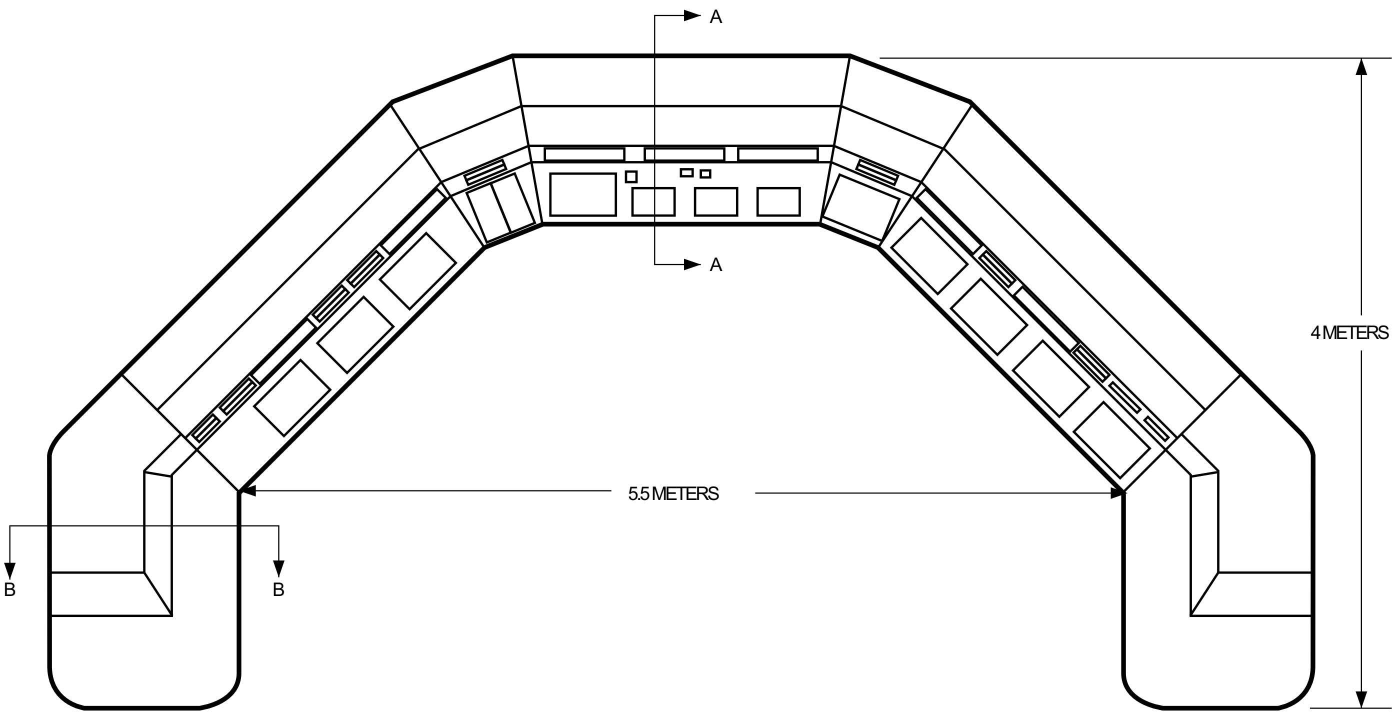


Figure 18C-2 Main Control Console Configuration

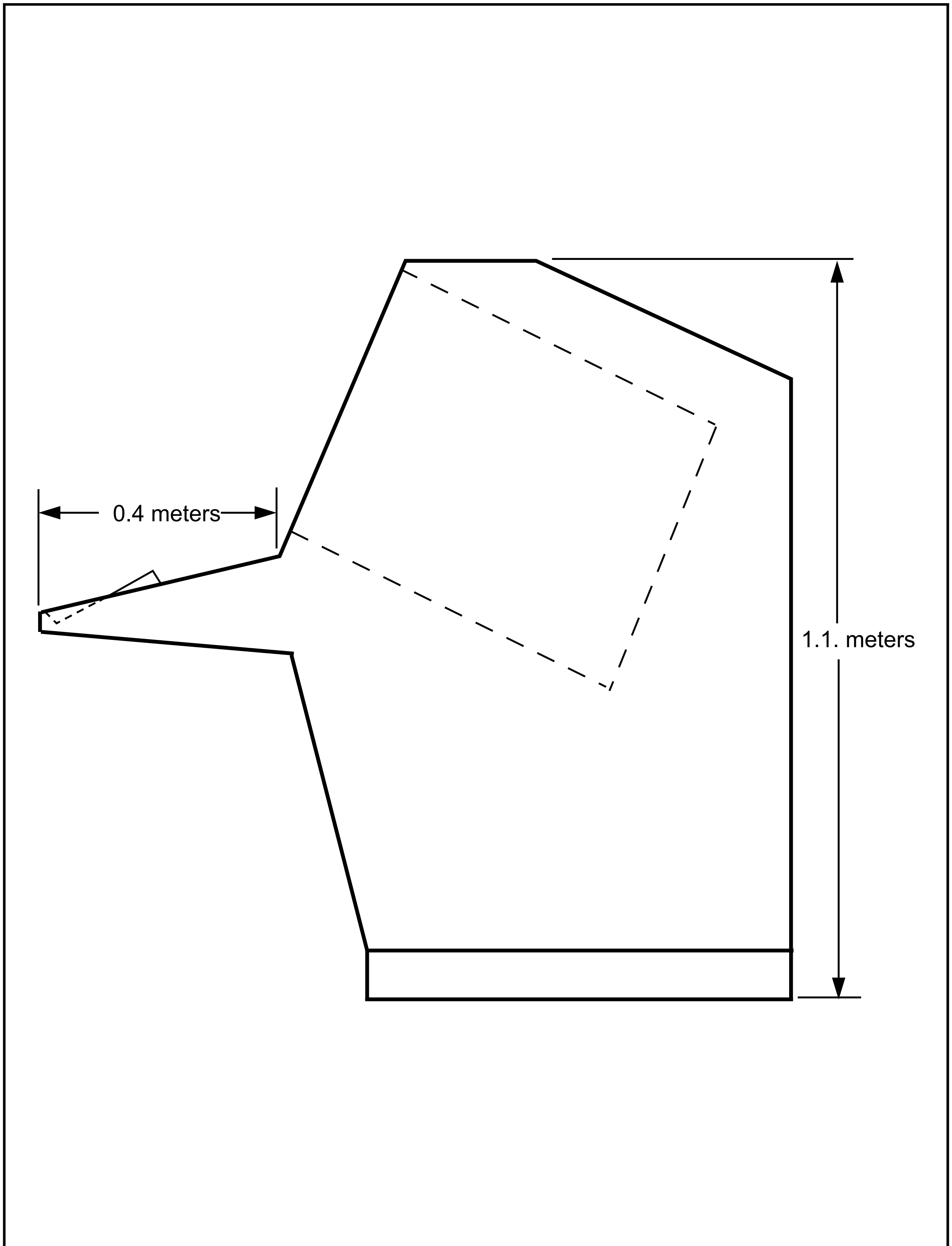


Figure 18C-3 Main Control Console Cross-Section A-A

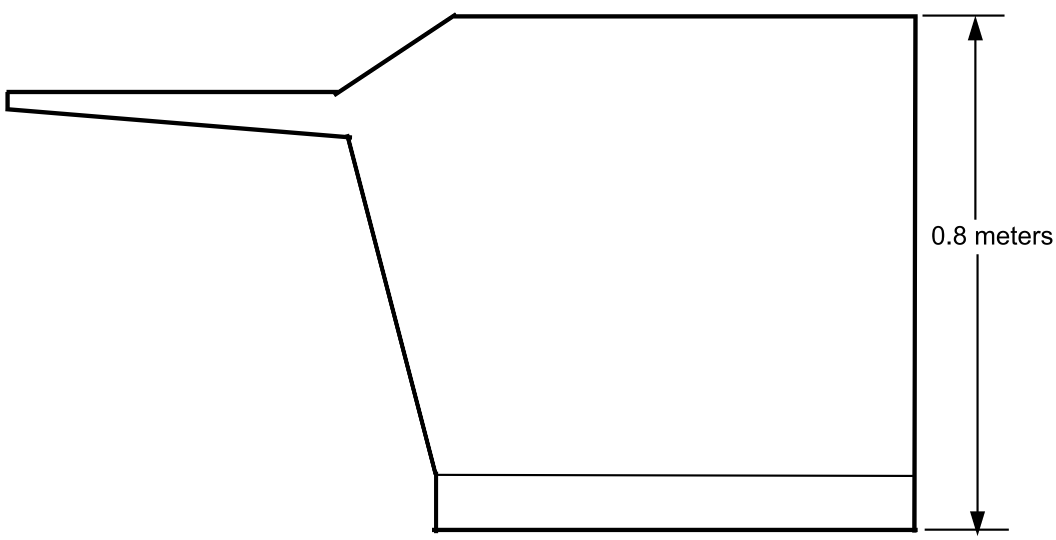


Figure 18C-4 Main Control Console Cross-Section B-B

The following figure is located in Chapter 21:

Figure 18C-5 Arrangement of Equipment of Main Control Console

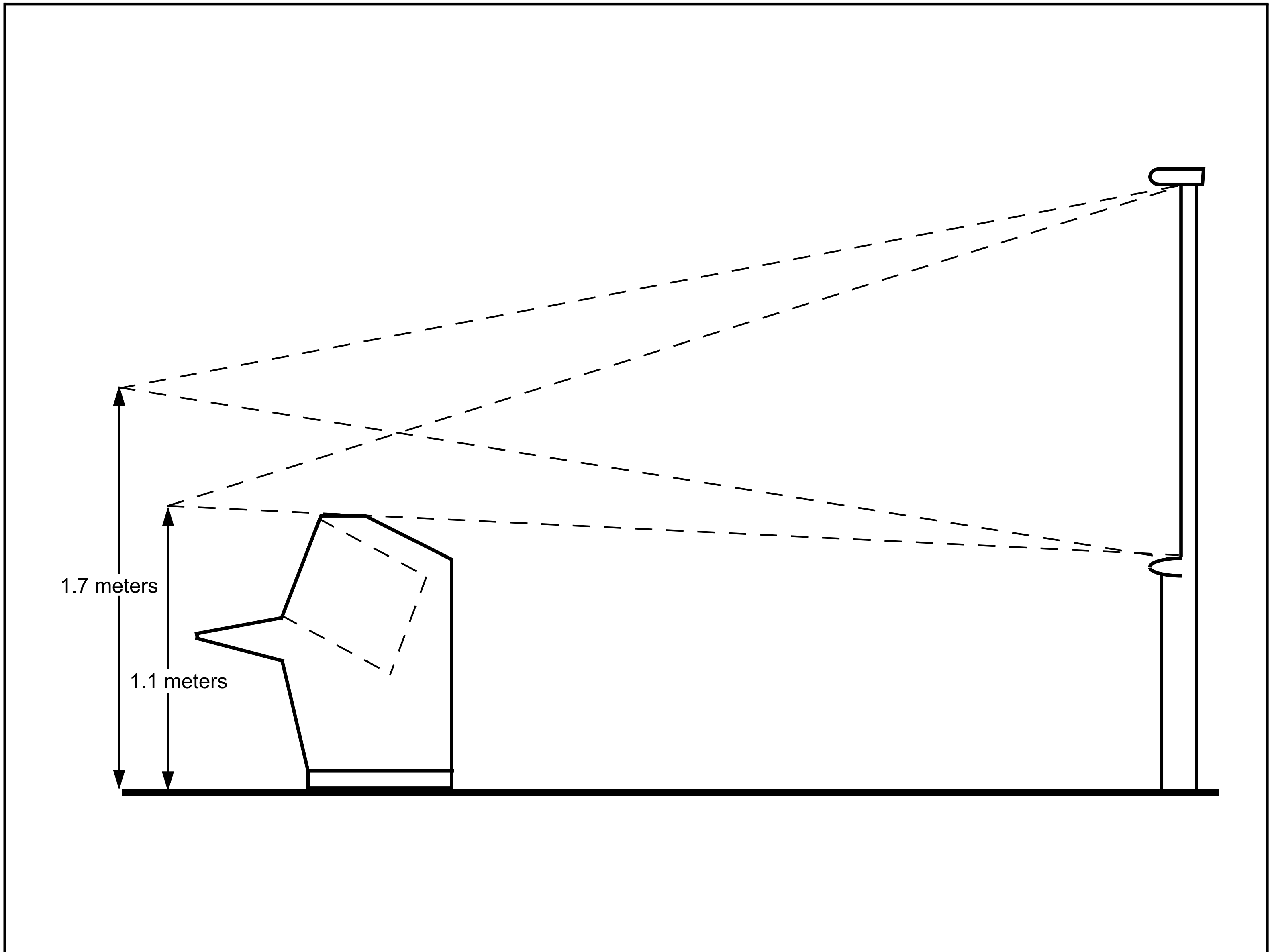


Figure 18C-6 Side View of Relative Positions of Main Console and Wide Display Device

The following figure is located in Chapter 21:

Figure 18C-7 Fixed-Position Display

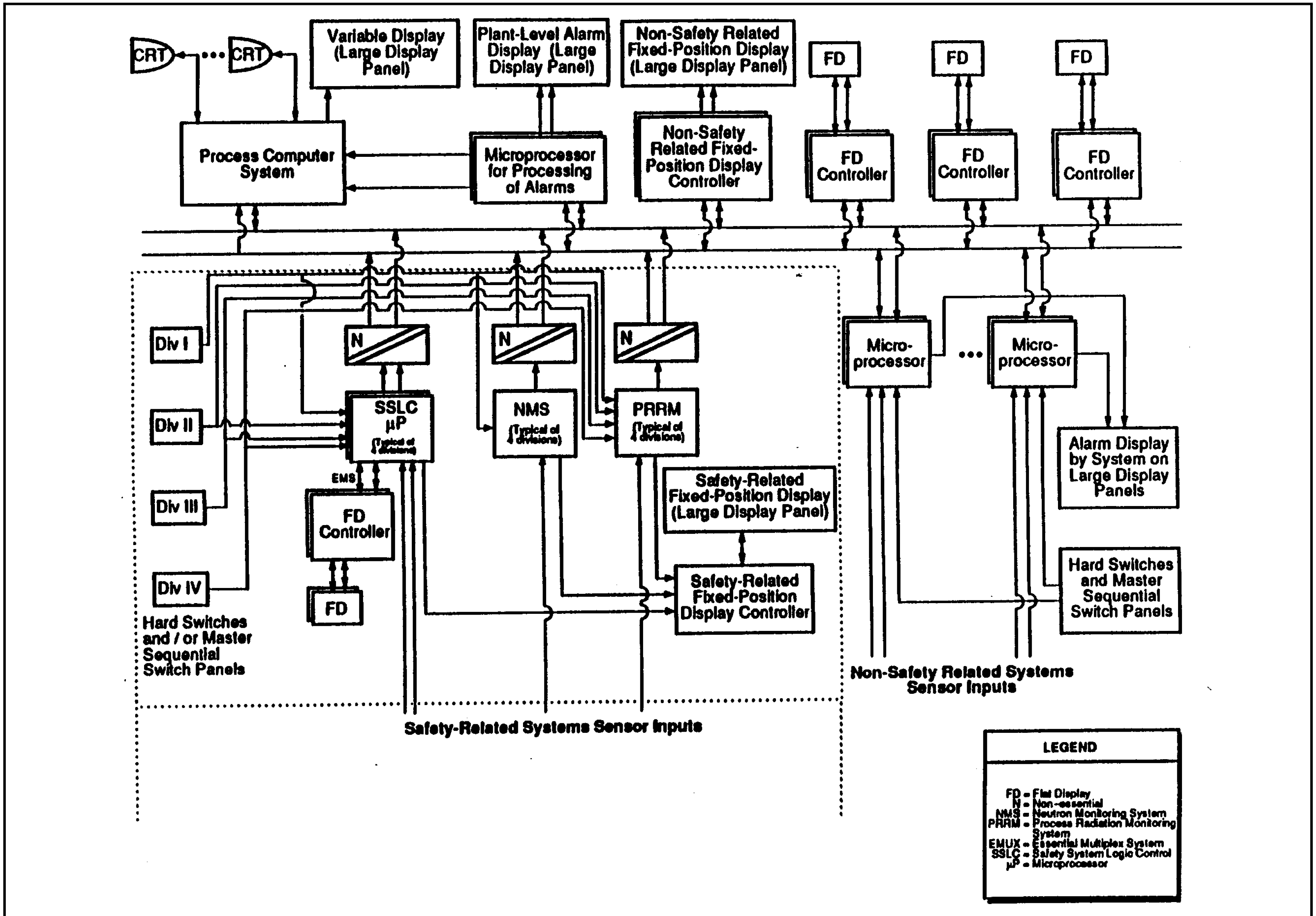


Figure 18C-8 Overall Configuration of Operator Interface System

18D Emergency Procedures Guidelines—Input Data and Calculation Results

18D.1 Introduction

The Emergency Procedure Guidelines (EPGs) given in Appendix 18A contain various limits for emergency plant operation. These operation limits are calculated based upon specific plant design parameters. This appendix contains the plant parameter values used for calculation of operation limits and results of these calculations. The calculation methods used are in accordance with those in Appendix C of the BWROG EPG, Revision 4.

The parameter values used for calculation of operation limits are given in Section 18D.2, and the results of calculations are given in Section 18D.3. Certain input values used for calculation are estimated values for the purpose of completing the calculations. The COL applicant is required to update the input parameters based upon specific installation details and, if necessary, recalculate affected operation limits. In addition, the EPGs in Appendix 18A shall incorporate these updated calculations, if required.

18D.2 Input Parameters

Table 18D-1 lists all plant parameters used for calculation of operation limits. The parameter definitions are in accordance with Appendix C of the BWROG EPG, Revision 4. Parameters indicated by a "*" in the "Parameter" column are estimated values which cannot be established until detailed plant design is completed or until specific plant installation details are known.

18D.3 Calculation Results

Table 18D-2 contains the results of calculations of operation limits. Calculations are performed in accordance with the methods given in Appendix C of the BWROG EPG, Revision 4. For each figure used in Appendix 18A, the data points used to construct the graphs are given in Table 18D-2 to provide flexibility in the use of these graphs, if desired. The graphs and other operation limits have been incorporated in the EPGs in Appendix 18A.

