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Subject: Submittal of Licensing Topical Report NEDO-33274, "ESBWR Human Factors Engineering Procedures Development Implementation Plan," Revision 4

The purpose of this letter is to submit Revision 4 of the GE Hitachi Nuclear Energy (GEH) Licensing Topical Report NEDO-33274, "ESBWR Human Factors Engineering Procedures Development Implementation Plan" in accordance with the corresponding HFE program element identified in Reference 1.

Enclosure 1 contains Licensing Topical Report NEDO-33274, "ESBWR Human Factors Engineering Procedures Development Implementation Plan," Revision 4.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

Richard E, Kingston
Vice President, ESBWR Licensing

Reference:

1. NUREG-0711, Revision 2, *Human Factors Engineering Program Review Model*, issued February 2004

Enclosures:

1. MFN 09-483 - Licensing Topical Report NEDO-33274, " ESBWR Human Factors Engineering Procedures Development Implementation Plan", Revision 4

cc: AE Cubbage USNRC (with enclosures)
JG Head GEH/Wilmington (w/o enclosures)
DH Hinds GEH/Wilmington (w/o enclosures)
eDRF Section 0000-0052-9516 R5

MFN 09-483

Enclosure 1

Licensing Topical Report NEDO-33274

ESBWR Human Factors Engineering Procedures Development Implementation Plan

Revision 4

GE Hitachi Nuclear Energy

NEDO-33274

Revision 4

Class I

DRF 0000-0052-9516

July 2009

Licensing Topical Report

ESBWR HUMAN FACTORS ENGINEERING PROCEDURES DEVELOPMENT IMPLEMENTATION PLAN

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IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

Please Read Carefully

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SUMMARY OF CHANGES (NEDO 33274, REV 4 VS. REV 3)

Location	Change	Comment
2.1.1 and 2.1.2	Removed or updated revision levels and titles of references as appropriate.	N/A
5.1 Third bulleted item	Revised third bulleted item to specify plant procedures derived from ESBWR SAGs.	As a result of RAI 14.3-453

1. OVERVIEW

Procedures are essential to plant safety because they support and guide personnel interactions with plant systems and with responses to plant-related events. Procedures used to operate the plant include:

- Normal Operating Procedures
  - General Plant Procedures (GPPs)
  - System Operating Procedures (SOPs)
  - Calibration, Inspection, and Testing Procedures
  - Maintenance and Modification Procedures
  - Radiation Control Procedures
- Abnormal Operating Procedures
  - Alarm Response Procedures (ARPs)
  - Abnormal Operating Procedures (AOPs)
- Accident Management Guidelines
  - Emergency Operating Procedures (EOPs)
  - Severe Accident Management Guidelines (SAMGs)
- Administrative Procedures

Procedures are an integral part of the Human-System Interface (HSI) development for the ESBWR and are controlled documents. The Combined Operating License (COL) owner's group maintains the controlled versions of the procedures throughout the plant operating life.

Human factor improvements in plant procedures help prevent or mitigate potential human error. Procedure development supports improvements in the Human System Interface (HSI), plant hardware (e.g. in ergonomic layout), training, and other areas. The approach to reducing human error is to simplify the information reaching the operating personnel and to enable control room personnel to have a clear understanding of the plant status at any time. Through the HSI and procedures, operating personnel control the plant under normal, abnormal, and emergency conditions. As shown in Figure 1, the ESBWR is designed using a systematic process for integrating human factor engineering principles into the system design as well as the procedures that are used to operate the plant. Figure 1 also demonstrates how the Human Factors Engineering (HFE) procedure development plan is an integral part of the Man-Machine Interface System (MMIS) and HSI development for the ESBWR.

Procedures specific to the ESBWR design and operating philosophy are developed or modified to reflect the characteristics and functions of the ESBWR plant improvements. As the details of the HSI are finalized, the Verification and Validation (V&V) processes shown in Figure 1 support evaluation of the HSI and the procedures. To verify complete integration and consistency in the procedures, human factors principles are applied to both the hardware and procedure development aspects of the HSI. Tools, such as dynamic simulators that represent the control room HSI, the plant response to selected events, and operator actions, are used to validate the integrated design.

In the ESBWR, opportunities for human factor improvements in the way procedures are used are enhanced through both the passive design and the use of digital computer systems. Digital controls, computers, and monitoring systems have advanced capabilities for monitoring progress in implementing procedure steps based on the controlling cue for a procedure, equipment status, and monitored variables. For example, computers can call up procedures for routine testing based on an established schedule. Additionally, computers can present the procedures that operators need to use for checking plant conditions and taking recovery actions if specific variables exceed preset conditions. Such Computer-Based Procedures (CBPs) are carefully designed, verified, and installed to ensure that residual faults and design errors do not mask or prevent any required safety action. Hard copy procedures are developed and maintained for use in the event that the CBP system is lost. CBP and hard copy procedures are developed and written in a coordinated manner to facilitate the smooth transition between the two presentation mediums.

