Human Factors Engineering Program Plan

Technical Report

Non-Proprietary

September 2013

Revision History

Revision	Page (Section)	Description
0	All	Issue for Standard

ABSTRACT

The purpose of the Human Factors Engineering Program Plan (HFEPP) is to provide a necessary and sufficient plan for advanced power reactor 1400 (APR1400) human factors engineering (HFE) program and human-system interface (HSI) design.

This technical report contains information about acceptable HFE design criteria, specifies the element of HFE program, and explains management process of HFE Program Review Model compliance with NUREG 0711, Revision 3, to those HFE program elements.

In addition, this document provides information for Design Control Document (DCD) Chapter 18.

TABLE OF CONTENTS

List of Appendices

List of Figures

List of Tables

List of Acronyms

ANS	American Nuclear Society
APR1400	advanced power reactor 1400
A/E	architect engineering
BOP	balance of plant
CBP	computer-based procedure
DCD	Design Control Document
DRN	design review notice
FRA/FA	functional requirements analysis and function allocation
HED	human engineering discrepancy
HDTM	human factor engineering design team meeting
HFE	human factors engineering
HFEPP	Human Factors Engineering Program Plan
HSI	human-system interface
I&C	instrumentation and control
IHA	important human actions
ISV	integrated system validation
ITS	issue tracking system
KHNP	Korea Hydro and Nuclear Power
KEPCO	Korea Electronic Power Corporation
LCS	local control station
LDP	large display panel
MCR	main control room
NRC	U.S. Nuclear Regulatory Commission
NSSS	nuclear steam supply system
OER	operating experience review
PRA	probabilistic risk assessment
RSR	remote shutdown room
SFA	system function analysis
TIHA	treatment of important human actions
TA	task analysis
TSC	technical support center
V&V	verification and validation
VDU	video display unit

1.0 Goal and Scope

1.1 General Information of HFE Program Plan

The purpose of this document is to provide a necessary and sufficient HFEPP for the advanced power reactor 1400 (APR1400) HFE process and human-system interface (HSI) design. This document describes an acceptable HFE design criteria, specifies the elements of the HFE program, and explains how the elements are managed by the Human Factors Engineering Program Review Model (Reference 1).

The HFE management program, as described in this Implementation Plan ensures that the HFE program is properly developed and implemented. The HSI design follows the HFEPP and the HSI is based on a human centered design process that is in compliance with Human Factors Engineering Program Review Model.

This document presents the requirements on the HFE design process, identifies criteria to meet the requirements described in Human Factors Engineering Program Review Model, and relates these to the plans for future HFE design activities. This provides a complete HFE management program plan for formal and systematic HSI design.

The HFE program plan includes the following topics:

- General HFE management program goals and scope,
- HFE design team and organization,
- HFE process and procedures,
- HFE issue tracking, and
- HFE technical program.

1.1.1 Assumptions and Constraints Identification

A fundamental HFE design assumption is that it is possible to operate the plant with the following key personnel: one reactor operator (RO) who has a reactor operator license, one turbine operator (TO), who has a reactor operator license, one electric operator (EO), one shift supervisor (SS) who has senior reactor operator license, and one shift technical advisor (STA) in the main control room (MCR) during postulated plant operating modes. This MCR staffing meets the regulatory requirements of 10 CFR 50.54(m)(2)(iii) (Reference 2).

The HSI system is designed to accommodate the MCR and plant staffing described above. The space and layout of the MCR are designed to accommodate the foreseen maximum number of operating and temporary staff. The HSI is designed on the Basic HSI Platform (Reference 3).

One of the most note-worthy characteristics of the system is the advanced control room with fully computerized HSI features containing redundant compact operator consoles, large display panel, computer-based procedure system, soft controls, and a separated safety console with a minimum number of fixed position displays and controls including spatially-dedicated, continuously visible display. These integrated design features help reduce operator error, which will ensure safe operation of the plant system.

1.1.2 Applicable Plant Facilities

The HFE program addresses the following facilities:

- main control room (MCR)
- remote shutdown room (RSR)
- technical support center (TSC)
- emergency operations facilities (EOFs) (communications and information requirements only)
- local control stations(LCS) associated with important human actions

The elements of the HFE program are applied in a graded fashion to facilities as shown in Table 1:

Table 1. Application of HFE Program to APR1400

Facilities	Planning & Analysis	Design	Verification and Validation	Implementation & Operation	Remarks
MCR	- HFEPP - OER - FRA/FA - TA - Staffing and Qualifications - Treatment of IHAs	- HSI Design	- HF V&V	- Design Implementation - Human Performance Monitoring	
RSR	- HFEPP - OER - FRA/FA - TA - Staffing and Qualifications - Treatment of IHAs	- HSI Design	- HF V&V	- Design Implementation - Human Performance Monitoring	

Facilities	Planning & Analysis	Design	Verification and Validation	Implementation & Operation	Remarks
TSC	- HFEPP	- HSI Design	- HF V&V	- Design Implementation	
EOFs	- HFEPP	- HSI Design		- Design Implementation	- Communication & Information Requirement Only
LCSs	- HFEPP - TA, Treatment of IHAs	- HSI Design	- HF V&V	- Design Implementation - Human Performance Monitoring	

1.1.3 Applicable HSIs, Procedures, and Training

The applicable HSIs, procedures, and training which are included in the HFE management program address operations, emergency response, maintenance, test, inspection surveillance interfaces and procedures.

The HFE program addresses the design of HSIs and identifies inputs to the development of procedures and training for all operations, accident management, maintenance, test, inspections, and surveillance tasks that operational personnel will perform or supervise. In addition, the HFE design process will identify training program input for the following personnel identified in 10 CFR 50.120. In addition, any other personnel who perform tasks directly related to plant safety will be included, such as information technology technicians who troubleshoot and maintain support systems and their HSIs.