Table 18D-1 BWROG EPG Rev. 4 Appendix C Input Data for ABWR

Parameter	Value	Parameter Definition
IDsuct_1	RHR (LPCF)	Suction identification
Dsuct_1	42.86 cm	Internal diameter of suction inlet to suppression pool
Hsuct_1	1.115 m	Elevation (inside bottom of suppression pool = El.0) of center of suction inlet to suppression pool
Wsuct_max_1	1130 m^3/h	Flow (maximum) through suction
IDsuct_2	HPCF	Suction identification
Dsuct_2	38.74 cm	Internal diameter of suction inlet to suppression pool
Hsuct_2	1.115 m	Elevation (inside bottom of suppression pool = El.0) of center of suction inlet to suppression pool
Wsuct_max_2	890 m^3/h	Flow (maximum) through suction
BWR type	6	BWR type (Enter: 1, 2, 3, 4, 5 or 6) (ABWR = 6)
Tcst	66°C	Temperature (maximum normal operating) of condensate storage tank water
Hvent_pc	24.5 m	Elevation of containment vent (center) line located above TAF (Main steamline penetration is specified since drywell has no vent provisions due to COPS).
Hsp_lco	7 m	Elevation of minimum suppression pool water level LCO
Hsc_tap*	14.2 m	Elevation of suppression chamber pressure instrument tap
Psp_des	310 kPa	Pressure rise (design load), suppression pool boundary
Psp_srv	152 kPa	Pressure rise (maximum load) on suppression pool boundary resulting from SRV actuation
Mf_sp_lco	3558426 kg	Mass of water in suppression pool with water level at minimum LCO and water temperature at maximum LCO for unrestricted operation at power
Ppc_vent	651.6 kPaG	Pressure (maximum) in airspace at which containment vent will open
Pdw_maxop*	5.198 kPaG	Pressure (maximum normal operating), drywell
Psc_maxop*	5.198 kPaG	Pressure (maximum normal operating), suppression chamber
Pdw_minop	0 kPaG	Pressure (minimum normal operating), drywell
Psc_minop	0 kPaG	Pressure (minimum normal operating), suppression chamber
Pdw_scram	11.77 kPaG	Pressure setpoint for high drywell pressure scram
Tsp_scram	43.3°C	Temperature of suppression pool at which reactor scram is required

Table 18D-1 BWROG EPG Rev. 4 Appendix C Input Data for ABWR (Continued)

Parameter	Value	Parameter Definition
Tdw_maxop*	57.2°C	Temperature (maximum normal operating), drywell
Tsc_maxop	35.0°C	Temperature (maximum normal operating), suppression chamber airspace
Tdw_minop*	49.4°C	Temperature (minimum normal operating), drywell
Tsc_minop	10°C	Temperature (minimum normal operating), suppression chamber airspace
Tsp_minop	10°C	Temperature (minimum normal operating) suppression pool
Tsc_des	103.9°C	Temperature (design), suppression chamber
Vdw	7350 m^3	Volume (free) of drywell and vent system I/II: Vol. drywell & vent system III/ABWR: Vol. drywell (vent sys=0)
Vsc_lco	6005 m^3	Volume (free) of suppression chamber above minimum suppression pool water level LCO
WLsp_srv	7.1 m	Water level (inside bottom of pool = 0) of suppression pool used to determine maximum suppression pool boundary load resulting from SRV actuation
WLsp_lco	7 m	Water level (inside bottom of pool = 0) LCO (minimum) of suppression pool
dPdw_ww	20.7 kPaD	Differential pressure capability (maximum), drywell below wetwell (if value is greater than 68.95 kPaD, enter 68.95)
Hdco	N/A	Elevation of Mark I/II downcomer openings
Vsc_dco	7619 m^3	Volume (free) of suppression chamber above Mark I/II downcover openings or volume (free) of suppression chamber above top of ABWR horizontal vents
Hhorvent	3.85 m	Elevation of top of Mark III/ABWR horizontal vents
Tcn_des	N/A	Temperature (design), Mark III containment
n_1	DRYWELL HEAD	Identification
H_1	36.14 m	Elevation (inside bottom of suppression pool = El.0)
Loc_1	DW	Location (Enter: DW or WW)
Mat_1	6	Material types (Enter: 1, 2, 3, 4, 5, or 6, 7) 1=SS304, SA240, SA320 and A312 2=S21800, A193 and A194 3=A36 4=A160 Gr. B and A105 5=A201 Gr. B, A212 and SA516 6=(User Definable Material No. 1) 7=(User Definable Material No. 2)

Table 18D-1 BWROG EPG Rev. 4 Appendix C Input Data for ABWR (Continued)

Parameter	Value	Parameter Definition
Pcalc_1*	668.8 kPaG	Pressure capability (maximum)
MatS_1	YS	Strength used to determine pressure capability (Enter: YS or TS)
Tcalc_1	371.11°C	Temperature used to determine pressure capability
n_2	RUPTURE DISC	Identification
H_2	17.2 m	Elevation (inside bottom of suppression pool = El.0)
Loc_2	WW	Location (Enter: DW or WW)
Mat_2*	7	Material types (Enter: 1, 2, 3, 4, 5, or 6, 7) 1=SS304, SA240, SA320 and A312 2=S21800, A193 and A194 3=A36 4=A160 Gr. B and A105 5=A201 Gr. B, A212 and SA516 6=(User Definable Material No. 1) 7=(User Definable Material No. 2)
Pcalc_2*	668.8 kPaG	Pressure capability (maximum)
MatS_2	TS	Strength used to determine pressure capability (Enter: YS or TS)
Tcalc_2	176.67°C	Temperature used to determine pressure capability
LHGRmax	47.24 kW/m	Linear heat generation rate (design maximum) (the maximum allowable value is 47.24 kW/m)
Kmarg_cs	N/A	Margin (demonstrated) to cold shutdown at most reactive point in life with worst rod out (only applicable for active fuel length less than or equal to 3.71 m)
Mclad	91128 kg	Mass of clad and channels
Mfuel*	171597 kg	Mass of fuel (UO_2)
Nbuns	872	Number of fuel bundles
Qrx_rated	3926 MWt	Power (rated)
vhand	354.68 cm^3	Volume of control rod blade handle and structure
f_1*	3.59-8GZ	Identification
Efuel_1*	0.71 Weight % U-235	Enrichment in blanket zone at top of fuel rods
Lctrl_1	12.7 cm	Control rod blade length of B_4C above enriched zone
Kinf_1*	1.21	K-infinity (max) cold and uncontrolled
Lfuel_1	381 cm	Length of active fuel
Wfuel_1*	173.888 kg	Weight of U (kg/bundle)

Table 18D-1 BWROG EPG Rev. 4 Appendix C Input Data for ABWR (Continued)

Parameter	Value	Parameter Definition
f_2*	3.59-10GZ	Identification
Efuel_2*	0.71 Weight % U-235	Enrichment in blanket zone at top of fuel rods
Lctrl_2	12.7 cm	Control rod blade length of B_4C above enriched zone
Kinf_2*	1.21	K-infinity (max) cold and uncontrolled
Lfuel_2	381 cm	Length of active fuel
Wfuel_2*	173.199 kg	Weight of U (kg/bundle)
f_3*	2.59-4GZ	Identification
Efuel_3*	0.71 Weight % U-235	Enrichment in blanket zone at top of fuel rods
Lctrl_3	12.7 cm	Control rod blade length of B_4C above enriched zone
Kinf_3*	1.18	K-infinity (max) cold and uncontrolled
Lfuel_3	381 cm	Length of active fuel
Wfuel_3*	175.338 kg	Weight of U (kg/bundle)
f_4*	123-NOG	Identification
Efuel_4*	0.71 Weight % U-235	Enrichment in blanket zone at top of fuel rods
Lctrl_4	12.7 cm	Control rod blade length of B_4C above enriched zone
Kinf_4*	1	K-infinity (max) cold and uncontrolled
Lfuel_4	381 cm	Length of active fuel
Wfuel_4*	176.748 kg	Weight of U (kg/bundle)
dPvent_rpv	N/A	Pneumatic supply-to-containment differential pressure (minimum) required to operate RPV vent valve(s) inside drywell
Hvent_rpv	N/A	Elevation (inside bottom of suppression pool=El.0) of lowest RPV vent valve solenoid inside drywell
Mrpv	1351682 kg	Mass of RPV, internals, recirculation loops (ABWR=internal pumps), and main steamlines inboard of outboard MSIVs (less fuel, clad and channels)
Mrpv_taf	689199 kg	Mass of recirculation loops (ABWR=internal pumps) and of RPV internals below TAF (less fuel, clad and channels)
Mg_rpv_hot	7150 kg	Mass of saturated steam in RPV and main steamlines inboard of outboard MSIVs with water level at high level trip setpoint and pressure at minimum at which an SRV is set to lift (spring pressure)

Table 18D-1 BWROG EPG Rev. 4 Appendix C Input Data for ABWR (Continued)

Parameter	Value	Parameter Definition
Mf_rpv_cld*	820925 kg	Mass of water in recirculation (ABWR=internal pumps), shutdown cooling, and RWCU loops and in RPV with water level at high level trip setpoint and water temperature at 20°C (68°F)
Mf_rpv_hot*	341991 kg	Mass of water in recirculation (ABWR=internal pumps) and RWCU loops and in RPV with water level at high level trip setpoint and water temperature at saturation temperature for minimum pressure at which an SRV is set to lift (spring pressure)
Psup_rpv	N/A	Pressure (minimum normal operating), pneumatic supply system for RPV vent valve(s) inside drywell
Vrpv_taf*	429.912 m^3	Volume (free) of recirculation (ABWR=internal pumps) and RWCU loops and of shutdown cooling loops and RPV below TAF
WLrpv_taf	9.0495 m	Water level at top of active fuel (from RPV invert)
WLinst_1	SHUTDOWN	Instrument identification
Href_surf_1	22.045 m	Elevation of condensing chamber water surface
Hrange_lo_1	12.604 m	Elevation of instrument range low end
Href_dw_1*	16.336 m	Elevation (centerline) of reference leg drywell penetration
Hvar_dw_1*	9.95 m	Elevation (centerline) of variable leg drywell penetration
Hvar_tap_1	12.22 m	Elevation (centerline) of variable leg RPV tap
Fhtc_1	N/A	Heat transfer coefficient (dimensionless—heated reference leg instruments only)
WLrpv_hi_1	12.825 m	Instrument range high end
WLrpv_lo_1	3.555 m	Instrument range low end
Prpv_cal_1	0 MPaG	Pressure in RPV at calibration
Tdw_cal_1	26.7°C	Temperature in drywell at calibration
Trb_cal_1	26.7°C	Temperature (normal shutdown) in Reactor Building (MK I/II/ABWR) or containment (MK III) at calibration
WLinst_2	NARROW	Instrument identification
Href_surf_2*	16.336 m	Elevation of condensing chamber water surface
Hrange_lo_2	12.604 m	Elevation of instrument range low end
Href_dw_2*	15.45 m	Elevation (centerline) of reference leg drywell penetration
Hvar_dw_2*	9.95 m	Elevation (centerline) of variable leg drywell penetration
Hvar_tap_2	12.22 m	Elevation (centerline) of variable leg RPV tap

Table 18D-1 BWROG EPG Rev. 4 Appendix C Input Data for ABWR (Continued)

Parameter	Value	Parameter Definition
Fhtc_2	N/A	Heat transfer coefficient (dimensionless—heated reference leg instruments only)
WLrpv_hi_2	5.080 m	Instrument range high end
WLrpv_lo_2	3.555 m	Instrument range low end
Prpv_cal_2	7.07 MPaG	Pressure in RPV at calibration
Tdw_cal_2	57.2°C	Temperature in drywell at calibration
Trb_cal_2	26.7°C	Temperature (normal shutdown) in Reactor Building (MK I/II/ABWR) or containment (MK III) at calibration
WLinst_3	WIDE	Instrument identification
Href_surf_3*	16.336 m	Elevation of condensing chamber water surface
Hrange_lo_3	9.0495 m	Elevation of instrument range low end
Href_dw_3*	15.45 m	Elevation (centerline) of reference leg drywell penetration
Hvar_dw_3*	7.7 m	Elevation (centerline) of variable leg drywell penetration
Hvar_tap_3	8.978 m	Elevation (centerline) of variable leg RPV tap
Fhtc_3	N/A	Heat transfer coefficient (dimensionless—heated reference leg instruments only)
WLrpv_hi_3	6.605 m	Instrument range high end
WLrpv_lo_3	0.0 m	Instrument range low end
Prpv_cal_3	7.07 MPaG	Pressure in RPV at calibration
Tdw_cal_3	57.2°C	Temperature in drywell at calibration
Trb_cal_3	26.7°C	Temperature (normal shutdown) in Reactor Building (MK I/II/ABWR) or containment (MK III) at calibration
WLinst_4	FUEL ZONE	Instrument identification
Href_surf_4*	16.336 m	Elevation of condensing chamber water surface
Hrange_lo_4	5.2395 m	Elevation of instrument range low end
Href_dw_4*	15.45 m	Elevation (centerline) of reference leg drywell penetration
Hvar_dw_4*	–3.25 m	Elevation (centerline) of variable leg drywell penetration
Hvar_tap_4	1.905 m	Elevation (centerline) of variable leg RPV tap
Fhtc_4	N/A	Heat transfer coefficient (dimensionless—heated reference leg instruments only)
WLrpv_hi_4	1.270 m	Instrument range high end
WLrpv_lo_4	–3.810 m	Instrument range low end

Table 18D-1 BWROG EPG Rev. 4 Appendix C Input Data for ABWR (Continued)

Parameter	Value	Parameter Definition
Prpv_cal_4	0 kPaG	Pressure in RPV at calibration
Tdw_cal_4	100°C	Temperature in drywell at calibration
Trb_cal_4	26.7°C	Temperature (normal shutdown) in Reactor Building (MK I/II/ABWR) or containment (MK III) at calibration
XB_slc	24530 ppm	Concentration (minimum normal operating) of boron in SLC tank
Wslc	11.3575 m^3/h	Flow rate of SLCs (minimum)
Tslc	68°C	Temperature (maximum normal operating) of solution in SLC tank
dPsrv*	620.6 kPaD	Pneumatic supply-to-drywell differential pressure (minimum) required to open SRVs (see Note 1)
Hsrv*	25.6448 m	Elevation (inside bottom of suppression pool=El.0) of lowest SRV solenoid
Wsrv_name*	405607 kg/h	Flowrate of SRV per nameplate
Nsrv_ads	8	Number of SRVs dedicated to ADS
Prpv_tp	9343 kPaG	Pressure in RPV used for SRV tail pipe design calculations
Psup_srv	1.38 MPaG	Pressure (minimum normal operating), pneumatic supply system for SRVs (see Note 1)
Psrv_lift	7930 kPaG	Pressure (minimum) in RPV at which an SRV is set to lift (spring pressure)
Psrv_name*	7930 kPaG	Pressure corresponding to nameplate flow rate
Pq_code*	149.3 N/mm^2	Stress (code allowable) for quencher
Pqs_code*	149.3 N/mm^2	Stress (code allowable) for quencher support
Ptp_code*	149.3 N/mm^2	Stress (code allowable) for SRV tail pipe
Ptps_code*	N/A	Stress (code allowable) for SRV tail pipe support
Pq_des*	149.3 N/mm^2	Calculated stress (design basis) for quencher
Pqs_des*	60 N/mm^2	Calculated stress (design basis) for quencher support
Ptp_des*	149.3 N/mm^2	Calculated stress (design basis) for SRV tail pipe
Ptps_des*	N/A	Calculated stress (design basis) for SRV tail pipe support
SRVtype*	5	Type of SRV (Enter: 1, 2, 3, 4 or 5) 1=Dresser 2=Crosby 3=2-stage TR 4=3-stage TR 5=Dikkers

Table 18D-1 BWROG EPG Rev. 4 Appendix C Input Data for ABWR (Continued)

Parameter	Value	Parameter Definition
WLsp_tp	7.1 m	Water level (inside bottom of pool=0) of suppression pool used for SRV tail pipe design calculations
IDpump_1	RHR (LPCF)	Pump (system) identification
Hpsuct_1*	–7.2 m	Elevation (centerline) of pump suction inlet
Hssuct_1	–7.085 m	Elevation (centerline) of system suction location in the suppression pool
IDpump_2	HPCF	Pump (system) identification
Hpsuct_2*	–7.2 m	Elevation (centerline) of pump suction inlet
Hssuct_2	–7.085 m	Elevation (centerline) of system suction location in the suppression pool
Wlpci	RPV Pressure (MPaG) / Flowrate (m^3/h): 0.00 / 1130 0.554 / 1105 0.821 / 933 1.193 / 684 1.440 / 489 1.639 / 293 1.828 / 0	Flowrate outside core shroud from one RHR (LPCF) pump as a function of RPV pressure—maximum ten data points, runout to shutoff
Wlpcs	ABWR does not have LPCS System	Flowrate from one LPCS pump as a function of RPV pressure—maximum ten data points, runout to shutoff
Vsp, Vsc_air	Pool Water Level (m) / Water Volume (m^3) / Airspace Volume (m^3): 0.00 / 0 / 9585 3.85 / 1966 / 7619 5.00 / 2553 / 7032 7.00 / 3580 / 6005 7.10 / 3625 / 5960 10.00 / 5042 / 4543 12.00 / 6019 / 3566 14.00 / 6996 / 2589 16.00 / 7973 / 1612 19.30 / 9585 / 0	Volume (free) of water and air in suppression chamber as a function of suppression pool water level (inside bottom of pool=0)—maximum ten data points, bottom to top of suppression chamber
WLL_(n)	SRVDL Type 1 SPWL (m) / WLL (m): 7.10 / 0.00 9.07 / 2.27 12.55 / 5.74 12.82 / 12.54	Water leg length (WLL) in SRV tail pipe (SRVDL) as a function of SP water level (SPWL) (inside bottom of pool=0). Reference WLL=0 at SPWL used for SRV tail pipe design calculations—maximum 8 data points per SRVDL type, up to 6 SRVDL types. (Note: SRVDL Type=different SRVDL routing from quencher to approx. 6.7m WLL above normal water level, longest WLL per SPWL is most limiting.)

Table 18D-1 BWROG EPG Rev. 4 Appendix C Input Data for ABWR (Continued)

Parameter	Value	Parameter Definition
sysFlow_1*	Flow rate Wsuct (m^3/h) / NPSH Required NPSHR (m) / Friction Head Loss Hfl (m) 0 / 3.2 / 0.00 820 / 3.6 / 1.01 954 / 3.8 / 1.37 1130 / 4.2 / 1.82	RHR (LPCF) System Flow dependent parameters—maximum ten data points
sysFlow_2*	Flow rate Wsuct (m^3/h) / NPSH Required NPSHR (m) / Friction Head Loss Hfl (m) 0 / 1.7 / 0.00 500 / 1.4 / 0.55 640 / 1.5 / 0.90 890 / 2.2 / 1.82	HPCF System Flow dependent parameters—maximum ten data points:
User Definable Material No. 1	Temp (°C) / Normalized Yield Strength / Normalized Tensile Strength 21 / 1.027 / N/A 93 / 0.910 / N/A 204 / 0.860 / N/A 316 / 0.740 / N/A Strength/ Location / Most Limiting temp (°C) TS/DW / N/A TS/WW / N/A YS/DW / 285 YS/WW / N/A	Enter data for using optional user definable material type

Table 18D-1 BWROG EPG Rev. 4 Appendix C Input Data for ABWR (Continued)

Parameter	Value			Parameter Definition
User Definable Material No. 2*	Temp (°C)	Normalized Yield Strength	Normalized Tensile Strength	Enter data for using optional user definable material type
	21	N/A	1	
	93	N/A	1	
	204	N/A	1	
	316	N/A	1	
	Strength/ Location	Most Limiting temp (°C)		
	TS/DW	N/A		
	TS/WW	176.67		
	YS/DW	N/A		
	YS/WW	N/A		

* These values are preliminary or approximate values used to complete the ABWR calculations. The applicant referencing the ABWR design will be required to re-evaluate these values as an “interface requirement” when plant specific installation details are completed.

Note 1:This value is dependent upon specific SRV selection. SRV pneumatic supply pressure will be established such that SRVs will be operable at the maximum COPS pressure. A consistent set of values for dPSRV and PSUP-SRV was selected for completing calculations.

Table 18D-2 BWROG EPG Rev. 4 Appendix C Results for ABWR

Parameter	Value			Parameter Definition
CSBW	541.8 kg			Cold Shutdown Boron Weight
MSBWP	4.2%*			Maximum Subcritical Banked Withdrawal Position
Tsp_hctl_2	145.6°C			Heat Capacity Temperature Limit Low-Pressure Endpoint Temperature
Tsp_hctl_1	111.8°C			Heat Capacity Temperature Limit High-Pressure Endpoint Temperature
Ppc_pcpl_1	646 kPaG			Primary Containment Pressure Limit at Elevation of Minimum Suppression Pool Water Level LCO
MNSRED	6			Minimum Number of SRVs Required for Emergency Depressurization
MRFP	354 kPaG			Minimum RPV Flooding Pressure
MSCRWL	–79.45 cm†			Minimum Steam Cooling RPV Water Level
MZIRWL	–111.2 cm†			Minimum Zero-Injection RPV Water Level
MSRP	0 kPaG			Minimum SRV Re-opening Pressure
WLsp_tpl_1	12.65 m			SRV Tail Pipe Level Limit Low-Pressure Endpoint Water Level
SCSIP	71.39 kPaG			Suppression Chamber Spray Initiation Pressure
[None]	2			Minimum Number of SRVs for which the Minimum Alternate RPV Flooding Pressure is below the lowest SRV lifting pressure
MARFP		SRVs (#)	MARFP (MPaG)	Minimum Alternate RPV Flood Pressure
		8 or more	0.93	
		7	1.08	
		6	1.27	
		5	1.55	
		4	1.96	
		3	2.65	
		2	4.02	
MCFI		SRVs (#)	MCFI (min)	Minimum Core Flooding Interval
		8 or more	43.5	
		7	59.4	
		6	84.3	

Table 18D-2 BWROG EPG Rev. 4 Appendix C Results for ABWR (Continued)

Parameter	Value			Parameter Definition
WLI_1	Highest DW Run Temp (°C)		Min. Indicated Level (cm)	Water Level Instrument Number 1: Shutdown (355.5 to 1282.5 cm)
	Low	High		
	—	65.6	402.6	
	65.6	121.1	416.1	
	121.1	176.7	434.3	
	176.7	232.2	458.2	
	232.2	287.8	490.7	
WLI_2	Highest DW Run Temp (°C)		Min. Indicated Level (cm)	Water Level Instrument Number 2: Narrow Range (355.5 to 508.0 cm)
	Low	High		
	—	65.6	361.7	
	65.6	287.8	355.5	
DWSIL	Drywell Pressure (kPaG)		Drywell Temperature (°C)	Drywell Spray Initiation Limit (See Figure in Section 18A.5)
	20.7		46.3	
	32.4		105.4	
	46.2		173.1	
	60.0		243.8	
	73.8		319.5	
HCTL	RPV Pressure (MPaG)		Suppression Pool Temp (°C)	Heat Capacity Temperature Limit (See Figure in Sections 18A.4, 18A.5)
	0.35		145.6	
	0.41		144.2	
	0.55		141.9	
	0.69		140.1	
	1.03		136.9	
	1.38		134.6	
	2.07		130.8	
	2.76		127.9	
	4.14		122.9	
	5.52		118.6	
	6.89		114.6	
	7.93		111.8	
HCLL	HCTL Margin (°C)		Suppression Pool Water Level‡ (m)	Heat Capacity Level Limit See Figure in Section 18A.5)
	0.0		7.00	0 m = Bottom of Suppression Pool
	2.8		6.48	
	5.6		6.02	
	8.3		5.62	
	11.1		5.28	
	13.9		4.97	
	16.7		4.70	
	19.4		4.46	
	44.4		4.46	