1.1 PURPOSE

The purpose of this plan is to provide the processes, methods, and criteria for generating procedures and verifying that the integrated plant procedures are consistent with accepted HFE practices and principles. The HFE design team ensures that human factor principles are incorporated into the development and updating of procedures using applicable requirements from NUREG-0800 Section 13.5 and NUREG-0711 Rev 2.

The procedure development process shows how the HFE design team uses the outputs from operational analysis and the HSI design to develop initial ESBWR procedures. These procedures are inputs to other steps in the overall HFE process (as shown in Figure 1) where enhancements are identified resulting in revisions to the procedures. Such improvements reduce the potential for human error and produce procedures that are compatible with the ESBWR Emergency Procedure Guidelines (EPGs), design, and the operating philosophy for the HSI.

At the end of the overall MMIS HFE implementation process, the responsible engineers and procedure writers provide approved procedures ready for verification. The MMIS implementation plan includes V&V steps that provide assurance that all functions and tasks assigned to be human actions or human backup are included in the integrated procedures. The MMIS implementation process also includes validation of the procedures using mockups, part-task simulators, and full-scope simulator facilities to simulate operations, transients, and accidents. The HFE design team provides evidence of the acceptable incorporation of HFE principles.

1.2 SCOPE

The scope of this implementation plan is to describe the process for ESBWR plant operating procedure development stressing the interface with other HFE tasks. The procedures include normal, abnormal, and emergency operating procedures used by the control room operators to manage plant operation and safety.

Normal, abnormal, and emergency operating procedures that match the HSI design are provided to the fleet-wide owner's group at the end of the overall process. The MMIS design implementation includes steps that verify all functions and tasks assigned to human action or human backup (as a result of operational analysis) are included in the normal, abnormal, or emergency operating procedures. This includes procedures used to accomplish normal operation, maintenance, radiation control, calibration, inspection and testing, and emergency actions performed at the operator interface in the Main Control Room (MCR), the Remote Shutdown Systems (RSSs), and risk-significant Local Control Stations (LCSs). The MMIS implementation process also includes validation of plant procedures using mockups, walk throughs, part-task and full-scope simulator facilities.

Procedure development evaluation includes verification and validation covering a full range of risk-significant plant operating modes, including startup, normal operations, abnormal operations, transient conditions, low power, and shutdown conditions. Additionally, the verification and validation process assures the efficacy of hard copy backup procedures through their use and through transitioning between them and CBPs. The HFE evaluation also addresses risk-significant personnel tasks during periods of maintenance of plant systems and equipment including the HSI equipment. As the maintenance, radiation control, and calibration, inspection, and testing procedures become available, they are validated through mockups, walk throughs, part-task and full-scope simulator facilities.

The details of the scope are described as follows:

- Procedure development process incorporates human tasks through the following:
  - Identification of procedure tasks from the areas of normal, abnormal, and emergency operations.
  - Evaluation of procedures for a full range of plant operating modes, including startup, low-power, normal operations, shutdown, abnormal, transient, and emergency operating conditions.
  - Inclusion of Human Actions (HAs) that have been found to affect plant risk by means of Human Reliability Analysis (HRA)/Probabilistic Risk Assessment (PRA) importance in the appropriate procedures.
  - The generation of procedures that are linked to controls in the HSI.
- The procedure development process addresses issues such as the following:
  - Procedure content and layout adheres to the procedure writer's guides.
  - Procedures exist to address the safety-related cues from the HSI.
  - Parameter readings for variables named in procedures match the scales and units in the HSI (as presented at the MCR, RSSs, and risk-significant LCSs).

- System and component numbering and labeling in the procedure matches the numbering and labeling in the HSI and plant (e.g., it is easy to select the correct procedure and components).
- Procedures match assumptions used for HRA quantifications of the Human Error Probability (HEP).

The procedure development process receives inputs from the operational analysis process, which incorporates inputs from the HRA/PRA, Baseline Record Review (BRR), Operating Experience Review (OER), and Design Control Document (DCD). Additional procedure development input comes from the HSI design process, and as feedback from training development, V&V, and Human Performance Monitoring (HPM) processes. Outputs of the procedure development process support the training development process, the V&V process, as well as provide feedback to the HSI design process.

The validated procedures are called the Integrated Operating Procedures (IOPs). The IOPs within the scope of the HFE evaluation process include instructions for addressing normal, abnormal, and emergency conditions. Administrative procedures provide administrative control over activities for the initial test program and operation of the facility.