1.2 Applicable Codes and Regulations

- Basic Requirements

  - NUREG-0800, Standard Review Plan, Chapter 18 Human Factors Engineering, 2007
  - NUREG-0711, Human Factors Engineering Program Review Model, 2012

- Human Factors Engineering Program Plan

  - 10CFR 50.34(f)(3)(vii), Domestic Licensing of Production and Utilization Facilities - Management and Technical Support Organization
  - RG 1.174, An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis, 2002

- NUREG-0737 and Supplements, Clarification of TMI Action Plan Requirements, 1980

- Operating Experience Review

  - 10 CFR 50.34(f)(3)(i), Domestic Licensing of Production and Utilization Facilities; Contents of applications; technical information
  - NUREG/CR-6400, HFE Insights for Advanced Reactors based upon Operating Experience, 1996
  - NUREG/CR-6749, Integrating Digital and Conventional Human-System Interfaces: Lessons Learned from a Control Room Modernization Program, 2002

- Functional Requirements Analysis and Function Allocation

  - 10 CFR 50, Appendix A, General Design Criteria for Nuclear Power Plants.
  - RG 1.62, Rev.1, Manual Initiation of Protective Actions, 2010.
  - NUREG/CR-3331, A Methodology for Allocating Nuclear Power Plant Control Functions to Human or Automatic Control, 1983
  - NUREG-0711, Rev. 3, Human Factors Engineering Program Review Model, 2012
  - ANSI/ANS 58.8-1994, Time Response Design Criteria for Safety-related Operator Actions, 1994.
  - IEEE 603-1991, Standard Criteria for Safety Systems for Nuclear Power Generating Stations, 1991.

- Task Analysis

  - NUREG/CR-3371, Task Analysis of Nuclear Power Plant Control Room Crews, 1983

- Staffing and Qualifications

  - 10 CFR 50.54(i) ~ (m), Domestic Licensing of Production and Utilization Facilities - Conditions of Licenses
  - RG 1.8, Qualifications and Training of Personnel for Nuclear Power Plants, 2000
  - NUREG/CR-6400, HFE Insights for Advanced Reactors based upon Operating Experience, 1997
  - NUREG/CR-6838, Technical Basis for Regulatory Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m), 2004

- Information Notice 95-48, Results of Shift Staffing Study, 1995
- Information Notice 97-78, Crediting of Operator Actions in Place of Automatic Actions and Modifications of Operator Actions, Including Response Times, 1997

- Treatment of Important Human Actions

  - 10 CFR 52.47(a)(27), A description of the design specific probabilistic risk assessment (PRA) and its results
  - 10 CFR 52.47(b)(1), Combined Licenses - Contents of applications; technical information
  - 10 CFR 52.79, Combined Licenses - Contents of applications; technical information in final safety analysis report
  - RG 1.200, An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities, 2009
  - NUREG/CR-1278, Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, 1983

- Human-System Interface Design

  - 10 CFR 50.34(f)(2), Domestic Licensing of Production and Utilization Facilities - Contents of applications; technical information
  - 10 CFR 50, Appendix A, General Design Criteria for Nuclear Power Plants Criteria 19 Control Room
  - RG 1.22, Periodic Testing of Protection System Actuation Functions, 1972
  - RG 1.47, Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems, 2010
  - RG 1.62, Manual Initiation of Protective Actions, 2010
  - RG 1.97, Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants, 2006
  - DI&C-ISG-04, Highly-Integrated Control Rooms-Communications Issues, 2009
  - DI&C-ISG-05, Highly-Integrated Control Rooms-Human Factors Issues, 2008
  - NUREG-0700, Human-System Interface Design Review Guidelines, 2002
  - NUREG-0696, Functional Criteria for Emergency Response Facilities, 1980

- Procedure Development

  - 10 CFR 50.34(f)(2)(ii), Domestic Licensing of Production and Utilization Facilities - Contents of applications; technical information
  - NUREG-0899, Guidelines for the Preparation of Emergency Operating Procedures, 1982

- UREG-1358, Lessons Learned From the Special Inspection Program for Emergency Operating Procedures, 1989
- NUREG/CR-6634, Computer-Based Procedure Systems: Technical Basis and Human Factors Review Guidance, 2000

- Training Program Development

  - 10 CFR 50.120, Additional Standards for Licenses, Certifications, and Regulatory Approvals - Training and qualifications of nuclear power plant personnel
  - 10 CFR 52.79, Combined Licenses - Contents of applications; technical information in final safety analysis report
  - 10 CFR 55, Operators' Licenses
  - RG 1.149, Nuclear Power Plant Simulation Facilities for Use in Operator Training and License Examinations, 2011
  - RG 1.8, Personnel Selection and Training for Nuclear Power Plants, 2000
  - NUREG-1021, Operator Licensing Examination Standards for Power Reactors, 2004
  - NUREG-1122, Knowledge and Abilities Catalog for Nuclear Power Plant Operators: Pressurized Water Reactors, 1998

- Human Factors Verification and Validation

  - DI&C-ISG-04, Highly-Integrated Control Rooms-Communications Issues, 2009
  - DI&C-ISG-05, Highly-Integrated Control Rooms-Human Factors Issues, 2008
  - NUREG/CR-6633, Advanced Information Systems: Technical Basis and Human Factors Review Guidance, 2000

- Design Implementation

  - NUREG-0711, Human Factors Engineering Program Review Model, 2012

- Human Performance Monitoring

  - NUREG-1649, Reactor Oversight Process, 2000
  - NUREG/CR-6751, The Human Performance Evaluation Process: A Resource for Reviewing the Identification and Resolution of Human Performance Problems, 2002

1.3 Definitions

Acceptance Criteria: Practical and reasonable objective pass/fail tests that identify approved requirements. Criterion is qualitative or quantitative, and defines sufficiency, not optimality.

Availability: Verification of task performance capability such that the necessary indications and controls accomplish a defined set of tasks (e.g., emergency operating procedures) are afforded in a specified work area (e.g., a control room).

Calendar-referenced: Use of specific, quantitative dates

Schedule-referenced: Use of relative, qualitative dates, reflecting relative order information among scheduled items (e.g., milestones).

Control Room Design Review**:** Practical, validated methodology for evaluating existing control room designs for possible human engineering deficiencies.

Human Factors Engineering: The study of designing industrial equipment or system to optimally fit the human body and its cognitive abilities.

HSI Style Guide: Equipment and system design guidance formulated to incorporate human factors principles.

HFE Principles: General principles of human factors, such as perception, cognition, and human actions that have practical implications for adequate and usable design.

HFE Specialists: Credited Individuals in the area of HFE equivalent to: (a) at least two years of successful graduate-level study of applicable subjects, plus a year of related design experience, or (b) five years of related design experience, or (3) any evenly proportioned combination of (a) and (b).

Interdisciplinary: A philosophy which incorporates multiple technical viewpoints by specialty with the aim of achieving a more well-around result. In the present context, the concern is the involvement of HFE specialists and operations experts in the design activities, along with instrumentation and control (I&C) and systems engineers.

Human-System Interface: The means through which personnel interact with the plant system, including the alarms, displays, controls, and job performance aids. Generically this includes maintenance, test, and inspection interface as well.

Operations Experts: Currently or formerly licensed operators with operating experience on similar US plants.