Table 18D-2 BWROG EPG Rev. 4 Appendix C Results for ABWR (Continued)

Parameter	Value		Parameter Definition
PSP	Suppression Pool Water Level‡ (m)	Suppression Chamber Pressure (kPaG)	Pressure Suppression Pressure (See Figure in Section 18A.5) *0 m = Bottom of Suppression Pool
	0.0	0.00	
	4.5	0.00	
	4.5	162.0	
	4.8	180.6	
	12.6	103.4	
	12.6	0.00	
PCPL	Primary Containment Water Level‡ (m)	Suppression Chamber Pressure (MPaG)	Primary Containment Pressure Limit (See Figure in Section 18A.5) 0 m = Bottom of Suppression Pool
	0.0	0.65	
	24.5	0.65	
	24.5	0.00	
MPCWLL	Suppression Chamber Pressure (MPaG)	Primary Containment Water Level‡ (m)	Maximum Primary Containment Water Level Limit See Figure in Sections 18A.4, 18A.5, 18A.8, 18A.11, 18A.12, and 18A.13) 0 m = Bottom of Suppression Pool
	0.0	24.5	
	0.65	24.5	
	0.65	0.0	
MCUTL	Time After Shutdown (min)	MCUTL (min)	Maximum Core Uncovery Time Limit (See Figure in Section 18A.11)
	43.5	4.19	
	60.0	4.62	
	90.0	5.24	
	120.0	5.55	
	500.0	8.46	
	1000.0	10.21	
	3000.0	14.09	
	6000.0	18.29	
STPLL	RPV Pressure (MPaG)	Suppression Pool Water Level‡ (m)	SRV Tail Pipe Level Limit (See Figure in Sections 18A.4, 18A.5) 0 m = Bottom of Suppression Pool
	0.0	12.7	
	2.76	12.6	
	9.34	7.1	

Table 18D-2 BWROG EPG Rev. 4 Appendix C Results for ABWR (Continued)

Parameter	Value		Parameter Definition
RHR VL	Pump Flow (m^3/h)	Suppression Pool Water Level‡ (m)	RHR (LPCF) Vortex Limit (See Figure in Sections 18A.4, 18A.12) 0 m = Bottom of Suppression Pool
	0	1.54	
	852	1.54	
	909	1.60	
	1022	1.73	
	1130	1.87	
HPCF VL	Pump Flow (m^3/h)	Suppression Pool Water Level‡ (m)	HPCF Vortex Limit (See Figure in Section 18A.4) 0 m = Bottom of Suppression Pool
	0	1.50	
	662	1.50	
	795	1.67	
	890	1.82	
RPVS	RVP Pressure (MPaG)	Temperature (°C)	RPV Saturation (See Figure in Section 18A.3) 0 m = Bottom of Suppression Pool
	7.93	295.2	
	6.89	285.8	
	5.52	271.3	
	4.14	253.8	
	2.76	231.2	
	1.38	197.7	
	0.69	169.9	
	0.41	152.9	
	0.14	126.0	
	0.07	115.2	
	0.00	100.0	
BIIT	Reactor Power (%)	SuppressioPool Average Temperature (°C)	Boron Injection Initiation Temperature (See Figure in Sections 18A.4, 18A.5, and 18A.12)
	0	93.4	
	2.21	93.4	
	8.26	43.3	
	10.00	43.3	

* 0% Fully Inserted

† 0=Top of Active Fuel (TAF)

‡ 0m = Bottom of Suppression Pool

Table 18D-2 BWROG EPG Rev. 4 Appendix C Results for ABWR (Continued)

Parameter	Value								Parameter Definition
RHR NPSH	Pump Flow (m^3/h)	Suppression Pool Temp (°C) for Overpressure of (MPa)							RHR (LPCF NPSH Limits (See Figure in Section 18A.4, 18A.12)
		0.00	0.034	0.069	0.103	0.173	0.241	0.276	
	0	90.6	101.7	109.4	116.1	126.7	135.6	138.9	
	820	85.6	97.8	106.7	113.9	125.0	133.9	137.2	
	954	82.8	96.1	105.6	112.8	124.4	133.3	136.7	
	1130	78.9	93.3	103.3	111.1	123.3	132.2	136.1	
HPCF NPSH	Pump Flow (m^3/h)	Suppression Pool Temp (°C) for Overpressure of (MPa)							HPCF NPSH Limits See Figure in Section 18A.3)
		0.00	0.034	0.069	0.103	0.173	0.241		
	0	95.6	105.0	112.2	118.9	128.9	136.7		
	500	95.0	104.4	112.2	118.3	128.3	136.7		
	641	93.3	103.3	111.1	117.8	127.7	136.1		
	890	87.8	99.4	107.8	115.0	125.6	134.1		

18E ABWR Human-System Interface Design Implementation Process

18E.1 Introduction

Section 18.3 discusses the program of human factors related activities conducted throughout the development of the ABWR plant system design, including the development of the Main Control Room (MCR) and Remote Shutdown System (RSS) designs. Appendix 18E describes the process through which the MCR and RSS human system interface (HSI) design implementations will be conducted and evaluated through the application of accepted human factors engineering (HFE) practices and principles. Section 18E.2 discusses the basic elements of this HFE design implementation process and includes identification of where in the process the results are planned to be made available for NRC review. The criteria to be used by the NRC in their review of the design implementation, (i.e., the Design Acceptance Criteria (DAC)), are presented in Section 18E.3.

[*Sections 18E.2 and 18E.3, including Tables 18E-1 through 18E-4 and Table 1.8-21, identify the commitments of Human-System Interface Design Implementation Process, which, if changed, requires NRC Staff review and approval prior to implementation. The applicable portions of the sections and tables for this restriction are italicized on the sections and tables themselves.*]*

18E.2 [HSI Design Implementation Process

The designs of the MCR and RSS areas of operator interface, for the execution of normal plant operation and emergency operation, will be implemented and evaluated in accordance with the process illustrated in Figure 18E-1. As shown in Figure 18E-1, the implementation process begins with the establishment of the Human Factors Engineering (HFE) Design Team which prepares the HFE Program and Implementation Plans and guides the process through the remaining steps to the final validation of the implemented design. Figure 18E-1 also identifies the relative timing of the planned NRC conformance reviews along with the corresponding table in Section 18E.3 that defines the acceptance criteria applicable to the individual reviews.

18E.2.1 The HFE Design Team

The HFE Design Team will be composed of experienced individuals whose collective expertise cover a broad range of disciplines relevant to the design and implementation process. These disciplines will include technical project management, control and instrument engineering, plant operations and architect engineering, as well as human factors engineering.

The duties of the HFE Design Team will be to establish the HFE Program and Implementation Plans, to guide and oversee the design implementation process and to assure that the execution and

* See section 3.5 of DCD/Introduction.

documentation of each step in the process is carried out in accordance with the established program and procedures. The team will have the authority to insure that all its areas of responsibility are accomplished and to identify problems in the implementation of the HSI design. The team will have the authority to determine where its input is required and to access work areas and design documentation. The team will also have the authority to control further processing, delivery, installation or use of HFE/HSI products until the disposition of a non-conformance, deficiency or unsatisfactory condition has been achieved.

18E.2.2 The HFE Program and Implementation Plans

The HFE Design Team will establish the HFE Program and Implementation Plans that provide overall direction and integration of the HFE-related design implementation and evaluation activities for the specific HSI scope which includes the RSS and MCR areas of operational interface. The HFE Program Plan will identify the individuals who comprise the HFE Design Team and establish the processes through which the HFE Design Team will perform its functions. Included in the HFE Program Plan will be a system for documenting human factors issues, that may be identified throughout the implementation of the designs, and the actions taken to resolve those issues. The HFE Design Team will also establish the Implementation Plans for conducting each of the following HFE-related activities:

- *(a) System functional requirements analysis*
- *(b) Allocation of functions*
- *(c) Task analysis*
- *(d) Human-system interface design*
- *(e) Human factors verification and validation*

The Implementation Plans will establish methods and criteria, for the conduct of each of these HFE-related activities, which are consistent with accepted HFE practices and principles. (For additional detailed information regarding the scope and content of the HFE Program and Implementation Plans, refer to the acceptance criteria presented in Table 18E-1)

18E.2.3 System Functional Requirements Analysis

Analyses of the system functional requirements will be conducted through application of the methods and criteria established by the HFE Design Team in the System Functional Requirements Analysis Implementation Plan. The system functional analysis will determine the performance requirements and constraints of the HSI design and establish the functions which must be accomplished to meet these requirements. Safety functions will be specifically identified along with any functional interrelationship that those safety functions may have with non-safety systems. In addition, critical functions (i.e., functions required to achieve major system performance requirements or functions which, if failed, could degrade system performance or pose a safety hazard to plant personnel or the general public) will be identified. Detailed narrative descriptions will be developed for each of the identified functions.

18E.2.4 Allocation of Functions

The functions defined through the function analysis will then be allocated (i.e., defined as a function to be performed by the human, the system equipment or by a combination of the human and system equipment) per the methods and criteria established by the HFE Design Team in the Allocation of Functions Implementation Plan. The allocation of functions will be done to take advantage of areas of human strengths and avoid allocating functions to personnel which would be impacted by human limitations. The allocation of functions to personnel, systems or personnel-system combinations will be made to reflect: sensitivity, precision, time and safety requirements, required reliability of system performance and the number and level of skills of personnel required to operate and maintain the system.

As alternative allocation concepts are developed, analyses and trade-off studies shall be conducted to determine adequate configurations of personnel and system-performed functions. Analyses will be done to confirm that the personnel elements can properly perform tasks that are allocated to them while maintaining proper operator situational awareness, workload and vigilance.

18E.2.5 Task Analyses

Following completion of the function allocation step, task analyses will be performed on those functions which have been allocated to personnel. These task analyses will be performed per the methods and criteria established by the HFE Design Team Task Analysis Implementation Plan. The task analyses will identify the behavioral requirements of the tasks associated with individual functions. Tasks are defined as groups of activities that have a common purpose, often occurring in temporal proximity, and which utilize the same displays and controls. The task analyses will: provide one of the bases for making design decisions; e.g., determining before hardware fabrication, to the extent practicable, whether system performance requirements can be met by combinations of anticipated equipment, software and personnel; assure that human performance requirements do not exceed human capabilities; be used as basic information for developing manning, skill, training and communications requirements of the system; and form the basis for specifying the requirements for the displays, data processing and controls needed to carry out the tasks.

The scope of the task analyses shall include all operations performed at the operator interface in the main control room and at the Remote Shutdown System. The analysis shall be directed to the full range of plant operating modes, including startup, normal operations, abnormal operations, transient conditions, low power and shutdown conditions. The analysis shall also address operator interface operations during periods of maintenance test and inspection of plant systems and equipment and of the HSI equipment.

18E.2.6 Human-System Interface Design

As established by the HFE Design Team in their development of the HSI Design Implementation Plan, human engineering criteria will be applied along with all other design requirements to *select and design the particular equipment for application to the MCR and RSS HSI. The HSI design will implement the information and control requirements that have been developed in the task analysis, including the displays, control and alarms necessary for the execution of those tasks identified in the task analyses as being critical tasks. The equipment design configuration will satisfy the functional and technical design requirements and insure that the HSI is consistent with applicable HFE principles.*

18E.2.7 Procedure Development

Plant and emergency operating procedures will be developed to support and guide human interactions with plant systems and to control plant-related events and activities. Plant procedure development is discussed in Section 13.5.

18E.2.8 Human Factors Verification and Validation

Following the methods and criteria established by the HFE Design Team in the Human Factors Verification and Validation Plan, the successful incorporation of human factors engineering into the implemented HSI design and the acceptability of the resulting HSI will be thoroughly evaluated as an integrated system.

The evaluations will include consideration of the HSI, the plant and emergency operating technical procedures and the overall work environment (e.g., lighting, ventilation, etc.). Individual HSI elements will be evaluated in a static mode to assure that all controls, displays and data processing that were identified in the task analyses are available and that they are designed according to accepted HFE principles, practices, and criteria. In addition, the integration of HSI elements with each other and with personnel will be evaluated and validated through dynamic task performance evaluation using evaluation tools such as a dynamic HSI prototype driven by real-time plant simulation models. The dynamic task performance evaluation will be conducted over the full range of operational conditions and plant maintenance activities including: normal plant operation; plant system and equipment failures; HSI equipment failures; plant transients and postulated plant emergency conditions.

18E.3 HSI Implementation Requirements

Section 18E.2 describes the process through which the ABWR Main Control Room (MCR) and Remote Shutdown System (RSS) areas of operator interface will be implemented and evaluated. Figure 18E-1 presents the relative timing of the NRC conformance reviews which are planned throughout the MCR and RSS Human-System Interface (HSI) design implementation. Tables 18E-1 through of this section define the requirements that are to be met by the HSI design implementation activities that are to be made available for review by the NRC. The HSI design implementation related Design Acceptance Criteria (DAC) which are established through Rulemaking, (refer to Section 3.1 of the Tier 1 Design Certification material for the GEH ABWR design), are defined such that there exists a direct correspondence between the DAC entries and requirements imposed herein on those design activities whose results are to be made available for the NRC conformance reviews, as identified in Figure 18E-1. Those *requirements presented in Table 18E-1 through which correspond to individual Tier 1 DAC acceptance criteria are specifically identified. Therefore, satisfaction of those specific requirements shall result in full compliance with the Certified Design Commitment and the corresponding Acceptance Criteria presented in the Tier 1 (Rulemaking) DAC established for the HSI design implementation.]* *

* See Section 18E.1.

Table 18E-1 Human Factors Engineering Design Team and Plans

(I) [HFE Design Team Composition

(Satisfaction of the requirements presented herein shall result in the creation of an HFE Design Team which is in full compliance with the Item 1a Acceptance Criteria presented in Table 3.1 of the Tier 1 Design Certification Material for the GEH ABWR design)

(1) The composition of the Human Factor Engineering (HFE) Design Team shall include, as a minimum, the technical skills presented in Article (4), below.

(2) The education and related professional experience of the HFE Design Team personnel shall satisfy the minimum personal qualification requirements specified in Article (4), below, for each of the areas of required skills. In those skill areas where related professional experience is specified, qualifying experience of the individual HFE Design Team personnel shall include experience in the ABWR main control room and Remote Shutdown System (RSS) Human System Interface (HSI) designs and design implementation activities. The required professional experience presented in those personal qualifications of Article (4) are to be satisfied by the HFE Design Team as a collective whole. Therefore, satisfaction of the professional experience requirements associated with a particular skill area may be realized through the combination of the professional experience of two or more members of the HFE Design Team who each, individually, satisfy the other defined credentials of the particular skill area but who do not possess all of the specified professional experience. Similarly, an individual member of the HFE Design Team may possess all of the credentials sufficient to satisfy the HFE Design Team qualification requirements for two or more of the defined skill areas.

(3) Alternative personal credentials may be accepted as the basis for satisfying the minimum personal qualification requirements specified in Article (4), below. Acceptance of such alternative personal credentials shall be evaluated on a case-by-case basis and approved, documented and retained in auditable plant construction files by the COL applicant. The following factors are examples of alternative credentials which are considered acceptable.

(a) A Professional Engineer's license in the required skill area may be substituted for the required Bachelor's degree.

(b) Related experience may substitute for education at the rate of six semester credit hours for each year of experience up to a maximum of 60 hours credit.

(c) Where course work is related to job assignments, post secondary education may be substituted for experience at the rate of two years of education for one year experience. Total credit for post secondary education shall not exceed two years experience credit.

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(4)	*Required Skill Area*		*Personal Qualification*
	(a)	*Technical Project Management*	*Bachelor of Science degree, and five years experience in nuclear power plant design operations, and three years management experience.*
	(b)	*Systems Engineering*	*Bachelor of Science degree, and four years cumulative experience in at least three of the following areas of systems engineering; design, development, integration, operation, and test and evaluation.*
	(c)	*Nuclear Engineering*	*Bachelor of Science degree, and four years nuclear design, development, test or operations experience.*
	(d)	*Instrumentation and Control (I&C) Engineering*	*Bachelor of Science degree, and four years experience in design of process control systems, and experience in at least one of the following areas of I&C engineering; development, power plant operations, and test and evaluation.*
	(e)	*Architect Engineering*	*Bachelor of Science degree, and four years power plant control room design experience.*
	(f)	*Human Factors*	*Bachelor of Science degree in human factors engineering, engineering psychology or related science, and four years cumulative experience related to the human factors aspects of human-computer interfaces. Qualifying experience shall include experience in at least two of the following human factors related activities; design, development, and test and evaluation, and four years cumulative experience related to the human factors field of ergonomics. Again, qualifying experience shall include experience in at least two of the following areas of human factors activities; design, development, and test and evaluation.*
	(g)	*Plant Operations*	*Have or have held a Senior Reactor Operator license; two years experience in BWR nuclear power plant operations.*

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(h) Computer System Engineering — *Bachelor of Science degree in Electrical Engineering or Computer Science, or graduate degree in other engineering discipline (e.g., Mechanical Engineering or Chemical Engineering), and four years experience in the design of digital computer systems and real time systems applications.*

(i) Plant Procedure Development — *Bachelor's degree, and four years experience in developing nuclear power plant operating procedures.*

(j) Personnel Training — *Bachelor's degree and four years experience in the development of personnel training programs for power plants, and experience in the application of systematic training development methods.*

(II) Human Factors Engineering Program Plan

(1) (Satisfaction of the requirements presented herein shall result in the creation of a Human Factors Engineering Program Plan which is in full compliance with the Item 1.b. Acceptance Criteria presented in Table 3.1 of the Tier 1 Design Certification material for the GEH ABWR design.) The Human Factors Engineering (HFE) Program Plan shall establish:

(a) Methods and criteria, for the development and evaluation of the Main Control Room (MCR) and Remote Shutdown System (RSS) HSI which are consistent with accepted HFE practices and principles. Within the defined scope and content of the HFE Program Plan, accepted HFE methods and criteria are presented in the following documents:

(i) AR 602-1, Human Factors Engineering Program, (Dept. of Defense)

(ii) DI-HFAC-80740, Human Engineering Program Plan, (Dept. of Defense)

(iii) DOD-HDBK-763, Human Engineering Procedures Guide, Chapters 5-7 and Appendices A and B, (Dept. of Defense)

(iv) EPRI NP-3659, Human Factors Guide for Nuclear Power Plant Control Room Development, 1984, (Electric Power Research Institute)

(v) IEEE-1023, IEEE Guide to the Application of Human Factors Engineering to Systems, Equipment and Facilities of Nuclear Power Generating Stations, (IEEE)

(vi) MIL-H-46855B, Human Engineering Requirements for Military Systems, Equipment and Facilities, (Dept. of Defense)

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(vii) NUREG-0700, Guidelines for Control Room Design Reviews, 1981, (US Nuclear Regulatory Commission) *(viii) NUREG-0737, Clarification of TMI Action Plan Requirements (Item I.C.5, "Feedback of Operating Experience to Plant Staff"), 1983, (US Nuclear Regulatory Commission)* *(ix) NUREG-0899, Guidelines for the Preparation of Emergency Operating Procedures, 1982, (US Nuclear Regulatory Commission)* *(x) NUREG/CR-3331, A Methodology for Allocating Nuclear Power Plant Control Functions to Human and Automated Control, 1983, (US Nuclear Regulatory Commission)* *(xi) TOP 1-2-610, Test Operating Procedure Part 1, (Dept. of Defense)* *Note that within the set of documents listed above, differences may exist regarding specific methods and criteria applicable to the HFE Program Plan. In situations that such differences exist, for a particular issue, all of the methods and criteria presented within those documents which address that particular issue are considered to be equally appropriate and valid and, therefore, any of those documents may be selected as the basis for how that particular issue is addressed in the HFE Program.* *(b) The methods for addressing:* *(i) The ability of the operating personnel to accomplish assigned tasks.* *(ii) Operator workload levels and vigilance.* *(iii) Operating personnel "situation awareness".* *(iv) The operator's information processing requirements.* *(v) Operator memory requirements.* *(vi) The potential for operator error.*

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(c) *HSI design and evaluation scope which applies to the Main Control Room (MCR) and Remote Shutdown System (RSS).*

The HSI scope shall address normal, abnormal and emergency plant operations and test and maintenance interfaces that impact the function of the operations personnel. The HSI scope shall also address the development of operating technical procedures for normal, abnormal and emergency plant operations and the identification of personnel training needs applicable to the HSI design. The development of operating technical procedures are COL license information requirements (see Section 13.5). The establishment of an operator training program which meets the requirements of 10CFR50 is also a COL license information requirement (See Subsection 18.8.8).