1.2.1 Normal Operating Procedures

Five types of normal operating procedures address conditions where operators control the plant when the plant systems are operating as expected. The five types of normal operating procedures are:

(1) General Plant Procedures (GPPs) - apply to startup, shutting down, shutdown, power operation and load changing, process monitoring, and fuel handling. Example procedures are shown in Table 1.

(2) System Operating Procedures (SOPs) - apply to energizing, filling, venting, draining, starting up, shutting down, changing modes of operation, and other instructions appropriate for operation of plant systems. Example ESBWR SOPs are shown in Table 2.

(3) Calibration, Inspection and Testing Procedures - apply to the process of demonstrating that systems and components are capable of satisfactory performance in the future. Some calibration, inspection, and tests are listed in the station's technical specifications and procedures are generated to support the performance of each required test. Example procedures are shown in Table 3.

(4) Maintenance and Modification Procedures - apply to repairing or replacing equipment or performing preventative maintenance designed to improve the reliability of the equipment. Example procedures are shown in Table 4.

(5) Radiation Control Procedures - apply to the monitoring and release of solids, liquids, and gasses, access controls, area radiation monitoring, and the program for keeping dose As Low As Reasonable Achievable (ALARA). Example procedures are shown in Table 5.

1.2.2 Abnormal Operating Procedures

Abnormal operating procedures address conditions during operation that involve an unplanned or undesired event or occurrence involving a Structure, System, or Component (SSC). These procedures provide steps to resolve the undesired alarm or event. For example, these procedures may call for the use of redundant plant systems and safety functions while the undesired event condition is being evaluated and resolved. Alarm response procedures (ARPs) are included under this general "abnormal" heading as they alert operators to system parameters that are out of their normal band. ARPs are not part of, nor are they structured like, the formal Abnormal Operating Procedures (AOPs) also presented here. The procedures are not individually listed in a table because the ARPs and AOPs are numerous and correspond to the number of alarms.

- Alarm Response Procedures (ARPs) - apply when operating variables depart from a normal range by providing instructions for restoring the variable. Each safety-related alarm has its own written response procedure, which typically contains:
  - Meaning of the alarm
  - Source of the signal and it's alarm set point
  - Actions that occur automatically
  - Initial operator action
  - Long-range operator actions

  The Alarm Response procedures comply with Section 4.5 of NUREG-0700 Rev 2 (plus errata).
- Abnormal Operating Procedures (AOPs) - apply when a function, system or component has degraded or failed necessitating that action be taken to restore the function, system, or component to normal operating conditions following a transient.

If application of the AOP is not successful in correcting the plant variable and a safety parameter is exceeded, EOPs apply.

1.2.3 Accident Management Guidelines

The EPGs and Severe Accident Guidelines (SAGs) function together as an integrated set of instructions. Each EPG guideline protects one of the principal barriers to radioactivity release through control of key plant parameters. The EPG contingencies form extensions to the top-level guidelines, providing more detailed instructions for controlling individual parameters under more degraded conditions. The SAGs extend the EPGs still further, addressing severe accident conditions.

(1) Emergency Operating Procedures (EOPs) - The EOPs are developed from ESBWR standard Emergency Procedure Guidelines (EPGs) that establish the engineering basis, strategies, and intent for managing plant transients. Table 6 provides a listing of BWR Owners Group contingencies and guidelines used in applying the EPGs to develop the specific EOPs. Any changes in the plant specific EOPs must conform to the EPGs and the EOP writer's guide.

(2) Severe Accident Management Guidelines (SAMGs) – The SAMGs are developed from ESBWR standard Severe Accident Guidelines (SAGs) that establish the engineering basis, strategies, and intent for managing plant accidents that are beyond the scope of the EOPs. Any changes in the plant specific SAMGs must conform to the SAGs and the EOP writer's guide.

The ESBWR EOPs and SAMGs comply with all applicable requirements EPG/SAG rev 2, NUREG-0899, and NUREG-737.

1.2.4 Administrative Procedures

Administrative procedures provide administrative control over activities for the initial test program and operation of the facility. The development of administrative control procedures shown in Table 7, and specific administrative procedures shown in Table 8, are not within the scope of the HFE review.

1.3 DEFINITIONS AND ACRONYMS

1.3.1 Definitions

Several terms are defined to provide a common basis for developing procedures referred to in this plan.

Abnormal Operating Procedure (AOP): Procedures that specify steps that operators take to restore an operating variable to its normal controlled value when it departs from its normal range or to restore normal operating conditions following a transient.

Accident Management Guidelines: A generic group of products that collectively provide technical strategies and guidance for implementation of accident management at BWR plants.