Suitability: Verification of task performance capability such that the HSI design items are individually acceptable (i.e., are usable, or suitable for their intended use).

Task Analysis**:** Formalized method of decomposing human job and task activities into constituent elements that information inputs and action outputs are identified.

Usable: Operable, maintainable, testable, assessable, efficient, effective, etc. (i.e., sufficient to support the operator's specified tasks). The act of studying, testing or examining to establish and document the system/procedure meets the regulatory or technical standard.

Verification: Availability and suitability of analysis process

Validation: Evaluation process demonstrates for trained user to test ability to successful performance of their anticipated role (e.g., emergency procedures) in the afforded task environment (e.g., the control room design review) under anticipated operating conditions (e.g., the validation scenarios).

2.0 HFE Design Team And Organization

The following section describes the HFE design team and organization.

2.1 HFE Team Responsibilities

The HFE design team is responsible (with respect to the scope of the HFE program) for the following:

- The development of HFE plans and procedures;
- The oversight and review HFE design, development, test, and evaluation activities;
- The initiation, recommendation, and provision of solutions for problems identified in the implementation of the HFE activities;
- The verification of implementation based on team recommendations;
- The assurance that HFE activities comply with the HFE plans and procedures; and
- The scheduling of activities and milestones.

Responsibilities for the HFE design team activities are identified in Table 2.

Table 2. Responsibilities for the HFE design team activities

Stage / Entity	Plan	Analysis	Design	Verification and Validation	Implementation and Operation
A/E Group	- Prepare HFEPP, OER, FRA/FA, TA , HSI Design and Integration, Treatment of IHAs and HF V&V plan - Peer review the results of other organizations	- Perform OER, FRA/FA, TA and Treatment of IHAs - Peer review the result of other organizations	- Provide HSI Style Guide - Apply design requirements for HSI design - Peer review the result of other organizations	- Perform suitability and availability verification as required for HSI design - Perform integrated validation for all HSI designs - Audit verification activities. - Finding and resolution of HED for HSI design	- Final plant verification

Stage / Entity	Plan	Analysis	Design	Verification and Validation	Implementation and Operation
NSSS System Group	- Prepare work plans for the HSI design - Peer review the results of other organizations	- Perform SFA of HSI design for NSSS System. - Peer review the result of other organizations	- Perform NSSS scope of HSI design. - Perform mockup design for NSSS scope of HSI design - Peer review the result of other organizations	- Perform suitability and availability verification for NSSS scope of HSI design - Support of HFE verification and validation including participation - Finding and resolution of HED for NSSS HSI design	- Final plant verification as a part of design implementation
Operating Group	- Prepare work plans for computer-based procedure (CBP) HSI design, staffing and qualifications, design implementation and human performance monitoring - Peer review the results of other organizations	- Perform TA for CBP design - Determine and provide the staffing and qualifications requirements to other organization for HSI design - Peer review the result of other organizations	- Perform CBP HSI design. - Perform mockup design for CBP HSI design - Peer review the result of other organizations	- Perform suitability and availability verification for CBP HSI design - Supporting of HF V&V including participation - Finding and resolution of HED for CBP design - Peer review the result of other organizations	- Monitoring the status of design implementation and human performance monitoring

2.2 HFE Organizational Placement and Authority

The organizational structure of HFE design team is shown in Figure 1. The primary members of HFE design team for APR1400 design are described below.

The individual responsibilities of HFE design team personnel are described below.

- Project manager

  The project manager is responsible for accomplishing design control objectives. Managing overall project scope, schedule, cost, quality, risk for final decisions are in charge of personnel responsibility.

- Quality assurance organization

  The quality assurance group applies the planned and systematic quality of activities to ensure that the project employs all processes needed to meet requirements.

- HFE design team leader (technical project manager)

  HFE design team leader performs technical project management for the HFE design process and has responsibility for overall HSI design. The HFE design team leader manages the HFE schedule and makes final decisions related to the unresolved issues assigned to the HFE design teams. The HFE design team leader has the authority for directing HFE design and helps to resolve conflicts between the HFE team and other teams. The HFE design team leader keeps the project manager informed on the status of unresolved issues, conflicts in the HFE design, and other design issues as appropriated.

- HFE coordinator:

  The HFE coordinator located in architect engineering (A/E) group coordinates with designers in operation group and nuclear system supply system (NSSS) design group for the resolution of human engineering discrepancies (HEDs) and HFE design team meeting (HDTM) action items.

  The HFE coordinator interacts with the organizations in HFE design team in order to ensure that their activities are effectively integrated with overall HFE design activities.

- Architect engineering group

  The A/E group is responsible for the work related to the balance of plant. The A/E group engineering disciplines include: balance of plant (BOP) system engineer, architect engineer, computer system engineer, reliability/availability engineer, BOP I&C engineer, system safety engineer, and, HF engineer.

- Operating group

  The operating group is responsible for plant operations. The operating group focuses on four areas: procedure, plant operations, personnel training, and maintainability/inspect-ability.

- NSSS design group

The NSSS design group is responsible for the work related to nuclear supply support system. NSSS design group has four sub-groups: NSSS engineering, NSSS I&C engineering, nuclear engineering and system safety engineering.

- HF engineer

  HF engineers are responsible for reviewing HSI design and design documents, as well as providing comments based on individual fields of expertise. HF engineers also participate in design review meetings related to key developments.

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Figure 1. APR1400 HFE Design Team Organization

2.3 HFE Organizational Composition

The HFE design team is a multi-disciplinary team comprised of personnel from several organizations. The design team is responsible for review of HSI design and design documents, as well as providing comments based on their fields of expertise. The team participates in design review meetings related to HSI development.

Figure 1 shows the HFE design team organizations. The HFE coordinator in A/E group takes a leading role for the implementation of HFE design program. The A/E group interfaces with operating group and NSSS design group.

Figure 1 shows the individuals in three different engineering groups – architect engineering group, operating group, and, NSSS design group- such as nuclear engineering, architect engineering, pre–startup operations, computer system engineering and probabilistic safety analysis, which are involved in design or review the HSI design based on their expertise.

2.4 HFE Organizational Staffing

The HFE team staffing, including minimum qualifications and job descriptions of team personnel, related organizational staffing for the HFE design team for the APR 1400 will be documented in Section 4.0 of Project Procedure Manual. (Reference 4)

Description of minimum qualifications, contributions of qualified staff and implementation to the HFE design is referenced from Human Factor Engineering Program Review Model.
In addition, qualifications and responsibilities are applicable throughout the elements of the HFE program, and for brevity these minimum qualifications will not be repeated throughout the HFE program.