(d) *The HFE Design Team as being responsible for:*

- (i) *The development of HFE plans and procedures.*
- (ii) *The oversight and review of HFE design, development, test, and evaluation activities.*
- (iii) *The initiation, recommendation, and provision of solutions through designated channels for problems identified in the implementation of the HFE activities.*
- (iv) *Verification of implementation of solutions to problems.*
- (v) *Assurance that HFE activities comply to the HFE plans and procedures.*
- (vi) *Phasing of activities*

(e) *The methods for identification, closure and documentation of human factors issues. [an acceptable method is described in Sections (2) (a) and (2) (b) below].*

(f) *The HSI design configuration control procedures.*

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(2) The HFE Program Plan shall also establish:

(a) That each HFE issue/concern shall be entered on the HFE Issue Tracking System log when first identified, and each action taken to eliminate or reduce the issue/concern shall be documented. The final resolution of the issue/concern, as accepted by the HFE Design Team, shall be documented along with information regarding HFE Design Team acceptance (e.g., person accepting, date, etc.) the individual responsibilities of the HFE Design Team members when an HFE issue/concern is identified, including definition of who should log the item, who is responsible for tracking the resolution efforts, who is responsible for acceptance of a resolution, and who shall enter the necessary closeout data.

(b) That the HFE Issue Tracking System shall address human factors issues that are identified throughout the development and evaluations of the Main Control Room and Remote Shutdown System HSI design implementation.

(c) That the MCR and RSS designs shall be implemented using HSI equipment technologies which are consistent with those defined in Section 18.4.3.

(d) That in the event other HSI equipment technologies are alternatively selected for application in the MCR and RSS design implementations:

(i) A review of the industry experience with the operation of those selected new HSI equipment technologies shall be conducted.

(ii) The Operating Experience Review (OER) of those new HSI equipment technologies shall include both a review of literature pertaining to the human factors issues related to similar system applications of those new HSI equipment technologies and interviews with personnel experienced with the operation of those systems.

(iii) Any relevant HFE issues/concerns associated with those selected new HSI equipment technologies, identified through the conduct of the OER, shall be entered into the HFE Issue Tracking System for closure.

(e) That a review of HSI operating experience shall be conducted as follows:

(i) For the first implementation of the ABWR Certified Design:

(a) That the lessons learned from the review of previous nuclear plant HSI designs, as defined by Attachment 1 to this Table 18E-1, shall be entered into the HFE Issue Tracking System to assure that problems observed in previous designs have been adequately addressed in the ABWR design implementation.

(b) Reviews of operating experience with the following ABWR HSI design areas, in which further development of the industry's experience base can be expected, shall be completed.

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

—Use of flat panel and CRT displays *—Use of electronic on-screen controls* *—Use of wide display panels* *—Use of prioritized alarm systems* *—Automation of process systems* *—Operator workstation design integration* *Those operating experience reviews shall include review of reports provided by industry organizations (i.e., EPRI, etc.); review of applicable research in these design areas, as may be documented in reports from universities, national laboratories and the NRC, and in proceedings published by HFE professional societies; and review of applicable research and experience reports published by the HSI equipment vendors. Further, the review of operating experience in each of the six above identified areas shall include feedback obtained from actual users. Therefore, if the documents selected for the conduct of the operating experience review for a particular area do not include the results of user feedback, then interviews with users of at least two applications of that particular technology area shall also be conducted. Finally, the results from all these operating experience review activities shall be entered into the HFE Issue Tracking System to assure that the ABWR implementation reflects the experience gained by the resolution of design problems in operating plants.* *(ii) For all subsequent implementations of the ABWR design:* *(a)If a previously implemented ABWR HSI design is utilized directly and without change, then no further review of operating experience is required.* *(b)If a previously implemented ABWR HSI design is not being utilized directly, then the operating experience of the most recent implementations, up to three, shall be reviewed through the conduct of operator interviews and surveys and the evaluation of Licensing Event Reports and the results of these reviews shall be entered into the HFE Issue Tracking System to assure that previous design problems have been adequately addressed in the ABWR design implementation.*

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(3) The HFE Program Management Plan document shall include:

(a) The purpose and organization of the plan.

(b) The relationship between the HFE program and the overall plant equipment procurement and construction program (organization and phasing).

(c) Definition of the HFE Design Team and their activities including:

(i) Description of the HFE Design Team function within the broader scope of the plant equipment procurement and construction program, including charts to show organizational and functional relationships, reporting relationships, and lines of communication.

(ii) Description of the responsibility, authority and accountability of the HFE Design Team organization.

(iii) Description of the process through which management decisions will be made regarding HFE.

(iv) Description of the process through which technical decisions will be made by the HFE Design Team.

(v) Description of the tools and techniques (e.g., review forms, documentation) to be utilized by the HFE Design Team in fulfilling their responsibilities.

(vi) Description of the HFE Design Team staffing, job descriptions of the individual HFE Design Team personnel and their personal qualifications.

(vii) Definition of the procedures that will govern the internal management of the HFE Design Team.

(d) Definition of the HFE Issue Tracking System and its implementation including:

(i) Individual HFE Design Team member responsibilities regarding HFE issue identification, logging, issue resolution, and issue closeout.

(ii) Procedures and documentation requirements regarding HFE issue identification.

These shall include description of the HFE issue, effects of the issue if no design change action is taken and an assessment of the criticality and likelihood of the identified HFE issue manifesting itself into unacceptable HSI performance.

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(iii) Procedures and documentation requirements regarding HFE issue resolution.

These procedures shall include evaluation and documentation of proposed solutions, implemented solutions, evaluated residual effects of the implemented solution and an evaluation of the likelihood that the implemented resolution of the HFE issue manifesting itself into unacceptable HSI performance.

(e) Identification and description of the following implementation plans to be developed:

(i) System Functional Requirements Development

(ii) Allocation of Function

(iii) Task Analysis

(iv) Human-System Interface Design

(v) Human Factors Verification and Validation

(f) Definition of the phasing of HFE program activities including:

(i) The plan for completion of HFE tasks which addresses the relationships between HFE elements and activities, the development of HFE reports and the conduct of HFE reviews.

(ii) Identification of other plant equipment procurement and construction activities which are related to HFE Design Team activities but outside the scope of the team (e.g., I&C equipment manufacture).

(g) Definition of HFE documentation requirements and procedures for retention and retrieval.

(h) Description of the manner in which HFE Program requirements will be communicated to applicable personnel and organizations, including those which may be subcontracted, who are responsible for the performance of work associated with the Main Control Room and Remote Shutdown System design implementation.

(III) System Functional Requirements Analysis Implementation Plan

(1) (Satisfaction of the requirements presented herein shall result in the creation of a System Functional Requirements Analysis Implementation Plan which is in full compliance with the Item 2.a acceptance criteria presented in Table 3.1 of the Tier 1 Design Certification material for the GEH ABWR design). The System Functional Requirements Analysis Implementation Plan shall establish:

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(a) *The methods and criteria for conducting the System Functional Requirements Analysis which are consistent with accepted HFE practices and principles. Within the context of system functional requirements analysis, accepted HFE methods and criteria are presented in the following documents:*

- (i) *AD/A233 168, System Engineering Management Guide, (Dept. of Defense, Defense Systems Management College, Kockler, F., et al)*
- (ii) *AR602-1, Human Factors Engineering Program, (Dept. of Defense)*
- (iii) *EPRI NP-3659, Human Factors Guide for Nuclear Power Plant Control Room Development, 1984, (Electric Power Research Institute)*
- (iv) *IEC 964, Design for Control Rooms of Nuclear Power Plants, (Bureau Central de la Commission Electrotechnique Internationale)*
- (v) *IEEE-1023, IEEE Guide to the Application of Human Factors Engineering to Systems, Equipment and Facilities of Nuclear Power Generating Stations*
- (vi) *MIL-H-46855B, Human Engineering Requirements for Military Systems, Equipment and Facilities, (Dept. of Defense)*
- (vii) *NUREG-0700, Guidelines for Control Room Design Reviews, 1981, (US Nuclear Regulatory Commission)*
- (viii) *NUREG/CR-3331, A Methodology for Allocating Nuclear Power Plant Control Functions to Human and Automated Control, 1983, (US Nuclear Regulatory Commission)*

Note that within the set of documents listed above, differences may exist regarding the specific methods and criteria applicable to the conduct of system functional requirements analysis. In situations that such differences exist, for a particular issue, all of the methods and criteria presented within those documents which address that particular issue are considered to be equally appropriate and valid and, therefore, any of those documents may be selected as the basis for defining how that particular issue is addressed in the system functional requirements analysis.

(b) *That system requirements shall define the system functions and those system functions shall provide the basis for determining the associated HSI performance requirements.*

(c) *That functions critical to safety shall be defined (i.e., those functions required to achieve safety system performance requirements; or those functions which, if failed, could pose a safety hazard to plant personnel or to the general public).*

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(d) *That descriptions shall be developed for each of the identified functions and for the overall system configuration design itself. Each function shall be identified and described in terms of inputs (observable parameters which will indicate systems status) functional processing (control process and performance measures required to achieve the function), functional operations (including detecting signals, measuring information, comparing one measurement with another, processing information, and acting upon decisions to produce a desired condition or result such as a system or component operation actuation or trip) outputs, feedback (how to determine correct discharge of function), and interface requirements so that subfunctions are related to larger functional elements.*

(2) *The System Functional Requirements Analysis Implementation Plan shall include:*

(a) *The methods for identification of system level functions based upon system performance requirements. The functions shall be defined as the most general, yet differentiable means whereby the system requirements are met, discharged, or satisfied. Functions shall be arranged in a logical sequence so that any specified operational usage of the system can be traced in an end-to-end path.*

(b) *The methods for developing graphic function descriptions (e.g., Functional Flow Block Diagrams and Time Line Diagrams). The functions shall be described initially in graphic form. Function diagramming shall be done starting at a "top level", where major functions are described, and continuing to decompose major functions to lower levels until a specific critical end-item requirement emerges, e.g., a piece of equipment, software, or an operator.*

(c) *The method for developing detailed function narrative descriptions which encompass:*

(i) *Observable parameters that indicate system status.*

(ii) *Control process and data required to achieve the function.*

(iii) *How to determine the manner in which proper discharge of function is to be determined.*

(d) *The analysis methods which define the integration of closely-related subfunctions so that they can be treated as a unit.*

(e) *The analysis methods which divide identified subfunctions into two groups according to whether:*

(i) *Common achievement of the subfunction is an essential condition for the accomplishment of a higher level function.*

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(ii) The subfunction is an alternative supporting function to a higher level function or the subfunction's accomplishment is not necessarily a requisite for a higher level function.

(f) The requirements to identify for each integrated subfunction:

(i) The basis for why accomplishment of the subfunction is required.

(ii) The control actions necessary for accomplishment of the subfunctions.

(iii) The parameters necessary for the subfunction control actions.

(iv) The criteria for evaluating the results of the subfunction control actions

(v) The parameters necessary for evaluation of the subfunction.

(vi) The criteria to be used to evaluate the subfunction.

(vii) The criteria for selecting alternative function assignments if the evaluation criteria b is not satisfied.

(IV) Allocation of Function Implementation Plan

(1) (Satisfaction of the requirements presented herein shall result in the creation of an Allocation of Function Implementation Plan which is in full compliance with the Item 3.a Acceptance Criteria presented in Table 3.1 of the Tier 1 Design Certification material for the GEH ABWR design). The Allocation of Function Implementation Plan shall establish:

(a) The methods and criteria for the execution of function allocation which are consistent with accepted HFE practices and principles. Within the context of function allocation, accepted HFE practices and principles are presented in the following documents:

(i) AD/A223 168, System Engineering Management Guide, (Dept. of Defense, Defense Systems Management College, Kockler, F., et al)

(ii) AR 602-1, Human Factors Engineering Program , (Dept. of Defense)

(iii) EPRI NP-3659, Human Factors Guide for Nuclear Power Plant Control Room Development, 1984, (Electric Power Research Institute)

(iv) IEC 964, Design for Control Rooms of Nuclear Power Plants, (Bureau Central de la Commission Electrotechnique Internationale)

(v) NUREG-0700, Guidelines for Control Room Design Reviews, 1981, (US Nuclear Regulatory Commission)

(vi) NUREG/CR-3331, A Methodology for Allocating Nuclear Power Plant Control Functions to Human and Automated Control, 1983, (US Nuclear Regulatory Commission)

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

Note that within the set of documents listed above, differences may exist regarding the specific methods and criteria applicable to the conduct and analysis of function allocation. In situations that such differences exist, for a particular issue, all of the methods and criteria presented within those documents which address that particular issue are considered to be equally appropriate and valid and, therefore, any of those documents may be selected as the basis for defining how the particular issue is to be addressed in the conduct of the function allocation and analysis.

(b) That aspects of system and functions definition shall be analyzed in terms of resulting human performance requirements based on the expected user population.

(c) That the allocation of functions to personnel, system elements, and personnel system combinations shall reflect:

- *(i) Areas of human strengths and limitations.*
- *(ii) Sensitivity, precision, time, and safety requirements.*
- *(iii) Reliability of system performance.*
- *(iv) The number and the necessary skills of the personnel required to operate and maintain the system.*

(d) That the allocation criteria, rationale, analyses, and procedures shall be documented.

(e) Analyses shall confirm that the personnel can perform tasks allocated to them while maintaining operator situation awareness, acceptable personnel workload, and personnel vigilance.

(2) The Allocation of Function Implementation Plan shall include:

(a) Establishment of a structured basis and criteria for function allocation.

(b) Definition of function allocation analyses requirements including:

- *(i) Definition of the objectives and requirements for the evaluation of function allocations.*
- *(ii) Development of alternative function allocations for use in the conduct of comparative evaluations.*
- *(iii) Development of criteria to be used as the basis for selecting between alternative function allocations.*
- *(iv) Development of evaluation criteria weighing factors.*
- *(v) Development of test and analysis methods for evaluating function allocation alternatives.*

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(vi) Definition of the methods to be used in conducting assessments of the sensitivity of the comparative function allocation alternatives analyses results to the individual analysis inputs and criteria.

(vii) Definition of the methods to be employed in selecting individual function allocation for incorporation into the implemented design.

(V) Task Analysis Implementation Plan

(1) (Satisfaction of the requirements presented herein shall result in the creation of a Task Analysis Implementation Plan which is in full compliance with the Item 4.a Acceptance Criteria presented in Table 3.1 of the Tier 1 Design Certification material for the GEH ABWR design). The Task Analysis Implementation Plan shall establish:

(a) The methods and criteria for conduct of the task analysis which are consistent with accepted HFE practices and principles. Within the context of performing task analysis, accepted HFE methods and criteria are presented in the following documents:

(i) AD/A223 168, System Engineering Management Guide, (Dept. of Defense, Defense Systems Management College, Kockler, F., et al)

(i) DOD-HDBK-763, Human Engineering Procedures Guide, Chapters 5-7 and Appendices A and B, 1991, (Dept. of Defense)

(ii) EPRI NP-3659, Human Factors Guide for Nuclear Power Plant Control Room Development, 1984, (Electric Power Research Institute)

(iii) IEC 964, Design for Control Rooms of Nuclear Power Plants, (Bureau Central de la Commission Electrotechnique Internationale)

(iv) IEEE-1023, IEEE Guide to the Application of Human Factors Engineering to Systems, Equipment and Facilities of Nuclear Power Generating Stations, (IEEE)

(v) MIL-H-46855B, Human Engineering Requirements for Military Systems, Equipment and Facilities, (Dept. of Defense)

(vi) MIL-STD-1478, Task Performance Analysis, (Dept. of Defense)

(vii) NUREG-0700, Guidelines for Control Room Design Reviews, 1981, (US Nuclear Regulatory Commission)

(viii) NUREG/CR-3331, A Methodology for Allocating Nuclear Power Plant Control Functions to Human and Automated Control, 1983, (US Nuclear Regulatory Commission)

(ix) NUREG/CR-3371, Task Analysis of Nuclear Power Plant Control Room Crews (Vol. 1), 1983, (US Nuclear Regulatory Commission)

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

Note that within the set of documents listed above, differences may exist regarding the specific methods and criteria applicable to the conduct of HFE task analysis. In situations that such differences exist, for a particular issue, all of the methods and criteria presented within those documents which address that particular issue are considered to be equally appropriate and valid and, therefore, any of those documents may be selected as the basis for defining how that particular issue is addressed in the task analysis.

(b) The scope of the task analysis which shall include operations performed at the operator interface in the Main Control Room and at the Remote Shutdown System. The analyses shall be directed to the full range of plant operating modes, including startup, normal operations, abnormal operations, transient conditions, low power and shutdown conditions. The analyses shall also address operator interface operations during periods of maintenance, test and inspection of plant systems and equipment including the HSI equipment.

(c) That the analysis shall link the identified and described tasks in operational sequence diagrams. Task descriptions and operational sequence diagrams shall be used to identify which tasks are critical to safety in terms of importance for function achievement, potential for human error, and impact of task failure. Human actions which are identified through PRA sensitivity analyses to have significant impact on safety shall also be considered "critical" tasks. Where critical functions are automated, the analyses shall address the associated human tasks including the monitoring of the automated function and the backup manual actions which may be required if the automated function fails.

(d) That the task analysis shall develop narrative descriptions of the personnel activities required for successful completion of the task. A task shall be a group of activities, often occurring in temporal proximity, which utilize a common set of displays and controls. Task analysis shall define the input, process, and output required by and of personnel.

(e) The task analysis shall identify requirements for alarms, displays, data processing, and controls.

(f) The task analysis results shall be made available as input to the personnel training programs.

(2) The Task Analysis Implementation Plan shall include:

(a) The methods and data sources to be used in the conduct of the task analysis

(b) The methods for conducting the initial (high level) task analysis including:

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(i) Converting functions to tasks.

(ii) Developing narrative task descriptions.

(iii) Developing the basic statement of the task functions.

(iv) Decomposition of tasks to individual activities.

(v) Development of operational sequence diagrams.

(c) The methods for developing detailed task descriptions that address:

(i) Information requirements (i.e., information required to execute a task, including cues for task initiation).

(ii) Decision-making requirements (i.e., decisions that are probably based on the evaluations, description of the decisions to be made and the evaluations to be performed).

(iii) Response requirements (i.e., actions to be taken, frequency of action, speed/time requirements, any tolerance/accuracy requirements associated with the action, consideration of any operational limits of personnel performance or of equipment, body movements required by an action taken, and any overlap of task requirements such as serial vs. parallel task elements).

(iv) Feedback requirements (i.e., feedback required to indicate adequacy of actions taken).

(v) Personnel workload (i.e., both cognitive and physical workload and the estimation of the level of difficulty associated with a particular workload condition).

(vi) Any associated task support requirements (i.e., special/protective clothing, job aids, reference materials, tools, equipment or any computer processing support aids).

(vii) Workplace factors (i.e., the workspace envelope required by the action taken, workspace environmental conditions, location that the work is to be performed, the physical/mental attributes of the work).

(viii) Staffing and communication requirements (i.e., the number of personnel, their technical specialty, and specific skills, the form and content of communications and other personnel interaction required when more than one person is involved).

(ix) The identification of any hazards involved in execution of the task.

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(d) *The methods for identification of critical tasks. The identified critical tasks shall include, at the minimum; those operator actions which have significant impact on the PRA results, as presented in Section 19D.7, and; the operator actions to isolate the reactor and inject water for the postulated event scenarios of a common mode failure of the Safety System Logic and Control System and/or the essential Multiplexing System concurrent with a design basis main steamline, feedwater line or shutdown cooling line break LOCA.*

(e) *The methods for establishing information and control requirements.*

(f) *The methods for conducting alarm, display, processing, and control requirements analysis.*

(g) *The methods through which the application of task analysis results are assembled and documented to provide input to the development of personnel training programs.*

(h) *The methods to be used to evaluate the results of the task analysis.*

(VI) *HSI Design Implementation Plan*

(1) *(Satisfaction of the requirements presented herein shall result in the creation of an HSI Design Implementation Plan which is in full compliance with the Item 5.a Acceptance Criteria presented in Table 3.1 of the Tier 1 Design Certification material for the GEH ABWR design). The HSI Design Implementation Plan shall establish:*

(a) *The methods and criteria for HSI equipment design and evaluation of HSI human performance, equipment design and associated work place factors, such as illumination in the MCR and in the RSS area, which are consistent with accepted HFE practices and principles. Within the context of performing these HSI design evaluations, accepted HFE methods and criteria are presented in the following documents:*

(i) *AD/A223 168, System Engineering Management Guide, (Dept. of Defense, Defense Systems Management College, Kockler, F., et al)*

(ii) *ANSI HFS-100, American National Standard for Human Factors Engineering of Visual Display Terminal Workstations, (Am. Nat'l. Standards Institute)*

(iii) *EPRI NP-3659, Human Factors Guide for Nuclear Power Plant Control Room Development, 1984, (Electric Power Research Institute)*

(iv) *EPRI NP-3701, Computer-Generated Display System Guidelines, 1984, (Electric Power Research Institute)*

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(v) ESD-TR-86-278, Guidelines for Designing User Interface Software, (Department of Defense)

(vi) IEC 964, Design for Control Rooms of Nuclear Power Plants, (Bureau Central de la Commission Electrotechnique Internationale)

(vii) MIL-H-46855B, Human Engineering Requirements for Military Systems, Equipment and Facilities, (Dept. of Defense)

(viii) MIL-HDBK-759A, Human Factors Engineering Design for Army, Material (Dept. of Defense)

(ix) DOD-HDBK-761A, Human Engineering Guidelines for Management Information Systems, (Dept. of Defense)

(x) MIL-STD-1472D, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, (Dept. of Defense)

(xi) NUREG-0696, Functional Criteria for Emergency Response Facilities, 1980, (US Nuclear Regulatory Commission)

(xii) NUREG-0700, Guidelines for Control Room Design Reviews, 1981, (US Nuclear Regulatory Commission)

(xiii) NUREG-0800, Standard Review Plan, (US Nuclear Regulatory Commission)

(xiv) NUREG-0899, Guidelines for the Preparation of Emergency Operating Procedures, 1982, (US Nuclear Regulatory Commission)

(xv) NUREG/CR-5228, Techniques for Preparing Flowchart Format Emergency Operating Procedures (Vols. 1 & 2), 1989, (US Nuclear Regulatory Commission)

(xvi) NUREG/CR-4227, Human Engineering Guidelines for the Evaluation and Assessment of Video Display Units, 1985, (US Nuclear Regulatory Commission)

(xvii) Gilmore, et. al. (1989), User-Computer Interface in Process Control: A Human Factors Engineering Handbook. San Diego, CA: Academic Press, Inc.

