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 18E-4 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 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 18E-4 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 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 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.

(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).

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

(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.

(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:

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

(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.

- *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*

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

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.

(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.

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

	(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.* *(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*

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

(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 ABWR design). The System Functional Requirements Analysis Implementation Plan shall establish:

(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

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

(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).

(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:

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

	(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.* *(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.*

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

(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 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 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) Not used

(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 communications function 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 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.

(C) Computer

Attachment 1 to Table 18E-1 Results of Operating Experience Review of Previous Nuclear Power Plant HSI Designs (Continued)

(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.*

(I) *Meters*

Attachment 1 to Table 18E-1
Results of Operating Experience Review
of Previous Nuclear Power Plant HSI Designs (Continued)

(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.

(O) Task Analysis

Attachment 1 to Table 18E-1
Results of Operating Experience Review
of Previous Nuclear Power Plant HSI Designs (Continued)

(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 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 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 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 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 6.b Acceptance Criteria presented in Table 3.1 of the Tier 1 Design Certification material for the 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.

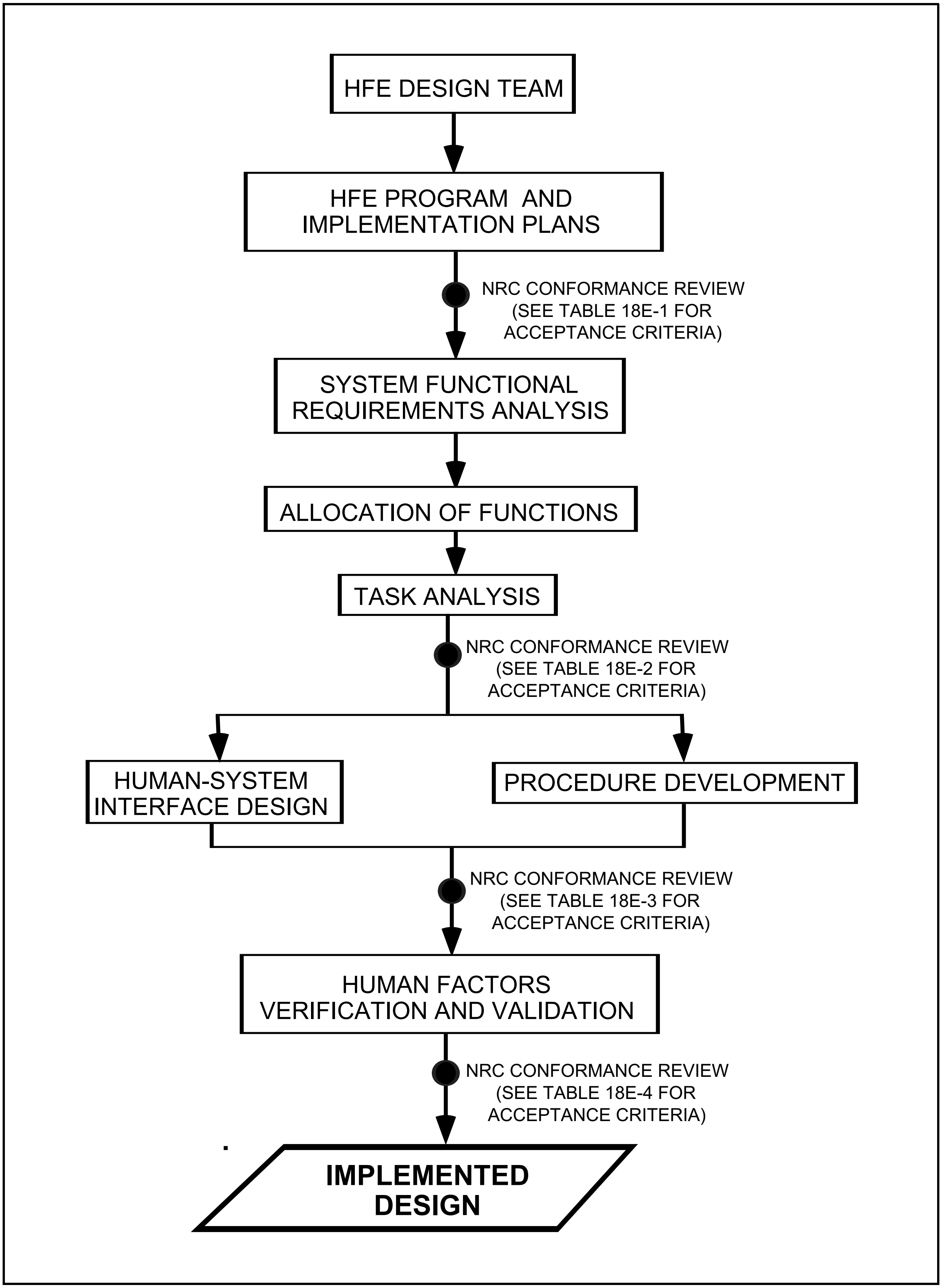

Figure 18E-1 ABWR Human-System Interface Design Implementation Process