The HFE design team compositions minimum qualifications are as follows,

- Project manager
    - Bachelor's degree
    - 10 years of experience in nuclear power plant design or operations
    - Seven years of management experience
- Technical project manager

- Bachelor's degree
- Five years of experience in nuclear power plant design or operations
- Three years of management experience

- HFE coordinator

  - Bachelor's degree in HFE engineering, psychology, or related science
  - Five years of experience in nuclear power plant design or operations
  - Four years of cumulative experience related to the human factors aspects of human computer interfaces. Qualifying experience will include at least the following activities within the context of large-scale, HSI systems (e.g., process control): design, development, and test and evaluation
  - Four years of cumulative experience related to the human factors aspects of workplace design. Qualifying experience should include at least two of the following activities: design, development, and test and evaluation

- Operating design coordinator

  - Bachelor's degree
  - Five years of experience in nuclear power plant design or operations
  - Three years of nuclear plant operating experience

- NSSS design coordinator

  - Bachelor's degree
  - Five years of experience in nuclear power plant design or operations
  - Three years of NSSS experience

Architect Engineering Group

- Systems engineer

  - Experience in BOP systems
  - Bachelor of Science degree
  - Four years of cumulative experience in at least three of the following areas of systems engineering; design, development, integration, operation, and test and evaluation

- Architect engineer

  - Bachelor of science degree:
  - Four years of experience in design of power plant control rooms

- I&C engineer

  - Experience in BOP systems
  - Bachelor of Science degree
  - Four years of experience in designing hardware and software aspects of process control systems
  - Experience in at least one of the following areas of I&C engineering: design, power plant operations, and test and evaluation
  - Familiarity with the theory and practice of software quality assurance and control

- Computer system engineer

  - Bachelor's degree in electrical engineering or computer science, or graduate degree in other engineering discipline (e.g., mechanical engineering or chemical engineering)
  - Four years of experience in the design of digital computer systems and real-time systems applications
  - Familiarity with the theory and practice of software quality assurance and control

- Systems safety engineer

  - Bachelor of science degree
  - Four years of experience in system safety engineering

- Reliability/Availability engineer

  - Bachelor's degree
  - Four years of cumulative experience in at least two of the following areas of power plant reliability engineering activity: design, development, integration, and test and evaluation
  - Knowledge of computer-based, human-interface systems

- Human factors engineer

- Bachelor's degree in HFE, engineering psychology, or related science
- Four years of cumulative experience related to the human factors aspects of human computer interfaces. Qualifying experience should include at least the following activities within the context of large-scale, human-machine systems (e.g., process control): design, development, and test and evaluation
- Four years of cumulative experience related to the human factors aspects of workplace design. Qualifying experience will include at least two of the following: design, development, and test and evaluation

Operating Group

- Plant operations expert
  - Has or has held a senior reactor operator license
  - Two years of experience in relevant nuclear power plant operations
- Plant procedure development
  - Bachelor's degree
  - Four years of experience in developing procedures for nuclear power plants
- Personnel training
  - Bachelor's degree
  - Four years of experience in developing personnel training programs for power plants
  - Experience in applying the systems approach to training
- Maintainability/Inspect-ability engineer
  - Bachelor in science degree
  - Four years of cumulative experience in at least two of the following areas of power plant maintainability and inspect-ability engineering activity: design, development, integration, and test and evaluation
  - experience in analyzing and resolving plant system and/or equipment-related maintenance problems

NSSS Design Group

- System engineer

  - Experience in NSSS system fields.
  - Bachelor of Science degree
  - Four years of cumulative experience covering in at least three of the following areas of systems engineering; design, development, integration, operation, and test and evaluation

- Nuclear engineer

  - Experience in NSSS system fields.
  - Bachelor of Science degree
  - Four years of nuclear design, development, test, or operations experience

- I&C engineer

  - Bachelor of science degree
  - Four years of experience in designing hardware and software aspects of process control systems
  - Experience in at least one of the following areas of I&C engineering: design, power plant operations, and test and evaluation
  - Familiarity with the theory and practice of software quality assurance and control

- Systems safety engineer

  - Bachelor's degree in Science
  - 4 years of experience in system safety engineering

3.0 HFE Design Process And Procedures

The HFE processes and procedures are developed to ensure that general HFE principles and guidelines are successfully applied to the HSI design activities. The following items are addressed for effective management of the HFE design activities.

3.1 HFE program milestones, schedule and duration

HFE milestones identify evaluations of the HFE effort, with critical checkpoints related to the integrated plant in the sequence events shown. The schedule for HFE program tasks indicates relationships between HFE elements. The schedule of HFE program is shown in the Figure 2. The HFE program will be in effect at least from the start of the design cycle through the completion of initial plant startup test program.

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Figure 2. APR1400 Program Milestones

All Implementation Plans are planned for DCD docketing in the first year. Result Summary Reports for OER and FRA/FA are planned for the second years

3.2 HFE Process and Procedures

The HFE processes and procedures are described in this section 3.2.

3.2.1 General Process Procedures

The HFE design team executes the HFE process based on their responsibilities and the following:

- HFE activities are assigned to the responsible engineering group and each group assigns the activities to individual members. HFE team leader conducts the internal management of the team such as design review meetings and project scheduling and makes management decisions regarding HFE.
- HFE design decisions are made through the design reviews and the design review meetings of the HFE design team. The HFE design team has the authority and organizational placement to assure that the HSI design is implemented in accordance with the HFEPP and accepted industry practices.
- The design process for governing the internal management of the team and equipment design changes are described in the Project Procedure Manual.
- The design team review of HFE products are performed in accordance with APR1400 Project Procedure Manual

3.2.2 HSI Design Process

The overall HSI design process is identified in Figure 3 including the overall relationships among the HFE design activities. The design approach is seen to be consistent with HFE methodology described in NUREG-0711 and is as follows:

- The design process is iterative
- HFE analyses, OER, FRA/FA, TA, and IHAs, are provided to the designers for incorporation into the HSI design
- Design tests and evaluations are used extensively to develop the HSI design
- Design reviews and review meetings for each member in HFE design team are interdisciplinary used for further process
- Standard HSI design is validated

- Final HSI product will be validated (e.g., full scope simulator)

HFE design activities are assigned to the cognizant engineering group and each group assigns the activities to individual members. The HFE team leader governs the internal management of the team such as design review meetings and project scheduling, and makes management decisions regarding HFE.