Note that within the set of documents listed above, differences may exist regarding the specific methods and criteria applicable to the conduct of HSI design evaluations. In situations that such differences exist, for a particular issue, all of the methods and criteria presented within those documents which address that particular issue are considered to be equally appropriate and valid and, therefore, any of those documents may be selected as the basis for defining how that particular issue is addressed in the HSI design evaluations.

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(b) *That the HSI design shall implement the information and control requirements developed through the task analyses, including the displays, controls and alarms necessary for the execution of those tasks identified in the task analyses as being critical tasks (See paragraph V.2.d of this table).*

(c) *The methods for comparing the consistency of the HSI human performance equipment, design and associated workplace factors with that modeled and evaluated in the completed task analysis.*

(d) *That the HSI design shall not incorporate equipment (i.e., hardware or software function) which has not been specifically evaluated in the task analysis.*

(e) *The HSI design criteria and guidance for control room operations during periods of maintenance, test and inspection of control room HSI equipment and of other plant equipment which has control room personnel interface*

(f) *The test and evaluation methods for resolving HFE/HSI design issues. These test and evaluation methods shall include the criteria to be used in selecting HFE/HSI design and evaluation tools which:*

- (i) *May incorporate the use of static mockups and models for evaluating access and workspace-related HFE issues.*
- (ii) *Shall require dynamic simulations and HSI prototypes for conducting evaluations of the human performance associated with the activities in the critical tasks identified in the task analysis.*

(2) *The Human System Interface Design Implementation Plan shall include:*

(a) *Identification of the specific HFE standards and guidelines documents which substantiate that the selected HSI Design Evaluation Methods and Criteria are based upon accepted HFE practices and principles.*

(b) *Definition of standardized HFE design conventions.*

(c) *Definition that the standard design features, presented in Section 18.4.2; the standard HSI equipment technologies, presented in Section 18.4.3; and the displays, controls and alarms presented in Tables 18F-1, 18F-2 and 18F-3, shall be incorporated as requirements on the HSI design.*

(d) *Definition of the design/evaluation tools (e.g., prototypes) which are to be used in the conduct of the HSI design analyses, the specific scope of evaluations for which those tools are to be applied and the rationale for the selection of those specific tools and their associated scope of application.*

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(VII) Human Factors Verification and Validation Implementation Plan

(1) (Satisfaction of the requirements presented herein shall result in the creation of a Human Factors Verification and Validation Implementation Plan which is in full compliance with the Item 6.a Acceptance Criteria presented in Table 3.1 of the Tier 1 Design Certification material for the ABWR design). The Human Factors Verification and Validation (V&V) Implementation Plan shall establish:

(a) Human factors V&V methods and criteria which are consistent with accepted HFE practices and principles. Within the context of performing human factors V&V, accepted HFE methods and criteria are presented in the following documents:

(i) AD/A223 168, System Engineering Management Guide, (Dept. of Defense, Defense Systems Management College, Kockler, F., et al)

(ii) DOD-HDBK-763, Human Engineering Procedures Guide, Chapters 5-7 and Appendices A and B, (Dept. of Defense)

(iii) DOD 5000.2, Defense Acquisition Management Policies and Procedures, (Dept. of Defense)

(iv) EPRI NP-3701, Computer-Generated Display System Guidelines, 1984, (Electric Power Research Institute)

(v) IEC 964, Design for Control Rooms of Nuclear Power Plants, (Bureau Central de la Commission Electrotechnique Internationale)

(vi) IEEE-845, IEEE Guide to Evaluation of Man-Machine Performance in Nuclear Power Generating Station Control Rooms and Other Peripheries, (IEEE)

(vii) MIL-H-46855B, Human Engineering Requirements for Military Systems, Equipment and Facilities, (Dept. of Defense)

(viii) DOD-HDBK-761A, Human Engineering Guidelines for Management Information Systems, (Dept. of Defense)

(ix) NUREG-0700, Guidelines for Control Room Design Reviews, 1981, (US Nuclear Regulatory Commission)

(x) NUREG-0899, Guidelines for the Preparation of Emergency Operating Procedures, 1982, (US Nuclear Regulatory Commission)

(xi) TOP 1-2-610, Test Operating Procedure Part 1, (Dept. of Defense)

(xii) NSAC-39, Verification and Validation for Safety Parameter Display Systems, (Electric Power Research Institute)

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(xiii) NUREG/CR-4227, Human Engineering Guidelines for the Evaluation and Assessment of Video Display Units, 1985, (US Nuclear Regulatory Commission)

Note that within the set of documents listed above, differences may exist regarding the specific methods and criteria applicable to the conduct of human factors V&V. In situations that such differences exist, for a particular issue, all of the methods and criteria presented within those documents which address that particular issue are considered to be equally appropriate and valid and, therefore, any of those documents may be selected as the basis for defining how that particular issue is addressed in the human factors V&V.

(b) That the scope of the evaluations of the integrated HSI shall include:

(i) The Human-System Interface (including both the interface of the operator with the HSI equipment hardware and the interface of the operator with the HSI equipment's software-driven functions).

(ii) The plant and emergency operating procedures.

(iii) HSI work environment.

(c) That static and/or "part-task" mode evaluations of the HSI equipment shall be conducted to confirm that the controls, displays, and data processing functions identified in the task analysis are designed per accepted HFE guidelines and principles.

(d) The integration of all HSI equipment with each other, with the operating personnel and with the plant and emergency operating procedures shall be evaluated through the conduct of dynamic task performance testing. The dynamic task performance testing and evaluations shall be performed over the full scope of the integrated HSI design using dynamic HSI prototypes (i.e., prototypical HSI equipment which is dynamically-driven using real time plant simulation computer models). In the event that the particular HSI design implementation under consideration is referenced to a previous HSI design for which dynamic task performance test and evaluation results are available, those existing results, along with the results of limited scope dynamic task performance tests which address the areas of difference between the two subject HSI designs, may be used to satisfy this requirement. The methods for defining the scope and application of the dynamic HSI prototype, past test results and other evaluation tools shall be documented in the implementation plan. The dynamic task performance tests and evaluations shall have as their objectives:

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(i) Confirmation that the identified critical functions can be achieved using integrated HSI design. *(ii) Confirmation that the HSI design and configuration can be operated using the established main control room staffing levels.* *(iii) Confirmation that the plant and emergency operating technical procedures of the scope as defined in Section 13.5 provide direction for completing the identified tasks associated with normal, abnormal and emergency operations.* *(iv) Confirmation that the time dependent and interactive (e.g., display format selection) aspects of the HSI equipment performance allow for task accomplishment.* *(v) Confirmation that the allocation of functions are sufficient to enable task accomplishment.* *(vi) Confirmation that the integrated HSI design implementation is consistent with accepted HFE practices and principles.* *(e) That dynamic task performance test evaluations shall be conducted over the range of operational conditions and upsets, including:* *(i) Normal plant operations, such as plant startup, shutdown, full power operations, and plant maintenance activities.* *(ii) Plant system and equipment failures (including instrumentation failures).* *(iii) HSI equipment failures.* *(iv) Plant transients.* *(v) Postulated plant accidents conditions, as defined in paragraph V.2.d of this table.* *(f) The HFE performance measures to be used as the basis for evaluating the dynamic task performance test results. These performance measures shall include:* *(i) Operating crew primary task performance characteristics, such as task times and procedure compliance.* *(ii) Operating crew errors and error rates.* *(iii) Operating crew situation awareness.* *(iv) Operating crew workload.* *(v) Operating crew communications and coordination.* *(vi) Anthropometry evaluations.* *(vii) HSI equipment performance measures.*

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(g) *The methods to confirm that HFE issues identified and documented in the Human Factors Issue Tracking System have been resolved in the integrated HSI design.*

(h) *The methods and criteria to be used to confirm that critical human actions, as defined by the task analysis, have been addressed in the integrated HSI design.*

(i) *The methods and criteria to be used to evaluate the adequacy of the operating technical procedures.*

(2) *The Human Factors Verification and Validation Implementation Plan shall include:*

(a) *Definition of test objectives.*

(b) *Definition of test methods and procedures.*

(c) *Identification of the participants in the dynamic task performance testing, which shall include licensed operators as test subjects.*

(d) *Definition of dynamic task performance test conditions which shall include:*

(i) *Plant startup operations.*

(ii) *Plant power operations.*

(iii) *Plant shutdown operations.*

(iv) *Plant refueling and maintenance operations.*

(v) *Individual plant system and equipment failures (including instrumentation failures).*

(vi) *Individual HSI equipment failure (e.g., loss of VDU functions).*

(vii) *Design basis transients (e.g., turbine trip, loss of feedwater).*

(viii) *Design basis accidents (e.g., LOCAs).*

(ix) *Execution of symptom-based emergency procedures.*

(x) *Execution of task scenarios which contain critical tasks as identified in the task analyses.*

(e) *Methods for defining scope and configuration of the prototypical HSI required to support testing.*

(f) *Methods for defining criteria and performance measures to be used in evaluating test results.*

(g) *Method for conducting analysis of test data.*

(h) *Requirement that the HSI design shall be reviewed and confirmed:*

Table 18E-1 Human Factors Engineering Design Team and Plans (Continued)

(i) To have incorporated the inventory of controls, displays and alarms presented in Tables 18F-1, 2 and 3. *(ii) That the implemented design is consistent with the standard design features and technologies as presented in Sections 18.4.2 and 18.4.3, respectively.* *(i) Requirements for the development of documented test & evaluation plans and procedures.* *(j) Requirements for documenting test results.]**

* See Section 18E.1.

Attachment 1 to Table 18E-1
Results of Operating Experience Review of Previous Nuclear Power Plant HSI Designs

(A) [Control Room Design

(1) The large size of the control room and console and their configuration contributed to operator dissatisfaction.

(2) Traffic flows should not be impeded by placement of consoles.

(3) Adequate levels of illumination are necessary to ensure that visual effectiveness is sufficient for task performance. Emergency lighting should be available.

(4) Noise levels in the main control room should be maintained within acceptable industry levels.

(5) The climate control system in the control room should be capable of continuously maintaining temperature and humidity within the human comfort zone.

(6) Convenient storage should be provided so that procedures, logs, and drawings needed for routine job performance are conveniently available. Storage should also be provided for equipment needed for emergency operation.

(B) Control Board Design

(1) Control boards should be optimized for minimum manning.

(2) Panels in the control rooms were observed to have large arrays of identical controls and displays and repetitive labels. The systems, subsystems, and components should be separated by appropriate demarcation methods.

(3) Controls and related displays should be located in close proximity so that the two items are readily associated and can be used conveniently with one another. Controls should be placed in an obvious and consistent order. The displays and controls used to monitor major system functions should be assigned to and arranged in functional groups.

(4) Flow arrangements between CRT display formats and controls on panels should not differ.

(5) Flow mimics should be used to aid (and not mislead) the operators.

(6) Panel arrangements for similar systems should be the same.

(7) Location of controls in areas and orientations that render them vulnerable to accidental contact and disturbance should be avoided.

(8) Unclear, illogical, overly complex, or mirror-imaged control board or panel layout arrangements have been observed to promote operational mishaps and should be avoided.

Attachment 1 to Table 18E-1 Results of Operating Experience Review of Previous Nuclear Power Plant HSI Designs (Continued)

(C) Computer

(1) Computer data should be available on CRT and hard copy output.

(2) Computer audible alarms should not be distracting.

(D) CRT Displays

(1) The nomenclature, labeling, and arrangement of systems on the CRT displays should be similar to the panels.

(2) CRT display should be comprehensible with a minimum of visual search. When data is presented in lines and columns, the lines of data should be separated by a space (blank line), one character high, every 4-5 lines.

(3) Display access should be efficient and require a minimum of key strokes.

(4) CRT displays should have convenient brightness, focus, and degauss controls.

(5) The character height should be the appropriate height for the viewing distance during normal and emergency conditions.

(6) Visibility of CRT displays should not be affected by glare.

(E) Anthropometrics

(1) Panel dimensions should accommodate the 5 to 95 percentile range of the user population to ensure that personnel can see and reach the displays and controls or the front and back panels. Displays should not be placed beyond the visual range of the operators.

(2) Controls should not be located in the control panels that require the operator to lean into the panel. This is a potential health risk to the operator and to the equipment.

(F) Controls

(1) Large controls were observed to have been used in place of preferred smaller controls. Larger controls impact panel size and should be avoided.

(2) Labeling or coding techniques should be used to differentiate controls and indicator lights of similar appearance.

(3) Control configurations should not introduce parallax problems.

(4) Control switches that must be held by the operator for operation should be avoided unless necessary.

(5) Projecting control handles should not cover or obstruct labels.

(6) Key lock switches require administrative control and should be avoided if possible.

Attachment 1 to Table 18E-1 Results of Operating Experience Review of Previous Nuclear Power Plant HSI Designs (Continued)

(7) Control handles should not be difficult to operate and should not cause the operators to resort to using unauthorized mechanical leveraging devices (i.e. "cheaters") so as to achieve reduced difficulty in operation.

(8) Controls should be built and installed following standard conventions for OPEN/CLOSE and INCREASE/DECREASE. Setpoint scales should not move up in response to a downward movement of the controller thumbwheel.

(9) Inadvertent operation of adjacent controls may be reduced through the use of shape coding such as using similar shaped handles for similar functions (i.e. pistol grips for pumps and round handles for valves).

(G) Indicator Lights

(1) Instances of improper use of qualitative indicators were observed where quantitative displays such as meters would be more effective.

(2) Light status (on/off) should be visible to the operator. Extinguished bulbs should be obvious and a test method provided. Lamp designs should allow for easy access for lamp removal.

(3) The use of so-called negative indications (the absence of an indication) should not be used to convey information to the operator.

(4) Indicator design selection and layout should be standardized to conserve panel space.

(5) A color code standard should be established for indicating lights.

(H) Display and Information Processing

(1) Plant parameter validity should not have to be inferred. In addition to secondary information, the quality or validity of the displayed parameter should be available to allow operators to readily identify improper ESF or other safety equipment status under various operating modes.

(2) Necessary information should be available during events such as SBO and LOOP. Systems and indications such as Neutron Monitoring System, control rod position indication, and drywell area radiation indication should all be available during these events.

(3) The main control room should contain an integrating overview display. The overview display should provide a limited number of key operating parameters.

(4) The same displays that are used during normal operation should be used by the operators during accident conditions to ensure their familiarity with the interface.

Attachment 1 to Table 18E-1 Results of Operating Experience Review of Previous Nuclear Power Plant HSI Designs (Continued)

(I) Meters

(1) Proper use of minor, intermediate, and major scale markings in association with scale numerals should be made. Formats should be customized to take into account identification of normal operating values and limits. Scale numerical progressions and formats should be selected for the process parameter being presented.

(2) Placement of meters above and below eye level, making the upper and lower segment of the scale difficult to read, (especially with curved scales), can present parallax problems.

(3) Meters were observed that fail with the pointer reading in the normal operating band of the scale. The instrument design should allow the operator to determine a valid indication from a failed indication.

(4) Placement of meters on panels should prevent glare and reflections caused by overhead illumination.

(5) Where redundant channels of instrumentation exist, software-based displays should provide for easy inspection of the source data and intermediate results without the need to display them continuously.

(6) Data presented to the operator should be in a usable form and not require the operator to calculate its value. Scale graduations should be consistent and easily readable. Zone markings should be provided to aid in data interpretation.

(7) Meter pointers should not obscure the scale on meters.

(8) Process units between the control room instruments and the operating procedures should be consistent.

(J) Chart Recorders

(1) Recorders should not be used in place of meters. Recorders should be selected with consideration given to minimizing required maintenance and high reliability.

(2) A recorder designed to monitor 24 parameters was observed to have 42 parameters assigned to it. This makes it extremely difficult to read the numerical outputs on the chart paper. The inputs assigned should be consistent with the design of the recorder.

(3) Operational limits should be defined on recorders. Proper selection of recorder scales will eliminate the need for overlays. The units for the process should be labeled on the recorder.

(4) Monitored inputs should be assigned to recorder pens in alphabetical order. The correlation of pen color to input parameter should be clearly defined by multi-pen recorder labels.

Attachment 1 to Table 18E-1
Results of Operating Experience Review
of Previous Nuclear Power Plant HSI Designs (Continued)

(5) The change of chart speed should also be noted on the chart paper when the paper is changed. The paper scales should match the fixed scales.

(6) Recorders should have fast speed and point select capability.

(7) Proper placement of recorders and adequate illumination should prevent glare and parallax problems with recorder faces.

(8) The pointers should not cover the graduation marks.

(9) When upper and lower pens coincide, the printout of the upper scale should still be visible.

(K) Annunciator Warning Systems

(1) Annunciators should be located near the control board panel elements to which they are related. Divisional arrangements should be consistent. Annunciators should be functionally located near the applicable system.

(2) "Advisory alarms" reporting expected conditions should not be grouped with true alarms. The audio and visual warning system signal should be prioritized to reduce the audio and visual burden placed on the operators during an event.

(3) Some alarms were observed to lack specificity. Multi-input alarms, e.g. xyz pressure/levels, hi/lo, frustrate, rather than inform the operator.

(4) Excessive alarms were observed during emergency conditions. Auditory signals should be coded to aid the operator in determining the panel location.

(5) Alarm operating sequence controls should be placed at specific locations to encourage operator acknowledgment.

(6) For standing and sit-down workstations, window size and lettering height should be consistent with the viewing distance.

(7) The labels should use consistent abbreviations and nomenclature and not be ambiguous.

(8) For traceability to response procedures, the windows should be identified with a location reference code.

(9) A consistent color coding convention should be employed.

(10) A "First Out" feature should be provided that presents prioritized parameters important to safety parameters for immediate operator response.

(11) Means should be provided for identification of out-of-service annunciators.

(12) Annunciators for conditions which signal an EOP entry condition should be located based on the functional analysis.

Attachment 1 to Table 18E-1
Results of Operating Experience Review
of Previous Nuclear Power Plant HSI Designs (Continued)

(L) Coding of Displays and Controls

(1) The color codes for the control boards should be systematically applied. Effective color coding should be used to aid in differentiating between identical controls placed in close proximity.

(2) The coding of indicators should inform the operator whether a valve is open or closed.

(3) Systematic approach to color and shape coding of controls should be taken.

(M) Labeling

(1) Label abbreviations, numbering, and nomenclature should be consistent. A label placement standard for the control room should be established. Labels should be placed consistently above or below the panel elements being identified and not placed between two components.

(2) Hierarchical labeling schemes including size coding or differentiation of labels should be used to identify major console panels, sub-panels, and panel elements. Hierarchical labeling will eliminate the need to place redundant labels on control or display devices.

(3) The content of the labels should be consistent with the procedures used by the operators.

(4) The labels should meet the readability guidelines and should not be obscured by the equipment that they mounted near. A control room standard for labels should be established that addresses label character size and font.

(5) Maintenance tags should not obscure labels or panel components such as displays.

(6) To minimize the mispositioning of valves and other equipment, the controls and displays should be labeled with the unique number or name of the valve or piece of equipment.

(N) Communications

(1) Communications in the control room should consider the ambient noise levels in the control room and plant. The control room operator should be able to communicate with necessary personnel in the plant. Communication equipment should also be provided at the remote shutdown panel.

(2) Communications equipment design should not limit the operator's access to the controls or displays.

(3) The communication system should be accessible from the operator's workstations.