Accuracy: A qualitative assessment of correctness, or freedom from error. [IEEE610]

Alarm Response Procedure (ARP): Procedures that guide operator steps for responding to plant alarms that indicate that a measured or calculated plant variable exceeds a specified set point level.

Calibration, Inspection and Testing Procedure: Normal operating procedures that provide instructions for calibration, inspection and operational testing required to demonstrate that systems and components are able to perform satisfactorily in service.

Component: One of the parts that make up a system, some of which may be broken down into more components or units; it may be personnel (e.g., operator, user), procedures, materials, tools, equipment (hardware), facilities, and software. [IEEE610, MIL882B]

Computer-based procedure system: Systems that present procedures in computer-based rather than paper-based formats.

Consistency: The degree of uniformity, standardization, and freedom from contradiction among the documents or parts of a system or component. [IEEE610]

Correctness: The degree to which software or its components is free from faults and/or meets specified requirements and/or user needs. [IEEE610]

Emergency Procedure: A simplified description of the post event procedures (EOPs) that provide instructions for controlling events with the potential for a release of radioactive material.

Emergency Procedure Guideline (EPG): Guidelines that form the basis for engineering strategies and intent used to develop the EOPs.

Emergency Operating Procedure (EOP): Emergency condition procedures that direct actions necessary for the operators to mitigate the consequences of transients and accidents that cause plant parameters to exceed the predetermined symptom based thresholds developed in either the Emergency Procedure Guidelines or related Plant Specific Technical Guidelines.

Functional analysis: The examination of the functional goals of a system with respect to available manpower, technology, and other resources, to provide the basis for determining how the function may be assigned and executed.

General Plant Procedure (GPP): Normal operating procedures that provide instructions for the integrated operations of the plant, e.g., startup, shutting down, shutdown, power operation and load changing, process monitoring, and fuel handling.

Generic Technical Guideline (GTG): Guidelines prepared for a group of plants with similar design. The guidelines identify the equipment or systems to be operated and list the steps necessary to mitigate the consequences of transients and accidents and restore safety functions. The guidelines represent the translation of engineering data derived from transient and accident analyses into information presented in such a way that it can be used to write EOPs. [adapted from NUREG-899]

HFE Design Team: The HFE design team (design team) is a team of engineers, as defined in Reference 2.1.1 (4), Man-Machine Interface System And Human Factors Engineering Implementation Plan, responsible for the design of the HSI systems.

HFE Issue Tracking System (HFEITS): An electronic database used to document human factors engineering issues not resolved through the normal HFE process and human engineering discrepancies (HEDs) from the design verification and validation activities. Additionally, the database is used to document the problem resolutions.

Human Action (HA): A manual response to a cue involving one person to achieve one task or objective. Potentially risk-important actions affect equipment or physical systems. Single human actions can be represented as an event in a fault tree or branch point in an event tree.

Human Error Probability (HEP): A measure of the likelihood that plant personnel will fail to initiate the correct, required, or specified action or response in a given situation, or by commission performs the wrong action. [ASME PRA Std]

Human Reliability Analysis (HRA): A structured approach used to identify potential human failure events and to systematically estimate the probability of those errors using data, models, or expert judgment. [ASME PRA Std]

Human-System Interface (HSI): The organization of inputs and outputs used by personnel to interact with the plant, including the alarms, displays, controls, and job performance aids. Generically, this includes maintenance, test, and inspection interfaces as well.

Integrated Operating Procedure (IOP): Normal, abnormal, and emergency operating procedures in the form of instructions, charts, and figures in combinations of paper and computer-based forms that are validated through simulator testing.

Local Control Station (LCS): An operator interface related to nuclear power plant (NPP) process control that is not located in the main control room. This includes multifunction panels, as well as single-function LCSs such as controls (e.g., valves, switches, and breakers) and displays (e.g., meters) that are operated or consulted during normal, abnormal, or emergency operations.

Normal Operating Procedure: A simplified description of the pre-event procedures that include the GPPs, SOPs, calibration inspection and testing, maintenance and modifications, and radiation control procedures.

Operational analysis: An iterative process that describes plant, system, and component state changes as a series of tasks including supporting information requirements. This is accomplished through performance of system functional requirements analyses, allocation of functions, and task analyses. The analysis process determines what must be done, who does it (man, machine, or shared), and how it is to be done (controls, indications, supporting information, and so forth). Results of the analyses are design requirements for the HSI, procedures, and training.

Operating experience review: A systematic review, analysis and evaluation of operating experience that can apply to the development of the man machine interface design.

Pre-initiator event: Errors in human activities such as maintenance, calibration, inspection and testing conducted during normal operation that can lead to inoperable equipment without causing a transient. The important errors are those that defeat redundant or diverse systems required for safety and leave the system in an unrevealed fault state (e.g., type A latent human errors).