3.3 Process Management Tools

Tools are provided to facilitate communication across design disciplines and organizations to enhance consistency and efficiency. A review and comment system and an issue tracking system (ITS) are two typical process management tools for the development of HSI. The review and comment system allows the designers and independent reviewers to make comments and opinions on HSI design and design documents. As HEDs are identified by the HFE program they will be entered into and tracked by the ITS. The ITS provides a means to track design issues identified during the process, as well as to review and comment on current design documents.

3.4 Integration of HFE and Other Plant Design Activities TS

Figure 3. HFE Design Process

The integration of design activities is based on the inputs from other plant design activities to the HFE program and the outputs from the HFE program to other plant design activities. Integration of HFE designs to other plant design activities is performed in accordance with KHNP Quality Assurance Program

Description for APR1400 Design Certification (Reference 5).

3.5 HFE Documentation

The scope of documentation includes HFE analysis plans and reports, HSI/MCR functional requirements, HSI/MCR design descriptions (or reports), HFE standard guidelines and bases, detail design specifications and drawings. Plans and result reports of HSI design tests and evaluations and that are-performed to ensure the acceptability of HSI design are documented. In addition the following elements of the HFE program are documented as described in this HFEPP and each supporting implementation plan for each element of the HFE program:

- HFEPP Implementation Plan
- OER Implementation Plan and Result Summary Report
- FRA&FA Implementation Plan and Result Summary Report
- TA Implementation Plan
- Staffing and Qualifications Implementation Plan,
- Treatment of IHAs Implementation Plan
- HSI design Implementation Plan
- HF V&V Implementation Plan
- Design Implementation Plan
- Human Performance Monitoring Implementation Plan

The review and comment system retains all documents described above and allows the designer and reviewer to access the design document.

3.6 Subcontractor HFE Efforts

HFE requirements are included in each subcontract for HFE support and the subcontractor’s compliance with HFE requirements is periodically verified through the quality assurance program. The process is described in the APR1400 Plant Procedures Manual and quality assurance plan.

4.0 TRACKING OF HFE ISSUES

An issue tracking system (ITS) is available to address HEDs that are known to the industries and identified throughout the life cycle of the HSI design including design resolution issues, development and evaluation. The tracking system enables the review, documentation and tracking of human factor issues through the different groups addressed during the design process through the first fuel loading.

The ITS receives input from the following sources: (1) operating experience review and (2) issues that were raised during the evaluation period such as HFE V&V. Only unresolved issues from these sources are entered into the database developed for the ITS. For each issue entered into the database, the actions taken to address the issue and the final resolution of the issue are documented. The HFE design team leader is responsible for the maintenance and documentation of the ITS. For each issue entered into the database, a cognizant-engineer is assigned to take the responsibility for the resolution of the issue. The logging, tracking, and resolution process of ITS is shown in Figure 4.

4.1 Availability

An ITS for the HSI development is available to address human factors issues formally raised in the life cycle of the HSI. The issues both known to the industry and identified throughout the HSI development will be successfully identified, addressed, and resolved. A computerized database is used for the effective manipulation and resolution tracking of the HFE issues.

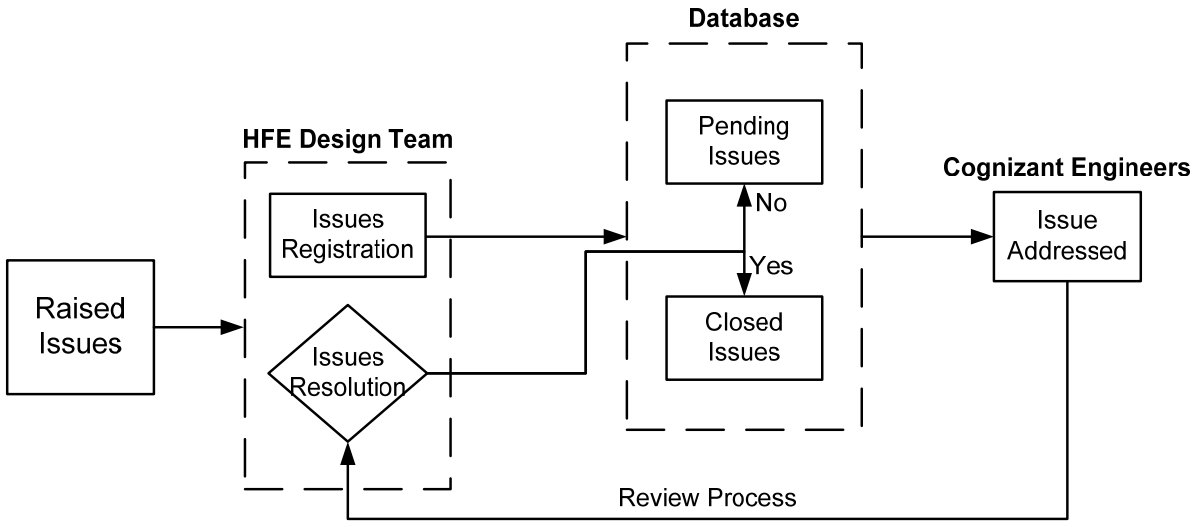

Figure 4. Issue Tracking System

4.2 Method

4.2.1 Access to Issue Tracking System

Sources from the raised issue (see Figure 4) include issues from HSI test and evaluations as well as issues selected from HSI design process. While access to the design review notice (DRN) is open to all of the HFE designers and reviewers whom participated in design process; however, access to the ITS is, limited to a few authorized personnel chosen by HFE design team so that the ITS database is not modified without formal authorization of the HFE design team.

4.2.2 Issue Entry

The entries to the ITS database include an entry number identified for the issue, a calendar-referenced date for issue entry and a description of the issue. The issue is formally evaluated by the HFE design team who is entered into ITS database.

4.2.3 Issue Resolution

The resolution of ITS entries include identification of the cognizant HFE and engineering group responsible for the resolution of the issue, classification of the issue, description of the resolution and related documents/drawings, identification of the additional evaluation and a calendar-referenced commitment date for its resolution. Acceptance criteria, that may be used to accept resolution, is also included in the ITS.

4.2.4 Issue Closeout

HFE issues addressed in ITS are closed if they are properly incorporated into the related HSI documents and drawings, and signed by the HFE design team manager. An ITS may also be closed when the issue does not require further tracked.

4.3 Documentation

Each issue that meets or exceeds the threshold established by the design team should be entered into the ITS soon after identification. The disposition if issues and action to be taken on resolution should be included in the ITS.

4.4 Responsibility

When an issue is identified and entered into ITS, a cognizant engineer may be assigned for resolution and implementation if necessary. The HFE design team approves the official entry, resolution, and closeout of ITS issues.