Attachment 1 to Table 18E-1
Results of Operating Experience Review
of Previous Nuclear Power Plant HSI Designs (Continued)

(O) Task Analysis

(1) Controls and displays should be located for effective operator response to postulated events. Information needed by the operator in the control room should be readily available and not located at remote panels in the plant.

(2) In addition to normal and emergency conditions, plant displays and controls should also consider low power and shutdown scenario information requirements.

(P) Procedures

(1) The measurement units in the procedure and the values indicated on display scales should be consistent.

(2) Control board designs should make provisions for the operator's simultaneous referral to the procedures and the operation of the control boards.

(3) The parameters displayed on electronic information systems or on the control boards should be designed to support the EOPs as well as other required monitoring tasks.

(4) The safety function parameter status should be presented in an organized, readily accessible format compatible with the EOPs.

(5) A procedure should address operator action in the event of computer, CRT, or printer problems or complete failure.

(Q) Operator Errors

(1) Operator mishaps were observed to be caused by the absence of a timely, attention-getting indication (either qualitative or quantitative) that informs the operator that some element of the system is not operating properly.

(2) Operator mishaps were also observed to result from incorrect lineup of valves.

(R) Maintenance and Testing

(1) The main control room should be designed in such a way that minimizes the need for maintenance and test personnel to work, or at least limit their presence, in the control room.

(2) Control room displays should be designed and installed for easy calibration and replacement.

*(3) Access for inspection, operation, and routine maintenance of components should not be restrictive.]**

* See Section 18E.1.

Table 18E-2 HFE Analysis

(I) [System Functional Requirements Analyses

(1) (Satisfaction of the requirements presented herein shall result in the conduct of system functional requirements analyses which are in full compliance with the Item 2.b Acceptance Criteria presented in Table 3.1 of the Tier 1 Design Certification material for the GEH ABWR design). The system functional requirements analyses shall be conducted in accordance with the requirements of the Human Factors Engineering Program Plan and the System Functional Requirements Analysis Implementation Plan.

(2) The results of the system functional requirements analyses shall be documented in a report that includes the following:

(a) Objectives of the system functional requirements analyses.

(b) Description of the methods employed in the conduct of system functional requirements analyses.

(c) Identification of deviations from the System Functional Requirements Analysis Implementation Plan.

(d) Presentation and discussion of the results of the system functional requirements analysis including discussion of design change recommendations derived from these analyses and/or negative implications that the current design may have on safe plant operations.

(e) Conclusions regarding the conduct of the analyses and the analyses results.

(3) The results of the HFE Design Team's evaluation of the conduct and results of the system functional requirements analyses shall be documented in a report that includes the following:

(a) The methods and procedures used by the HFE Design Team in their review of the system functional requirements analyses.

(b) The HFE Design Team's evaluation of the completed system functional requirements analyses including evaluation of the compliance with the System Functional Requirements Analysis Implementation Plan and the HFE Program Plan.

(c) Presentation and discussion of the HFE Design Team's Review findings.

Table 18E-2 HFE Analysis (Continued)

(II) Function Allocation Analyses

(1) (Satisfaction of the requirements presented herein shall result in the conduct of function allocation analyses which are in full compliance with the Item 3.b Acceptance Criteria presented in Table 3.1 of the Tier 1 Design Certification material for the GEH ABWR design). The function allocation analyses shall be conducted in accordance with the requirements of the Human Factors Engineering Program Plan and the Allocation of Functions Implementation Plan.

(2) The results of the function allocation analysis shall be documented in a report that includes the following:

(a) Objectives of the function allocation analyses

(b) Description of the methods employed in the conduct of the function allocation analyses.

(c) Identification of deviations from the Allocation of Function Implementation Plan.

(d) Presentation and discussion of the results of the function allocation analyses including discussion of design change recommendations derived from these analyses and/or negative implications that the current design may have on safe plant operations.

(e) Conclusions regarding the conduct of the analyses and analysis results.

(3) The results of the HFE Design Team's evaluation of the conduct and results of the function allocation analyses shall be documented in a report that includes the following:

(a) The methods and procedures used by the HFE Design Team in their review of the function allocation analyses.

(b) The HFE Design Team's evaluation of the completed function allocation analyses including an evaluation of the compliance with the Allocation of Function Implementation Plan and the HFE Program Plan.

(c) Presentation and discussion of the HFE Design Team's review findings.

(III) Task Analyses

(1) (Satisfaction of the requirements presented herein shall result in the conduct of task analyses which are in full compliance with the Item 4.b Acceptance Criteria presented in Table 3.1 of the Tier 1 Design Certification material for the GEH ABWR Design). The task analyses shall be conducted in accordance with the requirements of the Human Factors Engineering Program Plan and the Task Analysis Implementation Plan.

Table 18E-2 HFE Analysis (Continued)

(2) The results of the task analyses shall be documented in a report that includes the following: *(a) Objectives of the task analyses.* *(b) Description of the methods employed in the conduct of the task analyses.* *(c) Identification of deviations from the Task Analyses Implementation Plan.* *(d) Presentation and discussion of the results of the task analyses, including discussion of design change recommendations derived from these analyses and/or negative implications that the current design may have on safe plant operations.* *(e) Conclusions regarding the conduct of the analyses and the analyses results.* *(3) The results of the HFE Design Team's evaluation of the conduct and results of the task analyses shall be documented in a report that includes the following:* *(a) The methods and procedures used by the HFE Design Team in their review of the completed task analyses.* *(b) The HFE Design Team's evaluation of the completed task analyses including an evaluation of the compliance with the Task Analysis Implementation Plan and the HFE Program Plan.* *(c) Presentation and discussion of the HFE Design Team's review findings.]**

*See Section 18E.1.

Table 18E-3 Human System Interface Design

(I) [HSI Design Analyses

(1) (Satisfaction of the requirements presented herein shall result in the conduct of HSI design analyses which are in full compliance with the Item 5.b Acceptance Criteria presented in Table 3.1 of the Tier 1 Design Certification material for the GEH ABWR design). The HSI design implementation and analyses shall be conducted in accordance with the requirements of the Human Factors Engineering Program Plan and the HSI Design Implementation Plan.

(2) The results of the HSI design analyses shall be documented in a report that includes the following:

(a) Objectives of the HSI design analyses.

(b) Description of the methods employed in the conduct of the HSI design analyses.

(c) Identification of deviations from the HSI Design Implementation Plan.

(d) Presentation and discussion of the results of the HSI design analyses, including discussion of design change recommendations derived from these analyses and/or negative implications that the current design may have on safe plant operations.

(e) Conclusions regarding the conduct of the analyses and the analyses results.

(3) The results of the HFE Design Team's evaluation of the conduct and results of the HSI design analyses shall be documented in a report that includes the following:

(a) The methods and procedures used by the HFE Design Team in their review of the HSI design analyses.

(b) The HFE Design Team's evaluation of the completed HSI design analyses, including an evaluation of the compliance with the HSI Design Implementation Plan and HFE Program Plan.

*(c) Presentation and discussion of the HFE Design Team's review findings.]**

*See Section 18E.1.

Table 18E-4 Human Factors Verification and Validation

(I) [Human Factors Verification and Validation

(1) (Satisfaction of the requirements presented herein shall result in the conduct of human factors verification and validation (V&V) activities which are in full compliance with the Item 7.b Acceptance Criteria presented in Table 3.1 of the Tier 1 Design Certification material for the GEH ABWR design). The human factors V&V of the human system interface (HSI) design shall be conducted in accordance with the requirements of the Human Factors Engineering Program Plan and the Human Factors V&V Implementation Plan.

(2) The results of the human factors V&V activities of HSI shall be documented in a report that includes the following:

(a) Objectives of the human factors V&V.

(b) Description of the methods employed in the conduct of the human factors V&V.

(c) Identification of deviations from the Human Factors V&V Implementation Plan.

(d) Presentation and discussion of the human factors V&V results, including discussion of design change recommendations derived from the human factors V&V tests and evaluations and/or significant negative implications that the current HSI design may have on safe plant operations which may have been identified.

(e) Conclusions regarding the conduct of the human factors V&V of HSI and the results.

(3) The results of the HFE Design Team's evaluation of the conduct and results of the human factor verification and validation (V&V) shall be documented in a report that includes the following:

(a) The review methodology and procedures used by the HFE Design Team in their review of the human factor V&V.

(b) The HFE Design Team's evaluation of the completed human factors V&V, including an evaluation of the compliance with the Human Factors V&V Implementation Plan and HFE Program Plan.

*(c) The HFE Design Team's evaluation of the completed human factors V&V, including an evaluation of the presentation and discussion of the HFE Design Team's Human Factors s review findings.]**

*See Section 18E.1.

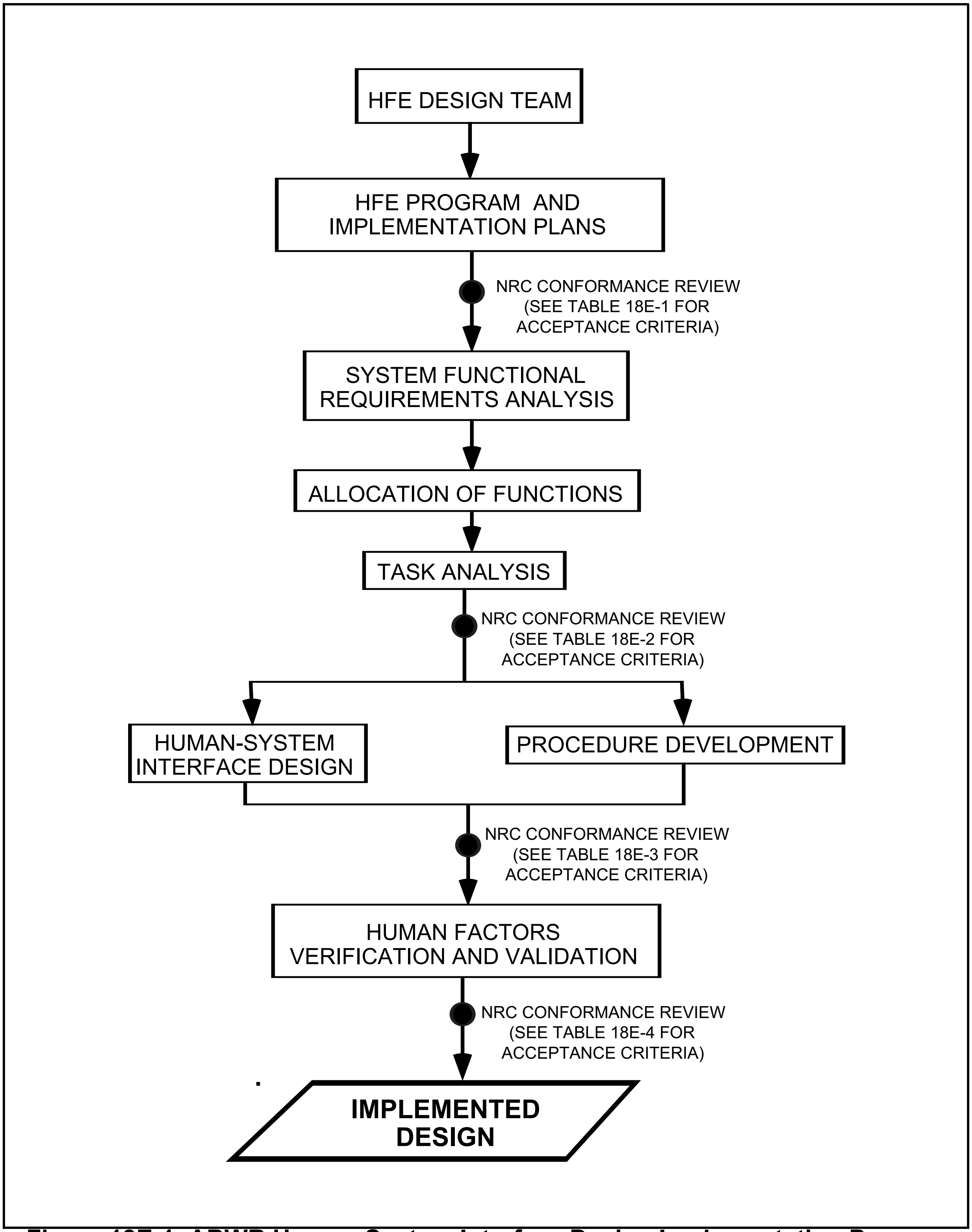


Figure 18E-1 ABWR Human-System Interface Design Implementation Process

18F Emergency Operation Information and Controls

18F.1 Introduction

This appendix contains the results of an analysis of information and control needs of the main control room operators. The analysis is based upon the operation strategies given in the ABWR Emergency Procedure Guidelines (EPGs) as presented in Appendix 18A and the significant operator actions determined by the Probabilistic Risk Assessment (PRA) described in Section 19D.7. The minimum inventory of controls, displays and alarms from this analysis are presented in Tables 18F–1 through 18F–3. The information and controls identified from this analysis do not necessarily include those from other design requirements (such as those from Section 18.4.2.11, SPDS). Supporting information is provided in Appendix 18H.

Information and control needs for each operative instruction or action were developed through task analyses conducted in the following manner:

- Each specific step in the EPGs (referred to as the EPG step) or specific operator action referenced in the PRA (herein referred to as the PRA operator action) was individually identified.
- A summary description of the step or PRA operator action was developed for each EPG step and PRA operator action.
- Information needs required for the operator to perform the specific EPG step or PRA operator action were then identified.
- Next, the control functions that the operators perform to execute the actions specified in the EPG step or PRA operator action were identified.
- The plant process parameters or other displays needed for execution of the individual EPG step or PRA operator action, were then identified.
- Similarly, the controls needed for the execution of each step, were identified.
- Alarms to perform step and alarms to provide feedback information to the operator were identified.
- Operator aids, such as supplementary procedures or other information needed to execute the step, were identified.
- Displays needed to provide confirmatory feedback to the operators that the specified control functions have been initiated or accomplished, were identified.
- Position of control devices that provide feedback to the operators to confirm that proper controls are manipulated to the correct positions, were identified.

- Annunciators which provide feedback to the operators to confirm that proper control actions are initiated or accomplished were identified.
- Operator aids, which provide feedback to the operators to confirm that proper control actions are initiated or accomplished, were identified.

The following operator actions are considered to be important operator actions in the ABWR PRA (refer to Section 19D.7):

(1) Backup manual initiation of HPCF

(2) Recovery of feedwater following a scram

(3) Use of condensate injection following scram with reactor depressurized

(4) Control of reactor water level in an ATWS

(5) Emergency depressurization of the reactor

(6) Alignment and initiation of firewater for RPV injection with ECCS failure

(7) Alignment and initiation of firewater for drywell spray

(8) Initiation of wetwell spray using RHR

(9) Isolation of water sources in an internal flooding

These actions are already specified in the EPGs and are included in the analyses.

Based upon the results of those operator task analyses, the listings of controls, displays and alarms that will be provided in the implemented ABWR design to support execution of the EOPs and PRA significant operator actions (as presented in Tables 18F-1, 18F-2, and 18F-3), were generated.

Table 18F-1
Inventory of Controls Based Upon the ABWR EPGs and PRA

No.	Fixed Position Controls
1	Manual Scram Initiation SW(A)
2	Manual Scram Initiation SW(B)
3	Reactor Mode SW
4	Div. I Main steamline Manual Isolation SW
5	Div. II Main steamline Manual Isolation SW
6	Div. III Main steamline Manual Isolation SW
7	Div. IV Main steamline Manual Isolation SW
8	Primary Containment Div. I Manual Isolation SW
9	Primary Containment Div. II Manual Isolation SW
10	Primary Containment Div. III Manual Isolation SW
11	RCIC Initiation SW
12	HPCF (B) Initiation SW
13	HPCF (C) Initiation SW
14	RHR (A) Initiation SW
15	RHR (B) Initiation SW
16	RHR (C) Initiation SW
17	DG(A) Start SW
18	DG(B) Start SW
19	DG(C) Start SW
20	RCIC System Standby Mode Initiation SW
21	Condensate Pump Standby Mode Initiation Switches (3)
22	Reactor Feedpump Standby Mode Initiation Switches (3)
23	Condensate Pump Startup Mode Initiation Switches (3)
24	Reactor Feedpump Startup Mode Initiation Switches (3)
25	SLC (A) Pump CS
26	SLC (B) Pump CS
27	ADS (A) Inhibit SW
28	ADS (B) Inhibit SW
29	RHR(A) Standby Mode SW
30	RHR(B) Standby Mode SW
31	RHR(C) Standby Mode SW

Table 18F-1
Inventory of Controls Based Upon the ABWR EPGs and PRA (Continued)

No.	Fixed Position Controls
32	Main Steam Isolation Valve CS (8)
33	Div. I Manual/Auto Main Steamline Isolation Reset SW
34	Div. II Manual/Auto Main Steamline Isolation Reset SW
35	Div. III Manual/Auto Main Steamline Isolation Reset SW
36	Div. IV Manual/Auto Main Steamline Isolation Reset SW
37	Primary Containment Div. I Isolation Reset SW
38	Primary Containment Div. II Isolation Reset SW
39	Primary Containment Div. III Isolation Reset SW
40	RHR(A) Shutdown Cooling Mode Initiation SW
41	RHR(B) Shutdown Cooling Mode Initiation SW
42	RHR(C) Shutdown Cooling Mode Initiation SW
43	ARI(A) Manual Initiation SW
44	ARI(B) Manual Initiation SW
45	Recirculation Runback Initiation SW(A)
46	Recirculation Runback Initiation SW(B)
47	RIP Start/Stop CS (10)
48	ARI(A) Logic Reset SW
49	ARI(B) Logic Reset SW
50	CRD Charging Water Pressure Low Scram Bypass SW(A)
51	CRD Charging Water Pressure Low Scram Bypass SW(B)
52	CRD Charging Water Pressure Low Scram Bypass SW(C)
53	CRD Charging Water Pressure Low Scram Bypass SW(D)
54	Manual Scram Reset SW
55	RPS Div. I Trip Reset SW
56	RPS Div. II Trip Reset SW
57	RPS Div. III Trip Reset SW
58	RPS Div. IV Trip Reset SW
59	RHR(A) Suppression Pool Cooling Mode Initiation SW
60	RHR(B) Suppression Pool Cooling Mode Initiation SW
61	RHR(C) Suppression Pool Cooling Mode Initiation SW

Table 18F-1
Inventory of Controls Based Upon the ABWR EPGs and PRA (Continued)

No.	Fixed Position Controls
62	RHR(B) Primary Containment Vessel Spray Mode Initiation SW
63	RHR(C) Primary Containment Vessel Spray Mode Initiation SW
64	SGTS(B) Initiation SW
65	SGTS(C) Initiation SW
66	Div I Manual ADS Channel 1 Initiation SW
67	Div I Manual ADS Channel 2 Initiation SW
68	Div II Manual ADS Channel 1 Initiation SW
69	Div II ADS Manual ADS Channel 2 Initiation SW
70	RCIC Div. I Isolation Logic Reset SW
71	RCIC Div. II Isolation Logic Reset SW
72	RCIC Inboard Isolation CS
73	RCIC Outboard Isolation CS
74	RHR(C) Manual Valves For Firewater Injection (F101, F102, F103)*
75	CUW Regenerative Heat Exchanger Manual Bypass Valve*
76	Turbine Building HVAC System Controls*
77	SLC Local Controls*
78	Fire Protection System Motor Pump Control SW†
79	Fire Protection System Diesel Pump Control SW†
80	Control Rod Scram Test Switches†
81	“A” Scram Solenoid Main Power Breaker CS†
82	“B” Scram Solenoid Main Power Breaker CS†
83	RPS Div. I Trip Inhibit SW†
84	RPS Div. II Trip Inhibit SW†
85	RPS Div. III Trip Inhibit SW†
86	RPS Div. IV Trip Inhibit SW†
87	Rod Worth Minimizer Bypass,†
88	CAMS(A) Operating Mode SW†
89	CAMS(B) Operating Mode SW†
90	CAMS(A) Sample Select SW†
91	CAMS(B) Sample Select SW†
92	FCS(B) Control SW†

Table 18F-1
Inventory of Controls Based Upon the ABWR EPGs and PRA (Continued)

No.	Fixed Position Controls
93	FCS(C) Control SW†

* Provided outside the main control room.

† To be provided at main control room area panels, not at the operator control panels.