Post-initiator human failure event: Human failure events that represent the impact of human errors committed during actions performed in response to an accident initiator. [ASME PRA Std]

Risk: A measure derived from the probability of failure events occurring and the assessed severity of sequences containing the failure events (including human and software errors).

Risk-Important Human Actions: Actions that are performed by plant personnel to provide assurance of plant safety. Actions may be made up of one or more tasks. There are both absolute and relative criteria for defining risk-important actions.

From an absolute standpoint, a risk-important action is any action whose successful performance is needed to provide reasonable assurance that predefined risk criteria are met. From a relative standpoint, the risk-important actions may be defined as those with the greatest risk in comparison to all human actions. The identification can be done quantitatively from risk analysis and qualitatively from various criteria such as task performance concerns based on the consideration of performance shaping factors.

Risk-Significant Local Control Station: A local control station at which risk-important human actions are performed or which control safety-related equipment.

Safety functions: Those functions that serve to ensure higher-level objectives and are often defined in terms of a design basis event (a boundary or entity that is important to plant integrity and the prevention of the release of radioactive materials). [Adapted from NUREG-1764]

System Operating Procedure (SOP): Normal operating procedures that provide instructions for energizing, filling, venting, draining, starting up, shutting down, changing modes of operation, preparing for maintenance or modification, performing maintenance, returning to service following maintenance and testing (if not contained in the applicable testing procedure), and other instructions appropriate for operation of plant systems.

Safety systems: Those systems that are designed to prevent or mitigate a design-basis accident. [ASME PRA Std. Amplified]

Severe Accident Guideline (SAG): Guidelines that form the basis for engineering strategies used to develop the SAMGs.

Severe Accident Management Guideline (SAMG): Emergency procedures that define strategies to be implemented when it is determined that predetermined thresholds have been exceeded and strategies beyond the scope of the Emergency Operating Procedures are required.

System: A composite, at any level of complexity, of personnel, procedures, materials, tools, equipment, facilities, and software. The elements of this composite entity are used together in the intended operational or support environment to perform a given task or achieve a specific production, support, or mission requirement [MIL882B].

Validation: The process of evaluating a system or component (including software and human interaction) during or at the end of the development process to determine whether it satisfies specified requirements [adapted from IEEE610].

Verification and Validation (V&V): The process of determining whether the requirements for a system or component (including software and human interactions) are complete and correct, the products of each development process fulfill the requirements or conditions imposed by the previous process, and the final system or component (including software) complies with specified requirements [adapted from IEEE610].

Verification: The process of evaluating a system or component (including software and human interactions) to determine whether the products of a given development process satisfy the requirements imposed at the start of that process [adapted from IEEE610].

1.3.2 Acronyms

The following is a list of acronyms used in this plan.

Acronym	Description
ABWR	Advanced Boiling Water Reactor
ADS	Automatic Depressurization System
ALARA	As Low As Reasonably Achievable
AOF	Allocation of Function
AOP	Abnormal Operating Procedure
APRM	Average Power Range Monitor
ARP	Alarm Response Procedure
ATWS	Anticipated Transient Without Scram
BRR	Baseline Review Record
BWR	Boiling Water Reactor
BWROG	Boiling Water Reactor Owners Group
CBP	Computer Based Procedure
CFR	Code of Federal Regulations
COL	Combined Operating License
CRD	Control Rod Drive
D3	Defense-in-Depth and Diversity
DCD	Design Control Document
DPV	Depressurization Valve
ECC	Emergency Core Cooling
ECCS	Emergency Core Cooling Systems
EOP	Emergency Operating Procedure
EPG	Emergency Procedure Guideline
FRA	Functional Requirements Analysis
FSS	Full-Scope Simulator
GDCS	Gravity Driven Cooling System
GE	General Electric Company
GEH	General Electric Hitachi Nuclear Energy
GPP	General Plant Procedure

Acronym	**Description**
GTG	General Technical Guideline
HA	Human Action
HEP	Human Error Probability
HFE	Human Factors Engineering
HFEITS	Human Factors Engineering Issue Tracking System
HPCI	High Pressure Coolant Injection
HPM	Human Performance Monitoring
HRA	Human Reliability Analysis/Assessment
HSI	Human System Interface
IOP	Integrated Operating Procedure
LCS	Local Control Station
MCR	Main Control Room
MMIS	Man Machine Interface System
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
OER	Operating Experience Review
PCCS	Passive Containment Cooling System
PRA	Probabilistic Risk Assessment
RCIC	Reactor Core Isolation Cooling
RPV	Reactor Pressure Vessel
RSR	Results Summary Report
RSS	Remote Shutdown System
RWCU	Reactor Water Cleanup
S&Q	Staffing and Qualifications
SAG	Severe Accident Guideline
SAMG	Severe Accident Management Guideline
SLC	Standby Liquid Control
SOP	System Operating Procedure

Acronym	Description
SPDS	Safety Parameter Display System
SRV	Safety Relief Valve
SSC	Structure, System and Component
TA	Task Analysis
TMI	Three Mile Island
V&V	Verification and Validation
VDU	Video Display Unit

2. APPLICABLE DOCUMENTS

Applicable documents include supporting documents, supplemental documents, codes and standards and are given in this section. Supporting documents provide the input requirements to this plan. Supplemental documents are used in conjunction with this plan. Codes and standards are applicable to this plan to the extent specified herein.