5.0 Technical Program

5.1 Design Process Elements

The development of implementation plans, analyses, and evaluations for the following HFE elements are identified and described in Figure 3:

- Operating Experience Review
- Functional Requirements Analysis And Function Allocation
- Task Analysis
- Staffing And Qualifications
- Treatment of Important Human Actions
- HSI Design
- Human Factors Verification and Validation
- Design Implementation
- Human Performance Monitoring

The HFE standards and specifications are source of HFE requirements which are identified and described in the NUREG 0711, Revision 3.

Evaluations and analyses of using simulator and reference plant operations may also be used to provide inputs in determining the adequacy of the HSI resources design. Testing and evaluation of HSI designs are conducted throughout the HSI development process.

5.2 Element Structure

In the Human Factor Engineering Program Review Model, each element is divided into the following four sections: background, objective, applicant submittals, and review criteria. A brief explanation of the rationale and purpose of the review is provided in the background. The review objective of the element is defined in the objective, and materials to be provided for NRC review are listed in applicant submittals. Acceptance criteria for design process products and the final design review are contained in the review criteria.

This HFEPP adopts the overall framework from Human Factor Engineering Program Review Model and divides each HFE element into three sections: Goals, Requirements, and Criteria; which map to Objective, Applicant Submittals, and Review Criteria, respectively. A summary of each of the HFE program's implementation plan is included in the appendices.

5.3 Goals

The goal statement expresses objectives of the program process, rather than objectives of the product from the process, for each HFE element. The goal describes the results to be achieved through the HFE element program process.

Goals are clear and achievable.

5.4 Requirements

The requirement is a set of HFE design activities to achieve the goal. Requirements are developed based on consideration of specific, applicable standards and regulations as well as practical need and objective acceptance criteria. Requirements that are not operated in this fashion are not used.

5.5 Criteria

The criteria specify the basis to satisfy the requirements. A criterion should be practical and objective and be a pass/fail test that can be applied with a minimum of subjectivity and inter-rater variability. Criterion can be either qualitative or quantitative, and define sufficiency. Though the criteria are usually more specific than the requirement, and are equally specific in some cases, they do not serve to detail the requirements. Rather, where further evaluation of the functional effectiveness of an element is desired, attention should be turned to evaluation of the design product, to see if problems (e.g., unsuitability) have resulted in the HSI design.

6.0 References

1. NRC, NUREG-0711, Rev. 3, Human Factor Engineering Program Review Model, 2012.
2. U.S Code of Federal Regulations, Part 50, “Conditions of Licenses” Title 10, “Energy,” Washington, DC: U.S. Government Printing Office.
3. KHNP, APR1400-E-J-NR-12009-P, “Basic Human-System Interface Platform,” September 2013.
4. KHNP, “Project Procedure Manual,” September 2013.
5. KHNP, APR1400-K-Q-TR-11005-N, “KHNP Quality Assurance Program Description for APR1400 Design Certification,” 2011
6. KHNP, APR1400-E-J-NR-12003-P, “Operating Experience Review Implementation Plan,”, September 2013.
7. KHNP, APR1400-E-J-NR-12001-P, “Function Requirements Analysis and Function Allocation Implementation Plan,” September 2013.
8. KHNP, APR1400-E-J-NR-12007-P, “Task Analysis Implementation Plan,” September 2013.
9. KHNP, APR1400-K-J-NR-13001-P, “Staffing & Qualifications Implementation Plan,” September 2013.
10. KHNP, APR1400-E-J-NR-13001-P, “Treatment of Important Human Actions Implementation Plan,” September 2013.
11. KHNP, APR1400-E-J-NR-12008-P, “ Human System Interface Implementation Plan,” September 2013.
12. KHNP, APR1400-E-J-NR-12010-P, “Human Factors Verification and Validation Implementation Plan,” September 2013.
13. KHNP, APR1400-K-J-NR-13002-P, “Design Implementation Plan.” September 2013.
14. KHNP, APR1400-K-J-NR-13003-P, “Human Performance Monitoring Implementation Plan,” September 2013.

Appendix 1. Operating Experience Review

1.0 Goals

The goal of the OER process is to ensure that HFE-related problems and issues encountered in previous plants similar to the APR1400 design are successfully identified and analyzed so they are avoided in the HSI development, or to ensure that they are retained in the case of positive features.

2.0 Requirements

Activity Specification: Activities in the OER process shall be specified to ensure applicable and important operating experiences as well as industry experiences are provided in a timely manner to the designers of HSI.

References and Studies: A list of industry and regulatory references is developed and evaluated as input to the design.

Formal Treatment of Safety Issues: Applicable generic safety issues (GSIs) and unresolved safety issues (USIs) shall be evaluated to ensure they are applied to the design as necessary.

3.0 Criteria

Activity Specification: OER activities to be performed are identified and provided in an official project document. Audit of transmittal records verify that the planned activities have been actively implemented.

References and Studies: A report summarizing the contents of the industry and regulatory references, that are potentially relevant to the design, is provided in an official project document. The report includes the design issues applicable to those designing HSIs.

Formal Treatment of Safety Issues: Selective audit of the appropriate records indicates that GSIs and USIs have been evaluated, and are being tracked and dis-positioned as required.

Details of Operating Experience Review implementation plan are described in the Operating Experience Review Implementation Plan (Reference 6).

Appendix 2. Functional Requirements Analysis and Function Allocation

1.0 Goals

The goal of FRA/FA process is to ensure that APR1400's safety functional requirements are defined, and that the function allocations take advantage of human strengths and avoid allocating functions that would be negatively affected by human limitations.

2.0 Requirements

Approach: FRA/FA shall be performed using a structured, well-documented process reflecting HFE principles.

Critical Safety Functions: Critical safety functions (e.g., reactivity control) shall be defined based on the reference plant. These include functions required to prevent or mitigate the consequences of postulated accidents that cause undue risk to the health and safety of the public. For each safety function, the set of plant processes (e.g., plant system configurations or success paths) that are responsible for or capable of carrying out the function shall be also defined.

Life Span: The functional requirements analysis shall be kept current over the life cycle of design development and held until decommissioning so that it is used for design when modifications are considered.

HFE Evaluation of Function Allocations: The TA, Availability Verification, Suitability Verification, and Design Validation activities shall be sources of feedback on allocation issues. The results of analysis shall support the adequate configurations of personnel and system-performed control functions. Analyses shall confirm that the personnel are capable of properly performing tasks allocated to them.

OER: Appropriate OER issues shall be considered during the FRA/FA.

Documentation: The technical basis on which the functional allocation was performed should be documented. The following documents shall be provided to regulatory staff for review: implementation plan and analysis result reports.