Table 18F-1
Inventory of Controls Based Upon the ABWR EPGs and PRA (Continued)

No.	Other Control Functions
94	HPCF(B) System controls for terminating system flow, injecting flow, and isolation of potential discharges to reactor building areas
95	HPCF(C) System controls for terminating system flow, injecting flow, and isolation of potential discharges to reactor building areas
96	RCIC System controls for terminating system flow, injecting flow, isolation of potential discharges to reactor building areas, and venting of the RPV to the main condenser
97	RHR(A) System controls for terminating system flow, injecting flow, suppression pool cooling, wetwell spray, drywell spray, shutdown cooling, and isolation of potential discharges to reactor building areas
98	RHR(B) System controls for terminating system flow, injecting flow, suppression pool cooling, wetwell spray, drywell spray, shutdown cooling, and isolation of potential discharges to reactor building areas
99	RHR(C) System controls for terminating system flow, injecting flow, suppression pool cooling, wetwell spray, drywell spray, shutdown cooling, and isolation of potential discharges to reactor building areas
100	Main steamline drain containment isolation valve controls
101	SRV opening and closing controls for each SRV
102	SGTS(B) System controls for venting of the primary containment, and control of secondary containment (reactor building) radiation
103	SGTS(C) System controls for venting of the primary containment, and control of secondary containment (reactor building) radiation
104	RBHVAC containment isolation valves controls
105	ACS containment isolation valves controls
106	SGTS(B) room cooler fan control
107	SGTS(C) room cooler fan control
108	CAMS(A) room cooler fan control
110	CAMS(B) room cooler fan control
111	RHR(A) pump room cooler fan control
112	RHR(B) pump room cooler fan control
113	RHR(C) pump room cooler fan control
114	HPCF(B) pump room cooler fan control
115	HPCF(C) pump room cooler fan control
116	RCIC pump room cooler fan control
117	FCS(B) room cooler fan control
118	FCS(C) room cooler fan control

Table 18F-1
Inventory of Controls Based Upon the ABWR EPGs and PRA (Continued)

No.	Other Control Functions
119	FPC(A) room cooler fan control
120	FPC(B) room cooler fan control
121	Fuel Pool Cooling System controls for isolation of discharges into reactor building areas
122	RCIC steamline isolation logic bypasses (area temperature high, RPV pressure low, steamline pressure low, RCIC turbine exhaust pressure low)
123	CUW isolation logic bypass (SLC initiation, regenerative heat exchanger area temperature high, RPV water Level 2)
124	MSIV and main steamline drain isolation logic bypass (level 15, main steamline high radiation, main steamline high flow, main steamline tunnel area temperature high, main steamline turbine area temperature high)
125	Logic bypass (RPV Level 3) of RBHVAC system isolation valves
126	Logic bypass (RPV Level 3) of atmospheric control system isolation valves
127	Logic bypass of high drywell pressure isolation for RBHVAC
128	High RPV water level (Level 8) HPCF(B) injection valve closure logic bypass
129	High RPV water level (Level 8) HPCF(C) injection valve closure logic bypass
130	Condensate and feedwater system controls for terminating flow and injecting flow into the RPV/containment
131	CRD System controls for terminating flow and injecting flow into the RPV/containment
132	Condensate Makeup Water System controls for terminating flow and injecting flow into the RPV/containment
133	SPCU System controls for terminating flow into the containment if aligned to take suction from the condensate storage tank
134	Feedwater Control System controls for terminating flow and injecting flow into the RPV/containment
135	Pressure Control System controls for the turbine bypass valves
136	Main Steam System controls for controlling main steamline drain and head vent valves
137	CUW System controls for alternate pressure control or decay heat removal
138	Rod Control and Information System controls for control rod insertions
139	Drywell Cooling System fan control
140	Nitrogen vent and purge mode of ACS
141	Containment purge mode of containment supply and purge subsystem of RBHVAC
142	RBHVAC System controls for venting of the containment
143	Atmospheric Control System controls for venting and purging of the containment
144	Main steam/feedwater tunnel HVAC fan controls

Table 18F-1
Inventory of Controls Based Upon the ABWR EPGs and PRA (Continued)

No.	Other Control Functions
145	Logic bypasses for Alternate Rod Insertion (ARI) (high RPV pressure, RPV Water Level 2)
146	Logic bypass of High RPV Water level (Level 8) trip of reactor feedpumps and condensate pumps
146	Logic bypasses of drywell cooling fans and associated cooling water (RCW) [Drywell Pressure High, RPV Water Level 1]

Table 18F-2
Inventory of Displays Based Upon the ABWR EPGs and PRA

No.	Fixed Position Displays	No.	Fixed Position Displays
1	RPV Water Level ⋆⋆	27	RHR(C) Flow ⋆⋆
2	RCIC Turbine Speed	28	RHR(C) Injection Valve Status
3	Wetwell Pressure ⋆⋆	29	Emergency Diesel Generator (A) Operating Status ⋆⋆
4	Suppression Pool Bulk Average Temperature ⋆⋆	30	Emergency Diesel Generator (B) Operating Status ⋆⋆
5	HPCF(B) Flow ⋆⋆	31	Emergency Diesel Generator (C) Operating Status ⋆⋆
6	HPCF(C) Flow ⋆⋆	32	Primary Containment Water Level ⋆⋆
7	RPV Pressure ⋆⋆	33	Condensate Storage Tank Water Level ⋆⋆
8	Drywell Pressure ⋆⋆	34	SLC Pump(A) Discharge Pressure⋆⋆
9	Reactor Power Level, (Neutron Flux, APRM) ⋆⋆	35	SLC Pump(B) Discharge Pressure ⋆⋆
10	Reactor Power Level (SRNM) ⋆⋆	36	Main Condenser Pressure
11	Reactor Thermal Power ⋆⋆	37	SRV Positions ⋆⋆
12	MSIV Position Status (Inboard And Outboard Valves) ⋆⋆	38	Suppression Pool Level ⋆⋆
13	Reactor Mode Switch Mode Indications	39	Main Steamline Flow ⋆⋆
14	Main Steamline Radiation ⋆⋆	40	SLC Boron Tank Water Level ⋆⋆
15	Scram Solenoid Lights(8) Status	41	Recirculation Pump Speeds
16	Manual Scram SW(A) Indicating Light Status	42	Average Drywell Temperature ⋆⋆
17	Manual Scram SW(B) Indicating Light Status	43	Wetwell Hydrogen Concentration Level ⋆⋆
18	RPV Isolation Status Display ⋆⋆	44	Drywell Hydrogen Concentration Level ⋆⋆
19	RCIC Flow ⋆⋆	45	Drywell Oxygen Concentration ⋆⋆
20	RCIC Injection Valve Status	46	Wetwell Oxygen Concentration ⋆⋆
21	HPCF(B) Injection Valve Status	47	FCS(B) Operating Status
22	HPCF(C) Injection Valve Status	48	FCS(C) Operating Status
23	RHR(A) Flow ⋆⋆	49	Main Stack Radiation Level ⋆⋆
24	RHR(A) Injection Valve Status	50	Time

⋆⋆ Denotes Regulatory Guide 1.97 Parameter

Table 18F-2
Inventory of Displays Based Upon the ABWR EPGs and PRA (Continued)

No.	Fixed Position Displays	No.	Fixed Position Displays
25	RHR(B) Flow ⋆⋆	51	Drywell Radiation Level ⋆⋆
26	RHR(B) Injection Valve Status	52	Wetwell Radiation Level ⋆⋆
⋆⋆ Denotes Regulatory Guide 1.97 Parameter			

Table 18F-2
Inventory of Displays Based Upon the ABWR EPGs and PRA (Continued)

No.	Other Displays
1	Reactor building differential pressure
2	Reactor building HVAC exhaust radiation level
3	Fuel handling area ventilation exhaust radiation level
4	RHR(A) pump room cooler operation status
5	RHR(B) pump room cooler operation status
6	RHR(C) pump room cooler operation status
7	HPCF(B) pump room cooler operation status
8	HPCF(C) pump room cooler operation status
9	RCIC pump room cooler operation status
10	FCS(B) room cooler operation status
11	FCS(C) room cooler operation status
12	FPC(A) room cooler operation status
13	FPC(B) room cooler operation status
14	SGTS(B) room cooler operation status
15	SGTS(C) room cooler operation status
16	CAMS(A) room cooler operation status
17	CAMS(B) room cooler operation status

Table 18F-3 Inventory of Alarms Based Upon the ABWR EPGs and PRA

No.	Fixed Position Alarms	No.	Fixed Position Alarms
1	Indicated RPV Water Level Abnormal	29	Leak Detection Isolation
2	RPV Water Level 3	30	CUW System Status
3	RPV Pressure High	31	Reactor Period Short
4	Drywell Pressure High	32	ADS Div. I Inhibited/Auto Out Of Service
5	Neutron Flux High–High	33	ADS Div. II Inhibited/Auto Out Of Service
6	Neutron Monitoring System Inoperative	34	Suppression Pool Bulk Average Temperature High
7	MSIV Closure	35	Drywell Average Temperature High,
8	CRD Charging Water Pressure Low	36	Suppression Pool Water Level High/Low
9	Rapid Core Flow Decrease	37	CAMS H_2/O_2 Level High
10	Main Turbine Trip	38	CAMS(A) System Abnormal
11	Main Generator Trip	39	CAMS(B) System Abnormal
12	Main Steamline Radiation High	40	Reactor Building ýP Low
13	Reactor Scram	41	Area Temperature High
14	RPV Level 3 Isolation Incomplete	42	Area HVAC ýT High
15	RPV Level 2 Isolation Incomplete,	43	RBHVAC Exhaust Radiation High
16	RPV Level 1.5/Drywell Pressure High Isolation Incomplete	44	Reactor Building Area Radiation High
17	RPV Water Level 2	45	Reactor Building Floor Drain Sump Water Level High–High
18	RPV Water Level 1.5	46	RBHVAC System Status
19	RPV Water Level 1	47	Stack Radioactivity High
20	Control Rod Not Inserted To/Beyond MSBWP ⋆⋆	48	RCW Radioactivity High
21	RPV Water Level 8	49	Radwaste Effluent Radioactivity High
22	Fire Protection System Status	50	Turbine Building Ventilation System (TBVS) Status
23	ADS(A) Logic Initiated	51	Radiation Monitor High
24	ADS(B) Logic Initiated	52	RCIC System Status
25	SRV Open	53	HPCF (B) System Status
26	Main Steamline Flow High	54	HPCF (C) System Status
27	HPIN(A) System Status		

⋆⋆ Denotes Regulatory Guide 1.97 Parameter.

Table 18F-3
Inventory of Alarms Based Upon the ABWR EPGs and PRA (Continued)

No.	Fixed Position Alarms	No.	Fixed Position Alarms
28	HPIN(B) System Status		
⋆⋆ Denotes Regulatory Guide 1.97 Parameter.			

Table 18F-3
Inventory of Alarms Based Upon the ABWR EPGs and PRA (Continued)

No.	Other Alarms
1	RPS Div. I Trip Inhibited
2	RPS Div. II Trip Inhibited
3	RPS Div. III Trip Inhibited
4	RPS Div. IV Trip Inhibited
5	RPV Water Level ≤ Zero–Injection Water Level
6	Drywell Radiation Upscale
7	Wetwell Radiation Upscale
8	Lower Drywell Water Level High
9	APRM Downscale

18G Design Development and Validation Testing

18G.1 Introduction

As part of the ABWR design development, a five-year (1986–91) program was undertaken for the purpose of "studying the application of man-machine technologies to enhance the efficiency of operation control of nuclear power plants". During the course of this program, a variety of tests, studies and evaluations were performed in a number of areas of control room equipment design. These studies and evaluations culminated in the fabrication and testing of prototype control room human-system interface (HSI) equipment designs at two separate facilities. The results of this development program form the basis for the ABWR control room HSI design.

The purpose of this report is to provide summary descriptions of the studies, evaluations and validation testing performed during the joint study program. The studies, evaluations and testing, other than the prototype validation testing, are described in Subsection 18G.2 and the validation testing of the control room equipment prototypes is discussed in Subsection 18G.3.

18G.2 Design Development

18G.2.1 General

The program research described in this section is discussed under the following subtitles:

(1) Standard control room design features

(2) Allocation of functions

(3) Operator work load

(4) Other Areas of Interest

18G.2.2 Standard Control Room Design Features

There are eighteen standard design features for the ABWR control room HSI which are listed as follows:

(1) 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.

(2) 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.

(3) The use of a separate set of on-screen control VDUs for safety system control and monitoring and 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 l-E standards.

(4) The use of dedicated function switches on the control console.

(5) Operator selectable automation of pre-defined plant operation sequences.

(6) The incorporation of an operator selectable semi-automated mode of plant operations, which provides procedural guidance on the control console VDUs.

(7) The capability to conduct these pre-defined plant operation sequences in manual mode.

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

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

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

(11) The independence of the fixed-position displays from the plant process computer.

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

(13) 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 supervisor.

(14) 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 a portion of the large display panel.

(15) The use of fixed-position alarm tiles on the large display panel.

(16) The application of alarm processing logic to prioritize alarm indications and to filter unnecessary alarms.

(17) A spatial arrangement between the large display panel, the main control console and the shift supervisors’ console which allows the control room operating crew to view the information presented on the large display panel from the seated position at their respective consoles.

(18) The use of VDUs to provide alarm information in addition to the alarm information provided via the fixed-position alarm tiles on the large display panel.

Specific studies and evaluations done in support of these standard design features, prior to the validation testing of the two prototype designs, are discussed in the following paragraphs of this subsection.

18G.2.2.1 Control Console

Analyses of trends in control panel configuration, including GEH's NUCLENET control room design, as compared to older designs, were completed. The results of operating crew task analyses were used to aid in control panel layout studies and support evaluations of the operating crew size. Studies of the feasibility of main control panel size reduction and consolidation of two or more panel functions into one panel were completed. Other studies were made of alternate arrangements of control and monitoring equipment on the console.

18G.2.2.2 Video Display Units (VDUs)

Studies of trends in VDU uses in control rooms were made. Since VDUs have been used previously, not only in control rooms of other industrial processing plants but in nuclear plants as well. The issue of concern was not whether to use these devices but how to use them most efficiently. Studies of VDU control devices were completed and development testing of on-screen control devices was done. Figure 18G-1 shows some data developed during evaluations of the precision obtainable with touch screens. Means of enhancing the reliability of certain types of VDUs (e.g., CRTs) were also studied. An evaluation was made of the merits of different types of computer input devices (i.e., light pens, trackballs, mice and touch-screens).

Methods of optimization of VDU screen systems for aiding operator responses (a) during normal plant operation, (b) after discovery of an anomaly, (c) after a scram and (d) in the event of an accident were examined. Screen selection methods and methods of integrating the use of the console VDUs with that of the large display panel were also reviewed. As part of this study, operator decision making processes during each of the above-mentioned plant conditions were analyzed.

18G.2.2.3 Plant Operations

Automation of normal plant operations (e.g., startup, shutdown, power maneuvers) was evaluated for potential ABWR application to enhance operability and minimize the burden on the operating staff. The extent of automated operations was carefully selected to ensure that the primary control of plant operations remains in the hands of the operators. The general approach which was followed in selecting the operations to be automated consisted of the following steps:

(1) Task analyses were performed which defined the type and sequence of tasks that are required for accomplishing normal plant operations. These analyses were done assuming completely manual operations (i.e., no automation).

(2) From these task analyses, assessments were made of the operator workload, the complexity of the operation, the degree of repetitiveness and tedium in the operation and the feasibility of automating the operation.

(3) From these evaluations, it was concluded that, for a given plant system, many tasks are conducted for the purpose of changing the operational status of that system (e.g., operation of the residual heat removal system in the suppression pool cooling mode). For many of these normal system operations, sequence master control functions were defined. This approach was applied to both safety-related and non-safety-related system operations. Dedicated sequence master control switches were incorporated into the main control console design for initiating these automation sequences. The sequence master control switches are located in the hard switch panels on the horizontal desk area of the main control panel.

(4) Operational changes in safety systems that require only minimal operator action (e.g., changing the position of the reactor mode switch) were not automated. Safety system mode changes are performed on the ABWR in a manner similar to conventional BWR operations.

(5) For tedious or repetitive operations, special plant level automation functions were incorporated into the control room design. Examples of such automated functions include control rod operations during startup (e.g., rod selection and movement of control rods to maintain the vessel heatup rate), changes in reactor recirculation flow controller setpoints to accomplish daily load following maneuvers, changes in the reactor pressure setpoint during normal heatup and cooldown of the reactor and transfers in the operational status of the reactor feed pumps.

In accordance with the above studies, the semi-automatic mode was provided to give the operator(s) automatic guidance for accomplishing the desired normal changes in plant status. In the semi-automatic mode of operation, the plant computer provides no control actions. The operator must activate all necessary system and equipment controls for the semi-automatic sequence to proceed.

A manual mode of operation was also retained in the design. The manual operating mode is equivalent to the manual operation of conventional BWR designs and is available at the operator’s discretion or when automatic operation is terminated due to abnormal plant conditions.

18G.2.2.4 Large Display Panel

Studies of trends in control room information presentation methods (e.g., the Halden IPSO project as described in Report No. HWR-184) were completed. An analysis of questionnaire survey responses from the manufacturing sector of Japanese industry, including fossil fuels and other process plants, indicated that large displays or combinations of large displays and console-mounted VDUs are regarded as an effective means of providing information to operators in a broad spectrum of industrial plant environments.

18G.2.2.5 Independence of Fixed-Position Displays

This feature was adopted as a result of evaluations of plant operations during periods of postulated equipment failures and studies of trends in fixed-position display designs throughout industry. The incorporation of the fixed-position displays provides redundancy in display modes and contributes to the ability to safely shut down the plant if the process computer system is lost.

18G.2.2.6 Large Video Display

Studies of large screen utilization trends and of how large screens can best be integrated with VDUs in the control room were performed. The large screen study topics are summarized in Table 18G-1.

Traditionally, during planned outages and at other times, large blackboards have been used, on a temporary basis, in control rooms to display information regarding the status of important ongoing processes. As summarized in Table 18G-1, large screens can be utilized as substitutes for these blackboards. Also, large screens can be used as industrial television monitors (ITV) to make local checks during normal plant operation. In addition, large screens can be used to display CRT screen formats to the entire control room crew simultaneously.

The technology for large screens was also reviewed. Video projectors and displays using liquid crystal projection, luminous source, liquid crystal transmission, LED and CRT technology were compared from the standpoint of screen size, optimum viewing distance, resolution, brightness and update speed.

18G.2.2.7 Alarms

Studies of alarm system technologies, the uses of alarms in control rooms and alarm prioritization and suppression methods to reduce the information load on the operating crew in times of upsets were carried out. Improvements in methods of distributing alarm functions between fixed-position indicators and VDUs were examined. Evaluations of VDU alarm presentation methods and formats were also done.

18G.2.2.8 Control Room Spatial Arrangement

Control room functions and arrangements were studied. Evaluations were made of the free space requirements of the control room. Regulations and legislation affecting areas of control room design such as comfort, human factors engineering and control room habitability considerations were reviewed.

18G.2.3 Allocation of Functions

Studies of trends in automation of operator functions in nuclear power plants were done. In the early days of the industry, improvements in the level of automation were related chiefly to maintenance of safety. Later, attention has come to be focused on the goal of reducing the burden on the operators. Accordingly, the task analyses discussed in Subsection 18G.2.2.3 “Plant Operations”, were performed and allocation of functions were made as described in that subsection.

18G.2.4 Operator Work Load

Studies of operator work load were performed as part of the automation studies. The task analyses performed on both system and plant operations were used to develop time histories of operator work load for both normal and abnormal operations. As discussed previously, the operator work load information was an important part of the basis for decisions regarding automation.

18G.2.5 Other Areas of Interest

Other study areas, not directly contributing to the development of the standard design features discussed in Subsection 18G.2.2, were also pursued. These other study areas included the following:

(1) Configuration of the HSI system:

- (a) Relation of process computer to other components
- (b) Data highway design

(2) Functions and configurations of plant data management systems:

- (a) Core management
- (b) Operation management
- (c) Maintenance management
- (d) Security controls
- (e) Management of documentary information
- (f) Management of site operation records

(3) Operator assistance technologies:

(a) Diagnosis

(b) Planning

(c) Routine maintenance assistance

(4) Audio response systems:

(a) Speech recognition

(b) Speech synthesis

18G.3 Validation Testing

18G.3.1 General

During the summer of 1990, a systematic program of testing on two separate prototypes was performed to validate the key features of the ABWR main control room equipment design. Three teams of three licensed plant operators each were used for the tests. The prototypes were fabricated according to a conceptual design prepared during the development program discussed in Section 18G.2.

18G.3.1.1 General Test Description

Schedule: The tests were conducted per the schedule shown in Table 18G.2.

Test Teams: The test teams were composed of a utility's operations personnel from operating boiling water reactors. Each team consisted of three individuals; one senior operator, one operator and one shift supervisor. The test sequences were conducted with the two operators at the main control console and the supervisor located at a desk about 4.5m behind the operators.

Data: Test data were collected in the form of (a) performance measures: these consisted of observations of operator actions and behavior during the tests and examination of video tapes taken during the tests, and (b) opinions, which took the form of post-test operator interviews and questionnaires filled out by the operators during the post-test debriefing sessions. The objective of the data collection methods was to obtain as complete a record as possible of the operator's interactions with the HSI model and each other as they reacted to the simulated plant conditions and of the operator's reactions to the equipment design.