2.1 SUPPORTING AND SUPPLEMENTAL GEH DOCUMENTS

2.1.1 Supporting Documents

The following supporting documents were used as the controlling documents in the production of this plan. These documents form the design basis traceability for the requirements outlined in this plan.

(1) ESBWR DCD, Chapter 13, (GE 26A6642BL).

(2) ESBWR DCD, Chapter 18, (GE 26A6642BX).

(3) ESBWR DCD, Chapter 19, (GE 26A6642BZ).

(4) NEDE 33217P and NEDO-33217, Rev 5, ESBWR Man-Machine Interface System And Human Factors Engineering Implementation Plan.

2.1.2 Supplemental Documents

The following supplemental documents are used in conjunction with this document plan:

(1) NEDO-33219, Rev 3, ESBWR HFE Functional Requirements Analysis Implementation Plan.

(2) NEDE-33220P and NEDO-33220, Rev 3, ESBWR HFE Allocation of Function Implementation Plan.

(3) NEDE-33221P and NEDO-33221, Rev 3, ESBWR HFE Task Analysis Implementation Plan.

(4) NEDO 33226P and NEDO 33226, Rev 4, ESBWR I&C Software Management Program Manual.

(5) NEDO-33262, Rev 2, ESBWR HFE Operating Experience Review Implementation Plan.

(6) NEDO-33266, Rev 2, ESBWR HFE Staffing and Qualifications Implementation Plan.

(7) NEDO-33267, Rev 3, ESBWR HFE Human Reliability Analysis Implementation Plan.

(8) NEDE-33268P and NEDO-33268, Rev 4, ESBWR HFE Human System Interface Design Implementation Plan.

(9) NEDO 33275, Rev 3, ESBWR HFE Training Program Development Plan.

(10) NEDE-33276P and NEDO 33276, Rev 2, ESBWR HFE Verification & Validation Implementation Plan.

(11) NEDO 33277, Rev 3, ESBWR HFE Human Performance Monitoring Plan.

2.2 CODES AND STANDARDS

(1) ANSI/ANS 3.2, Administrative Controls and Quality Assurance for the Operational Phase of NPPs, 1994 (R1999).

(2) IEEE Std. 338, Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems, 1993.

(3) IEEE Std. 603, Criteria for Safety Systems for Nuclear Power Generating Stations, 1991.

(4) IEEE Std 610, IEEE Standard Glossary of Software Engineering Terminology, 1990.

2.3 REGULATORY GUIDELINES

(1) NUREG/CR-5228, Techniques for Preparing Flowchart Format Emergency Operating Procedures, Volumes 1 and 2, 1989.

(2) NUREG/CR-6634, Computer-Based Procedure Systems: Technical Basis and Human Factors, 2000.

(3) NUREG-0700, Rev 2 (plus errata), Human-System Interface Design Review Guidelines, 2002.

(4) NUREG-0711, Rev 2, Human Factors Engineering Program Review Model, 2004.

(5) NUREG-0737, Clarification of TMI Action Plan Requirements Supplement 1, 1983.

(6) NUREG-0800, 13.5.1, Rev 0, Administrative Procedures, 1981.

(7) NUREG-0800, 13.5.2.1, Rev 1, Operating and Emergency Operating Procedures, 2005.

(8) NUREG-0800, 13.5.2.2, Rev 0 Draft, Maintenance and Other Operating Procedures, 1996.

(9) NUREG-0899: Guidelines for the Preparation of Emergency Operating Procedures, 1982.

(10) Regulatory Guide 1.118, Rev 3, Periodic Testing of Electric Power and Protection Systems, 1995.

(11) Regulatory Guide 1.33 Rev. 2, Quality Assurance Program Requirements, 1978.

(12) 10 CFR 50.34, Contents of Applications, Technical Information.

2.4 DOD AND DOE DOCUMENTS

None.

2.5 INDUSTRY AND OTHER DOCUMENTS

(1) BWR Emergency Procedure and Severe Accident Guidelines, Rev 2, March, 2001.