3.0 Criteria

Critical Safety Functions: A description of the critical safety functions and the design basis for their

implementation is documented sufficiently to permit understanding of the operator's safety-related role: (a) as allocated as an integral part of the overall system design, (b) as incorporated by the design basis evaluations performed to establish the adequacy of the plant critical safety functions, and (c) as evaluated by TA and HFE V&V activities.

Process Description: A summary description is provided for each plant process.

Unchanged Processes: Processes that were identified as unchanged after comparing to those of the System 80+ and the Basic HSI Platform, those for which the control function allocation between personnel and system elements is unchanged. This latter group is described as having modified function allocations. The level of automation is briefly described (e.g., fully automatic, fully manual, automatic with manual backup) for each unchanged function with unchanged allocation.

Modified Function Allocation: Unchanged processes that have modified function allocations are analyzed in terms of resulting human performance requirements based on the expected user population. A rationale for the resulting allocation is provided.

Modified Processes: Modified processes are analyzed in terms of resulting human performance requirements. A rationale for the resulting allocation is provided. This analysis reflects the following considerations at the stage of detail design:

(a) Sensitivity, precision, time, and safety requirements; and
(b) Required reliability.

Details of Functional Requirements Analysis and Function Allocation are described in the Function Requirements Analysis and Function Allocation Implementation Plan (Reference 7).

Appendix 3. Task Analysis

1.0 Goals

The goal of this process (i.e., TA process) is to ensure that the behavioral requirements of the tasks to be performed are successfully identified and analyzed. Task Analysis should identify the human operator's detailed input and output requirements for a representative set of control room tasks, remote shutdown tasks for normal, abnormal, and emergency operations, as well as any local control tasks required for emergency operations.

2.0 Requirements

Task Inventory: The TA reports shall describe analyses which include all emergency operating procedure tasks and additional selection of control room normal and abnormal operating procedures.

Methodology: The TA method shall provide a criterion, basis, and evaluation of operator loading.

Staffing Assumptions: The staffing assumptions shall be incorporated in the TA.

Design Basis: TA shall provide a basis for making design decisions such as specifying the requirements for the displays, data processing, and controls needed to carry out tasks.

Human Performance Basis: TA shall ensure that human performance requirements do not exceed human capabilities.

Procedure, Staffing, and Training Basis: TA shall provide basic information for developing procedures and identifying requirements for staffing and training.

Critical Tasks: Human tasks identified as making a significant contribution to risk or needed for safe plant operations by the DCD's Chapter 19 PRA, Chapter 15 credited manual actions and Chapter 7 defense-in-depth analysis shall be addressed in the TA process.

Documentation: TA implementation plan and TA results report are provided to HFE staff for review. The TA report shall receive formal interdisciplinary review from the HFE design team.

3.0 Criteria

Task Inventory: The TA reports describe analyses which include all emergency operating procedure tasks and additional selection of control room normal and abnormal operating procedures. The TA reports also describe the basis for identifying the set of evaluated tasks as representative of all tasks required by anticipated operating occurrences.

Methodology: The TA method provides a criterion, basis, and evaluation of operator loading.

Staffing Assumptions: The staffing assumptions are incorporated in the TA and described in the TA reports. Operator loading is evaluated in the TA reports.

Critical Tasks: Critical tasks are identified by PRA, are addressed in TA and are documented.

A detail of Task Analysis is described in the Task Analysis Implementation Plan (Reference 8).

Appendix 4. Staffing And Qualifications

1.0 Goals

The objective of the staffing analysis is to evaluate the adequacy of initial staffing levels, i.e., the number and qualifications of operating personnel in the MCR.

2.0 Requirements

Final plant staffing is the utility responsibility. The utility addresses the staffing levels and qualifications of plant personnel, including operations, maintenance, engineering, instrumentation and control technicians, radiological protection technicians, security, and chemists. Thus responsibility for the staffing element belongs to the utility, rather than the HSI designer.

The analysis of staffing by the utility requires designer's input about the nature of the plant and its control room. The utility, however, performs its own analyses based on its preferences and experience with previous nuclear power plant operation. Therefore, when necessary, HFE design team interacts with the organization responsible for staffing in order to ensure that the HFE design activities performed by the HFE design team are effectively integrated into the decision process on the plant staffing levels. Those HFE design activities include: operating experience review, functional requirements analysis and function allocation, task analysis, human reliability analysis, HSI design and integration, and human factors verification and validation (HF V&V).

The staffing assumption used in the development of the HSI is developed based on the following information and references: (a) operating experiences with predecessor plants, (b) operating experience review documents, (c) utility requirements and human factors guidelines relevant to HSI design, and (d) government regulations. The initial staffing levels are iteratively evaluated for acceptability, and modified as the HSI design and evaluation proceeds.

Details of Staffing and Qualifications are described in the Staffing and Qualifications Implementation Plan (Reference 9).

Appendix 5. Treatment Of Important Human Actions

1.0 Goals

In the HFE design, results of Treatment of Important Human Actions are used to identify human actions that are important to plant risk i.e., “critical tasks.” Since Treatment of Important Human Actions is performed as a part of the DCD Chapter 7, 15 and 19 which is not the responsibility of HFE design team but of other in the organization. The HFE design team therefore interacts with the organization responsible for the process in order to ensure that the Treatment of Important Human Actions (TIHA) are effectively integrated with other HFE design activities for HSI development. The integration activities include the following:

- HFE design team provides the PRA and design team with the necessary results of HSI design for the integration into the process of TIHA
- PRA and design team provides HFE design team with critical tasks and human error mechanism resulting from TIHA
- HFE design team addresses the critical tasks, human error mechanisms in the design of HSI in order to minimize the likelihood of personnel error and to provide for error detection and recovery capability.

2.0 Requirements

The integration activities with regard to other HFE elements include the following:

- Task Analysis – The critical tasks and performance requirements resulting from TIHA are used as input to TA.
- HSI Design – Results of HSI design are used to confirm and/or refine TIHA assumptions. Tasks identified in the TIHA that affect plant safety and reliability are re-examined by TA. HSI design identifies changes to the operator task or plant operating environment to minimize the likelihood of operator error and provide for error detection and recovery capability.
- Human Factors Verification and Validation – TIHA performance assumptions-e.g., actions to be performed and time within which they are completed are validated as part of HF V&V.

While HFE element 7, “procedure development” and HFE element 8, “training program development” is an important contributor to human reliability, they are not explicitly addressed in the integration with TIHA because they are the utility’s responsibility.