Equipment Configuration: The control room prototypes included the following key design features, which are correlated to the ABWR standard design features listed in Section 18G.2.2:

(1) 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 [Standard Design Feature (1)].

(2) The use of on-screen control video display units (VDUs) for safety system monitoring and non-safety-related system control and monitoring [Standard Design Feature (2)].

(3) The use of a separate set of on-screen control VDUs for safety system control and monitoring [Standard Design Feature (3)].

(4) The use of dedicated function hardware switches on the control console [Standard Design Feature (4)].

(5) Operator-selectable automation of predefined plant operation sequences [Standard Design Feature (5)].

(6) The incorporation of an operator-selectable semi-automated mode of plant operations, which provides procedural guidance on the control console VDUs [Standard Design Feature (6)].

(7) The capability to conduct these pre-defined plant operation sequences in an operator manual mode [Standard Design Feature (7)].

(8) The incorporation of a Large Display Panel, located behind the main control console, which presents information for use by the entire control room operating staff [Standard Design Feature (8)].

(9) The inclusion on the Large Display Panel of key plant parameters and major equipment status displayed at fixed positions on the panel [Standard Design Feature (9)].

(10) The inclusion on the Large Display Panel of critical plant parameters which are continuously displayed at fixed positions on the panel [Standard Design Features (10) and 14)].

(11) The independence of the fixed-position displays from the process computer [Standard Design Feature (11)].

(12) The inclusion on the Large Display Panel of a large video display unit to supplement the information presented on the fixed displays [Standard Design Feature (12)].

(13) The use of fixed-position alarm tiles on the Large Display Panel [(Standard Design Feature (15)].

(14) The application of alarm processing logic to prioritize alarm indications and to filter unnecessary alarms [Standard Design Feature (16)].

(15) Spatial arrangement between the large display panel, the main control console and the supervisors' console which allow the entire control room crew to monitor the information presented on the large display panel [Standard Design Feature (17)].

(16) The use of VDUs to provide low-level alarm indications and detailed information on the alarms which are presented on fixed-position alarm tiles [Standard Design Feature (18)].

Standard Design Feature (13) was not specifically incorporated in the prototype testing program. The essential feature of the supervisors' console which was modelled was its lack of control capability.

Test Items: The testing consisted of exercising a variety of plant operation scenarios which were generated by a dynamic simulator. The operating crew would respond to the changing plant conditions during the scenarios by monitoring the information which was available to them and manipulating the appropriate controls. The scenarios included in the test program are summarized in Table 18G-3. Video tapes were taken of the operators as the scenarios were being run.

18G.3.1.2 Test Results

The operator interviews and questionnaire data collected during debriefing sessions at both test facilities, plus the video tape evaluations, fully supported the key design features summarized previously in Section 18G.3.1.1. Specific, relevant results regarding those key features are summarized below.

(1) Under normal, abnormal and accident conditions it is easy to comprehend the plant condition from the information presented on the Large Display Panel (LDP).

(2) The LDP contributes much to improve overall monitorability of the plant.

(3) The fixed position displays and large alarm tiles on the LDP are very effective in promoting understanding of the conditions during accidents.

(4) The large variable display on the LDP is watched more often during normal operation than during abnormal operation. However, in general, the large variable display is not watched as often as the fixed position displays.

(5) Suggested formats for display on the large variable screen include trends, plant summary and Safety Parameter Display System (SPDS) information during abnormal/ accident events and alarms.

(6) Work space and sitting posture at the Main Control Console are good, in general.

(7) Work space on the tested Main Control Console arrangement would be crowded if more than two operators were required at the console.

(8) The presentation of top-level, fixed position alarms on the LDP is very effective.

(9) The display of individual alarms on the VDUs is good.

(10) The size of the CRT screens was preferred over that of the flat panel devices. However, the touch screen operations on the flat panels were rated as better than on the CRTS.

The operator's comments focused on those design features which were new to them. Hence, the comments dealt with the LDP, alarm presentation scheme, main console configuration and operations with touch screens. There were little or no comments regarding the automated, semi-automated or manual operating modes or the hardware switches because of the particular operator's experience with such features.

The direct operator feedback and evaluation of the test sequence video tapes also provided much additional data which was relevant to the specific details of the equipment employed and the scope of the prototype control console dynamic simulation. Although these additional test results are not pertinent to the evaluation of the ABWR key features described in Section 18G.2.2, they are being addressed and incorporated into the ongoing control room.

Table 18G-1 Large Screen Utilization Topics

		During Planned Outages	During Startup & Shutdown	During Normal Operation	During Abnormalities / Accidents
BLACKBOARD	SUBSTITUTES	• Status of system isolation • Status of refueling • Status of incoming power	• Startup/shutdown curves	• Status of equipment repair • Schedule tables • Load-following curves	• Weather / environment • Instrumentation during accidents
USED CONCURRENTLY	AS ITV	• Local Equipment status • MSIV room • Turbine operating floor, etc.	• Status of startup and shutdown auxiliaries • Drywell inspection status	• Radwaste control room, etc.	• Local equipment status
	AS VDU	• Plant summary • Ordinary alarms • Trend displays	• Plant summary • Ordinary alarms • Trend displays • Summary display of core status	• Plant summary • Ordinary alarms • Trend displays • Summary display of core status	• Emergency alarms • Plant summary • ECCS summary • Trend displays

Table 18G-2 Validation Test Schedules

	Prototype Facility A	Prototype Facility B
First Test Team	June 6–8, 1990	June 11–18, 1990
Second Test Team	June 25–27, 1990	July 10–12, 1990
Third Test Team	July 26–27, 1990	July 23–25, 1990

Table 18G-3 Test Scenarios and Evaluations

Test Case Classification	Test Scenarios	Key Items of Evaluation
Normal Startup/Shut down and Surveillance	Reactor Critical Reactor Temperature Increase Power Adjustment to Support Drywell Inspection Generator in Parallel Condensate/ Feedwater System Alignment Power Increase Generator Trip/Turbine Trip Reactor Core Isolation Cooling System Surveillance	1) Transition to manual from automated operations. 2) Hardware switch operation capability. 3) Functions identified for implementation using hardware switches. 4) Adequacy and effectiveness of displayed information for monitoring. 5) Location of displayed information. 6) Adequacy and need for expansion of operator support function(s).
Equipment Trips	Reactor Feed Pump Trip Reactor Internal Pump Trip Condensate Pump Trip	Items 2) through 5), plus 7) Large display panel effectiveness. 8) Alarm system effectiveness.
Scrams and Accidents	MSIV Closure Loss of Preferred Power Loss-of-Coolant Accident	Items 2) through 5) and 7) through 8), plus 9) Appropriateness and effectiveness of level of automation after a scram.
Computer Failure	Loss of Automated Operating Mode Loss of all Process Computer supported VDUs	Items 1) through 5), plus 10) Operability by sub-loop automation.

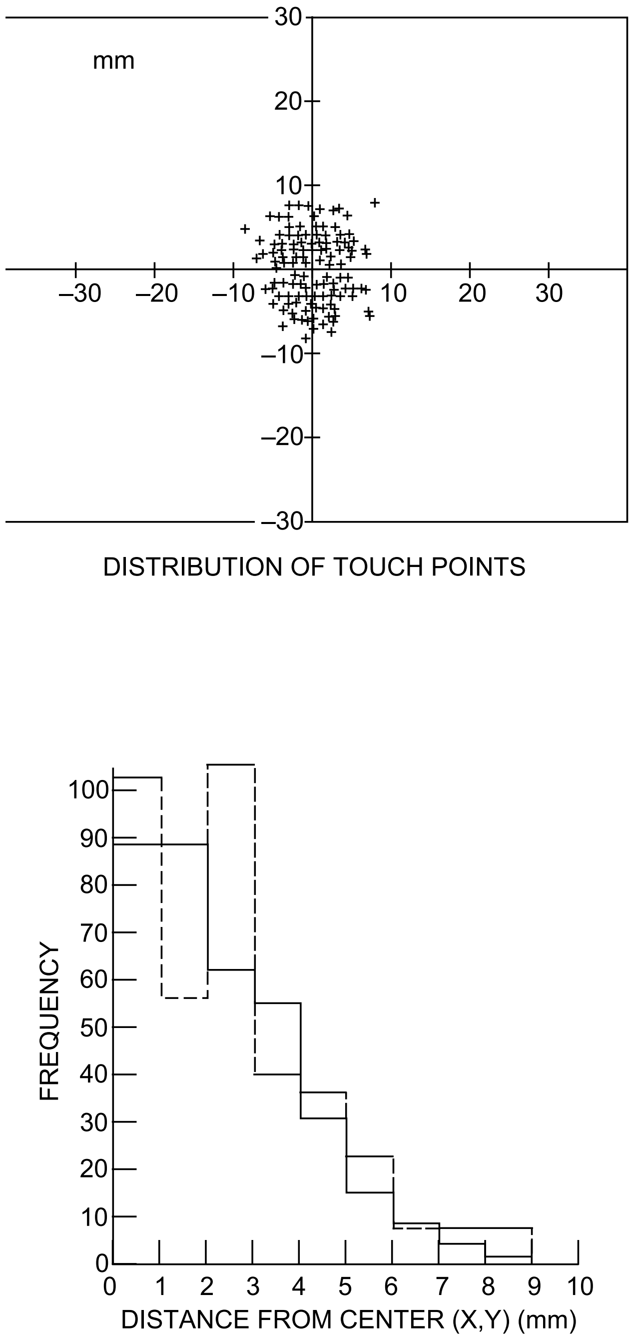


Figure 18G-1 Typical Data from Touch Screen Precision Tests

18H Supporting Analysis for Emergency Operation Information and Controls

18H.1 Introduction

This appendix contains the supporting analysis of information and control needs of the main control room operators. The analysis is based upon the operation strategies given in the ABWR Emergency Procedure Guidelines (EPGs) as presented in Appendix 18A and the significant operator actions determined by the Probabilistic Risk Assessment (PRA) described in Section 19D.7. The information contained in this appendix is the same as those previously submitted for NRC staff review per Reference 18H-1, with additional discussion provided in Section 18H.3. The minimum inventory of controls, displays and alarms from this analysis are presented in Appendix 18F.

Information and control needs for each operation instruction or action are given in a table containing fourteen (14) columns of information. Information presented in each of those columns in the tables is as follows:

1. STEP REFERENCE.

   Reference to either the EPGs or to the PRA as the basis of the particular step addressed by the associated set of table entries.

2. STEP.

   Specific step in the EPGs (referred to as the EPG step) or specific operator action referenced in the PRA (herein referred to as the PRA step) or item reference in the PRA.

3. DESCRIPTION OF STEP.

   A summary description of the step or operator action.

4. INFORMATION TO PERFORM STEP.

   Information needs of the operator to perform the specific EPG step or PRA operator action.

5. CONTROL FUNCTIONS TO PERFORM STEP.

   Control functions that the operators perform to execute the actions specified in the EPG step or PRA operator action.

6. PARAMETER DISPLAYS TO EXECUTE STEP.

   Plant process parameters or other displays that are necessary for execution of the step given in the EPG step or PRA operator action.

7. CONTROLS TO EXECUTE STEP.

   Controls necessary for the execution of the step.

8. ALARMS TO PERFORM STEP.

   Annunciators necessary for the execution of the step.

9. OPERATOR AIDS TO PERFORM STEP.

   Operator aids such as supplementary procedures or other information necessary for the execution of the step.

10. DISPLAYS TO JUDGE ACTION ACCOMPLISHMENT OR INITIATION.

    Displays to provide a feedback to the operators to confirm that the specified control functions have been initiated or accomplished.

11. POSITION OF CONTROLS TO JUDGE ACTION ACCOMPLISHMENT OR INITIATION.

    Position of control devices that provide feedback to the operators to confirm that proper controls are manipulated to the correct positions.

12. ALARMS TO JUDGE ACTION ACCOMPLISHMENT OR INITIATION.

    Annunciators to provide feedback to the operators to confirm that proper control actions are initiated or accomplished.

13. OPERATOR AIDS TO JUDGE ACTION ACCOMPLISHMENT OR INITIATION.

    Operator aids to provide feedback to the operators to confirm that proper control actions are initiated or accomplished.

14. DISPLAY, CONTROL, OR ALARM THAT ARE CLASS 1E OR REGULATORY GUIDE 1.97 INSTRUMENT.

    Identification of those devices that are Class 1E, provided by Class 1E, or Regulatory Guide 1.97 instrumentations.

The following guidelines, developed from a research program of advanced control panel designs, were used to specify the type of implementation device for controls, displays, and alarms:

(a) Fixed Position Controls
- Manual starting and resetting of safety systems,
- Manual starting of emergency backups,
- Mode switches for initiation of automation sequences.

(b) Divisional VDUs
- Individual controls of safety system components,
- Lineup displays of safety systems.

(c) Non-Divisional VDUs
- Monitoring of non-safety systems and control of individual controls of non-safety systems,
- Individual alarms.

(d) Fixed Position Alarms
- Important plant level and system level alarms.

(e) Fixed Position Display
- Monitoring of important plant parameters.

The following operator actions are considered to be important operator actions in the ABWR PRA (refer to subsection 19D.7):

(1) Backup manual initiation of HPCF

(2) Recovery of feedwater following a scram

(3) Use of condensate injection following scram with reactor depressurized

(4) Control of reactor water level in an ATWS

(5) Emergency depressurization of the reactor

(6) Alignment and initiation of firewater for RPV injection with ECCS failure

(7) Alignment and initiation of firewater for drywell spray

(8) Initiation of wetwell spray using RHR

(9) Isolation of water sources in an internal flooding

These actions are already specified in the EPGs and are included in the analyses.

18H.2 Presentation of Results

The results of the operational analysis of each step of the ABWR EPGs and PRA important operator actions are given in Tables 18H-1 through 18H-11. Tables 18H-12 through 18H-14 are inventories of the controls, displays, and alarms which have been identified in those operational analyses as being the minimum primary means of accomplishing a particular function of main control room operation. These inventories do not necessarily include controls, displays, and alarms from consideration of other design requirements.

In the ABWR man-machine interface design, control, display and alarm indication functions are implemented through the use of divisional VDUs (referred to as “Div. VDUs”), non-divisional VDUs (referred to simply as “VDUs”) and/or through the use of dedicated and fixed position devices. Refer to Subsection 18.4.3.1, Safety Systems, and Subsection 18.4.3.2, Non-Safety Systems, for descriptions of the man-machine interface design, control, display, and alarm presentation capabilities. In Tables 18H-1 through 18H-11, the particular method of design implementation for each control, display and alarm function is indicated in brackets as part of each relevant table entry.

In these tables, entries are identified by bold face type and capitalized letters when they are first identified in the analysis as being the primary method of executing a particular control, display or alarm function. An example is the indication of RPV water level as a critical parameter displayed on the fixed mimic panel in the main control room:

(A) RPV WATER LEVEL [FIXED POSITION].

Information given in the brackets indicate the type of implementing device. Since one of the purposes of the control room inventory analysis is to identify a minimum set of fixed control, display, and alarm devices, to minimize needless duplication or table entries, subsequent identification of the same design attribute is indicated in the tables within an underline and is not bold type or capitalized. An example of indication of RPV water level in subsequent steps is:

(a) <u>RPV water level [Fixed Position]</u>.

Critical process parameters that are displayed on the fixed position display panel are provided by Class 1E instruments via a non-safety related display controller. For these parameters, they are also available in the divisional Video Display Units (VDUs) and the non-divisional VDUs. Therefore, when a monitoring function is specified (entry conditions and usually the conditional statements of each step of the EPGs) and the primary source of the monitored parameter is identified for the first time as a parameter displayed on the fixed position display panel, the corresponding divisional VDUs and non-divisional VDUs are also included. However, to minimize unnecessary duplication in the table entries, subsequent identification of the same primary monitoring source (fixed display) will not have its corresponding display on divisional VDUs and VDUs identified. As an example, if average drywell pressure display is identified for the first time:

(A) AVERAGE DRYWELL TEMPERATURE

[FIXED POSITION],

(b) Average drywell temperature [Div.VDUs],

(c) Average drywell temperature [VDU].

Subsequent identification of average drywell temperature as a fixed display will be as follows:

(a) <u>Average drywell temperature</u>

[Fixed position].

To further reduce duplicate efforts, table entries which are underlined will not have their instrumentation classification summarized in the column 14 table entries.

In certain columns of the tables, such as columns 7, Controls to Execute Step, and columns 10, Displays To Judge Action Accomplishment or Initiation, system controls or a system lineup display is specified in divisional VDUs and non-divisional VDUs. In the case of column 7 for controls, all remote control equipment of a particular system can be controlled from the VDU. Also in column 7, certain controls are specified as Mode Switches. An example is the RHR(A) Suppression Pool Cooling Mode Switch. Actuation of a system mode switch will initiate a predefined sequence of system level control actions, such as aligning valves and starting pumps. In column 10, a system lineup display typically represents a graphical mimic of the system similar to that presented in a system P&ID, where the position of valves, operating status of pumps, and status of other components of the system are indicated. Key system parameters and process parameters are also indicated.

Certain displays in these tables are indicated as being fixed displays. Examples of this type of fixed displays are switch position indication of a standby liquid control pump control switch and mode switch selection indication of RHR shutdown cooling mode. For these examples, process parameters such as standby liquid control pump discharge pressure and RHR flow, respectively, provide sufficient information feedback on actions initiated by the operator. In addition, certain fixed displays such as recirculation pump trip status indication, main turbine stop valve and control valve status indication are not considered to be absolutely required because fixed position alarms are provided which will present the same status information to the operators. These types of fixed position displays are not indicated by bold face type and capitalized letters and hence will not be included as part of the minimum inventory of displays.

In Tables 18H-1 through 18H-11, numerical numbers used in the EPGs and in column 3 represent typical values. These values should be confirmed by plant-specific calculations and methods and updated if deemed necessary for a particular application of the information presented. Other clarification of the information presented in the tables are indicated by notes in the columns of the tables. Controls located outside of the main control room are indicated by an asterisk and a note at the end of column 7.

Tables 18H-12 through 18H-14 are inventories of minium controls fixed displays, and fixed alarms necessary based upon the operational analyses of each step of the ABWR EPGs and certain PRA important operator actions. These devices are summarized in Appendix 18F.

18H.3 Analysis of Changes to EPGs

Since submittal of the Reference 18H-1 document, several EPG steps were added by request of the NRC staff to address operator actions associated with ATWS stability. In addition, several EPG Steps were deleted to address NRC staff issues associated with ATWS stability, containment spray, and low pressure venting of the containment. These changes and their effect on information and control needs are discussed in this Section.

For ATWS stability, the following EPG Steps were added:

(1) RC/Q-6, first bullet item, "When periodic neutron flux oscillations in excess of [25% (Large oscillation threshold)] peak-to-peak commence or continue, or". The required information is reactor neutron flux and reactor thermal power which are already included in Table 18H-13, Items number 9 and 11 as fixed position displays.

(2) C5-2: "If any MSL is not isolated, bypass low RPV water level interlocks to maintain the main condenser as a heat sink." This action has been analyzed previously for Step RC/P-2 Override Statement.

(3) C5-4: "If RPV water level is above [164.9 cm (Maximum Power Control RPV Water Level)] and the reactor is not shutdown, lower RPV water level to below [164.9 cm (Maximum Power Control RPV Water Level)] by terminating and preventing all injection into the RPV except from boron injection systems and CRD." The lowering of RPV water level and terminating and preventing of injection systems has been analyzed in Step C5-3. The information need of RPV water level has been previously included in analyses of RC/L steps.

To address the containment spray issue, EPG Step PC/P-1, which specifies wetwell spray, has been deleted. The deletion of two fixed position controls (Wetwell Spray Mode Initiation Switch) have been included in the Reference 18H.4-1 submittal. Wetwell spray and drywell spray are now combined in Step PC/P-2 and consequently, the fixed position controls formerly labeled as RHR(B) Drywell Spray Mode Initiation Switch and RHR(C) Drywell Spray Mode Initiation Switch are now labeled as RHR(B) Containment Spray Mode Initiation Switch and RHR(C) Containment Spray Mode Initiation Switch, respectively. Finally, EPG Step PC/H-1.3, "If drywell or suppression chamber oxygen concentration are not below 5%, purge the primary containment with air or nitrogen in accordance with [procedure for primary containment purging]", was deleted since purging of the containment with air after an accident using ACS is not allowed. Deleting this step does not require any changes to the initial control room inventory since the previous step, PC/H-1.2, uses the same information and controls.

Based on the above observations, there are no required changes to the minimum inventory as a result of these changes in the EPGs.

18H.4 References

18.8-1 Letter, Jack Fox to Chet Poslusny, Submittal Supporting Accelerated ABWR Schedule - Revised Appendix 18F, DSER Confirmatory Item 18.4.3-1, June 9, 1993.

Table 18H - 1 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 2 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 3 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 4 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 5 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 6 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 7 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 8 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 9 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 10 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 11 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 12 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 13 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]

Table 18H - 14 [Proprietary information not included in DCD (Refer to SSAR Appendix 18H, Amendment 34)]