(2) BWR Owners Group Accident Management Guidelines Overview Document.

(3) EPRI-NP-1567, Human Factor Review of Power Plant Maintainability, Seminara, 1981.

(4) EPRI-NP-2360, Human Factors Methods for Assessing and Enhancing Power Plant Maintainability, Seminara, 1982.

(5) EPRI-NP-3659, Human Factors Guide for Nuclear Power Plant Control Room Development, 1984.

(6) EPRI-NP-3701, Vol. II and I, Computer-Generated Display System Guidelines.

(7) IAEA-TECDOC-525, Guidebook on Training to Establish and Maintain the Qualification and Competence of Nuclear Power Plant Operations Personnel, Vienna, 1989.

(8) IP 42001: Emergency Operating Procedures. NRC, periodically updated.

(9) IP 42700: Plant Procedures, NRC, periodically updated.

(10) NEI 91-04: Nuclear Energy Institute Severe Accident Issue Closure Guidelines.

(11) Review Guidance, O'Hara, Higgins, Stubler, and Kramer, 2000.

3. METHODS

3.1 PROCEDURE DEVELOPMENT PLAN

3.1.1 Background

Procedures are essential to plant safety because they support and guide personnel interactions with plant systems and responses to plant-related events. Their development has historically been considered the responsibility of individual utilities. Procedures at most domestic Boiling Water Reactor (BWR) plants are based on procedure guidelines. The resulting procedures have evolved into paper procedures most often in the form of notebooks for System Operating Procedures (SOPs), calibration, inspection and testing procedures, Abnormal Operating Procedures (AOPs), and Alarm Response Procedures (ARPs).

In the case of Emergency Operating Procedures (EOPs) and Severe Accident Management Guidelines (SAMGs), most domestic BWRs use a large flow chart format. Each flow chart is one unique EOP with defined entry conditions. Typically, at domestic utilities, the number of flow charts provided range from six to nine EOPs and two SAMGs. EOPs have call-outs to other plant procedures (e.g., AOPs, ARPs, etc.) that have levels of detail for performing specific tasks (e.g., control switch name and location) not found in the EOPs. The EOP writer's guide provides details of the specific methods for translating and transcribing the plant EPGs into EOPs and SAMGs. An EOP flow chart designer produces the EOPs and SAMGs in a style, format, and design used by other operating plants, while maintaining the Emergency Procedure Guideline (EPG) logic and strategy. The EOP designer considers the "ease of use" and other criteria on the EOPs design based on operator feedback and operating experience of operation plants.

For new plant designs, the procedures should be developed as part of the same design process as the Human System Interfaces (HSIs) and training to verify a high degree of integration and consistency. Figure 2 outlines how the ESBWR procedure development process functions as an integral part of the MMIS HFE process. As shown in the Figure, inputs to the operational analysis include, but are not limited to, experience from previous BWR and Advanced Boiling Water Reactor (ABWR) designs through the OER/BRR, technical guidance-derived from plant design bases, system-based technical requirements and specifications, and critical human actions identified in the Human Reliability Analysis / Probabilistic Risk Assessment (HRA/PRA).

During operational analysis, detailed Functional Requirements Analyses (FRA), Allocations of Functions (AOF), and Task Analyses (TA) are performed. The operational analysis portion of the Human Factors Engineering (HFE) process generates procedure requirements and outlines as well as HSI requirements. These requirements resulting from the operational analyses, writer's guides, EPG/SAG Rev 2, and the HSI design process feed into the procedure development process governed by this plan. Completed procedures input to the V&V and training processes.

3.1.2 Goals

The procedures generated by the process incorporate the following:

- HFE principles and guidance
- Pertinent system design requirements
- Technical accuracy
- Content that is both explicit and comprehensive
- Ease of use
- Validation

Additionally, procedures are revised as HPM analysis identifies enhancements necessary for safe operation of the plant and are maintained and updated as the plant is modified.

3.1.3 Requirements

Normal, abnormal, and emergency operating procedures, and the writer's guides that govern their creation, conform to the principles set forth in:

- NUREG-0711, Rev 2, Section 9
- NUREG-0800, Section 13.5
- NUREG-0899 (applicable to EOPs)

The HFE design team reviews and verifies that normal, abnormal, and emergency operating procedures use accepted HFE principles in their form and presentation of information, and in their direction of operator interactions with the HSI. Information and control needs for each operative instruction or action are developed through task analysis. The results of this evaluation are placed in the Results Summary Report (RSR). Additionally, CBPs conform to the principles set forth in NUREG/CR-6634 and NUREG-0700 Rev 2 and the following requirements, unless the use of simulation during V&V reveals deficiencies and the need for implementing improvements to these requirements:

(1) Normal, abnormal, and emergency operating procedures are in the form of logic, flow charts, or text instructions.