Details of TIHA are described in the TIHA Implementation Plan (Reference 10).

Appendix 6. Human-System Interface Design

1.0 Goals

The goal of this plan is to implement necessary and sufficient system functions and operator tasks to the detailed HSIs, and successfully apply HFE principles into the HSI design to ensure that the final HSIs reflect the state-of-the-art in HFE.

2.0 Requirements

HSI Style Guide: An HSI Style Guide, a collection of pertinent HFE principles to be applied to the HSI design, shall be collected and organized by the HFE design team. The Style Guide shall include coverage of the following topics:

- alarm systems
- visual and auditory indications
- displays and controls
- workstation layout and organization
- workspace layout and environment
- labeling and locator aids
- large display panel
- computer-based procedure
- safety console
- communication,
- anthropometry
- maintainability

Documentation: The design for the MCR and RSR indications and controls (i.e., screen design, panel layout, etc.) shall be detailed through a systematic process incorporating HSI Style Guide, and documentation for this process shall include the results of design reviews. Design documents shall receive a documented interdisciplinary review, including participation of HFE specialists and operations experts. Other documentation for the design of HSI shall be identified in the HSI Implementation Plan (Reference 11).

3.0 Criteria

HSI Style Guide

- Provision - The HSI Style Guide is assembled by the HFE design team. Original guideline therein is developed by HFE specialists.
- Applicability - The HSI Style Guide is applicable to the HSIs in all engineering operations and control centers, including the MCR, the RSR, local control stations associated with IHA.
- Basis - A technical basis for the HSI Style Guide is provided. This includes the scientific and/or technical references, studies, or rationale that supports the HFE guideline provided.
- Contents - The HSI Style Guide includes coverage of the following topics:

  - alarm systems,
  - visual and auditory indications,
  - displays and controls,
  - workstation layout and organization,
  - workspace layout and environment,
  - labeling and locator aids,
  - large display panel
  - computer-based procedure
  - safety console,
  - communications,
  - anthropometry, and
  - Maintainability

- Promulgation - The HSI Style Guide is verified by document distribution forms to have been formally promulgated by the responsible management structure to the HFE design team for implementation in the HSI design.

HFE Design Assumptions

- Workspace Conditions - The HSI design and the corresponding Style Guide accommodate working conditions imposed within applicable workspaces as assumed in the analysis of safety-related design basis events.

- Staffing Assumptions - Staffing assumptions embodied in the HSI design or Style Guide do not preclude the ability of the design to satisfy the requirements for minimum staffing.

HSI Design

- Documentation - The HSI designs are documented in detail within official program documents.
- Review - The HSI design documents shall receive a documented interdisciplinary review, including participation of HFE specialists and operations experts.
- Mock-up Development - Corresponding mockups are verified to have been constructed for the HSI design.

Appendix 7. Human Factors Verification And Validation

1.0 Goals

The goal of this process for Human Factors V&V (HF V&V) is to ensure the following:

- The HFE design provides all necessary displays and controls, including alarms, to support plant personnel tasks (i.e., availability verifications);
- The HFE design conforms to HFE principles, guidelines, and standards (i.e., suitability verification); and
- The HFE design is effectively operated by personnel within all performance requirements (integrated design validation).

2.0 Requirements

V&V Scope: The general scope of human factors V&V shall include the following:

- Hardware-based HSI,
- Software-based HSI, and
- Overall work environment design.

V&V Activities: The human factors V&V shall include the following activities, as they are ordered:

- Availability Verification
- Suitability Verification
- Integrated System Validation

V&V Facilities: A dynamic mockup or simulator of the HSI shall be used for the final validation to ensure adequate evaluation of the integrated system.

Databases: An I&C inventory database derived from design specification shall be provided whose data entries include device type, units, and required range, scale precision, and accuracy. A task inventory shall be available, which is derived from Task Analysis.

Integrated System Validation: Formal and final design validation exercises for the MCR, the remote shutdown panel, and any local control station required for emergency operations shall be observed and

documented by a team including HFE specialists and operations experts. Subjective feedback from the tested operators shall be a formal component of the evaluation.

ITS Closeout: All items in HSI ITS, including safety significant HEDs resulting from the V&V program shall be closed.

Documentation: The following documents shall be provided with regulatory staff for review: human factors V&V implementation plan and results reports.

3.0 Criteria

Databases: A I&C inventory database derived from design specifications, and a task inventory derived from Task Analysis are provided.

Task Support Verification

HFE Design Verification

Integrated System Validation: Validations for the MCR, the remote shutdown panel, and local control stations required for emergency operations are performed and documented. HFE specialists and operations experts are involved in the validation activities and documentation. Subjective feedback from the tested operators becomes a formal component of the evaluation.
ITS Closeout: There are no open issues in HSI ITS.

Details of Human Factors Verification and Validation are described in the Human Factors Verification and Validation Implementation Plan (Reference 12).

Appendix 8. Design Implementation

1.0 Goals

The purpose of the design implementation is to ensure the following:

- The utility's implementation of plant changes considers the effect on personnel performance and provides the necessary support to ensure safe operations.
- The utility's as-built design conforms to the verified and validated design that resulted from the HFE design process.

2.0 Requirements

This process addresses the implementation of the HFE aspects of the design for both new plants and plant modifications. For a new plant, the implementation phase is well defined and carefully monitored by start-up procedures and testing.

Plant modifications effect personnel in various ways. Change to systems and components affect the role of personnel and the way their tasks are performed. Often such plant modifications lead to changes in HSIs, procedures, and training as well. Modifications also address the HFE aspects of the plant even though the plant's systems and components are not changed.

For both new and modified designs, it is important to determine that the design that is implemented (i.e., the "as-built" design) accurately reflects the verified and validated design.

Details of Design Implementation are described in the Design Implementation Plan (Reference 13).

Appendix 9. Human Performance Monitoring

1.0 Goals

The purpose of the human performance monitoring is to assure that the utility has prepared a human performance monitoring strategy for ensuring that no significant safety degradation occurs because of any change made in the plant, and to provide adequate assurance that the conclusions that have been drawn from the elevations remain valid over time. The utility incorporates this monitoring strategy into their problem identification and corrective action program.

2.0 Requirements

A human performance monitoring strategy will help to ensure that the confidence developed by the completion of the integrated system validation is maintained over time. There is no intent to periodically repeat the full integrated system validation; however, there should be sufficient evidence to provide reasonable confidence that plant personnel have maintained the skills necessary to accomplish the assumed action.

Details of Human Performance Monitoring are described in the Human Performance Monitoring Implementation Plan (Reference 14).