(2) Normal, abnormal, and emergency operating procedures provide the parameters necessary for the operator to make each decision from the same display as the procedure.

(3) Normal, abnormal, and emergency operating procedures include checklists of prerequisites or interlocks to steps needed to complete an action where applicable.

(4) Normal, abnormal, and emergency operating procedures provide the capability for the operator to access those non-safety controls needed to carry out the tasks directly from the same Video Display Unit (VDU). Safety-related controls will be accessed from the safety system VDUs.

(5) Normal, abnormal, and emergency operating procedures provide feedback for tracking operator decisions. The operator retains final control and authority on whether or not to proceed with specific actions. Automatic logging of event management decisions taken includes variance from any computer recommended decisions.

(6) Plant parameters and status presented as part of the procedure displays are continuously updated. Operational analysis and HSI Design portions of the HFE process determine the data sampling and screen refresh rates.

(7) Normal, abnormal, and emergency operating procedures displayed in the HSI conform to Section 8 of NUREG-0700, Rev. 2 (plus errata), regarding HFE principles for computer displayed controls and procedures.

The EPGs are based on analysis of transients and accidents that are specific to the ESBWR design and operating philosophy. The EPGs provide a basis for human factors evaluations of emergency operations. An analysis of differences in content between the ESBWR Emergency Procedure Guidelines and the U.S. Boiling Water Reactor Owners Group (BWROG) Emergency Procedure and Severe Accident Guideline (EPG/SAG), Revision 2, is performed. In the case of backup and response actions, HRA/PRA evaluations identify risk-important HAs that are performed using EOPs. If HRA/PRA results show that a change in the priority of actions minimizes human error and reduces plant risk, then the EPGs/EOPs can be adjusted accordingly[1].

3.1.4 General Approach

The procedure development process starts with example procedure writer's guides from existing BWRs and ABWRs and EPG/SAG Rev 2. The HFE design team uses these documents to generate ESBWR HFE infused writer's guides for station procedures. The procedure development team then uses the writer's guides to properly combine and structure the HSI design and operational analysis inputs and other required information into useable procedures. The procedures are inputs to the training process for use in the development and presentation of training and the V&V process, where they are evaluated to ensure they meet all required attributes.

The V&V, HSI design, training, and HPM processes provide feedback that is evaluated to determine whether or not procedure revisions are warranted. When feedback is received, the HFE design team evaluates potential resolutions including changes to HSI design, plant design, training, procedures, etc. If a solution is not identified through this normal feedback loop, the issue is entered into HFEITS for tracking and resolution. Once all issues are resolved and revisions are validated, procedures are made available for use and the HPM process monitors their use over time. Future enhancements are identified as they become apparent.

3.1.5 Application

When the procedure development plan is implemented in the method described in Section 3.1.4 and shown in Figure 2, the goals of the plan are fulfilled as follows:

(1) The process generates writer's guides that become governing inputs to procedure development ensure the following are included in new and revised procedures:

a. HFE principles and guidance

[1] The BWROG EPGs listed alternatives for accomplishing a function do not necessarily imply an order or priority for the actions.

b. Pertinent system design requirements

c. Technical accuracy

d. Ease of use

e. Content that is both explicit and comprehensive

(2) The BWROG EPG/SAG Rev 2 guidance is incorporated into the EOP writer's guide and used to generate ESBWR generic emergency procedures. These procedures are symptom-based, allowing operators to take mitigation actions without first having diagnosed the specific event cause or component failure. Symptom-based EOPs contain the human action steps necessary to mitigate transients and accidents in a sequence as determined by key safety parameters. The example parameters used in implementing the EOPs are listed in Table 6. These monitored variables support detecting cues for entering an EOP, selecting steps to execute the EOP, and evaluating impact of executed steps. Thus, the ESBWR procedures use the same design and operating philosophy as previous BWRs to support the goal of safe operation.

(3) Operational analysis is performed including detailed FRA, AOF, and TA. The procedure outlines generated by this process, including component manipulations, indications and data accessed, set points, and sequencing, are input into the HSI design process and the procedure development process governed by this plan. This portion of the process supports the goals of incorporation of HFE principles and guidance, pertinent system design requirements, technical accuracy, easy to use, safe operation of the plant, and the content that is both explicit and comprehensive.

(4) HSI design input into the procedure development and revision process, and feed back from the procedure revision process to HSI design, ensures alignment between procedure content and structure and the HSI content, capabilities, and presentation format. When procedures are analyzed through the V&V process, any issues identified are provided as feedback and are resolved by training, procedure revision, HSI change, or plant modification. Issues not resolved in this way are entered into the HFEITS process for tracking and resolution. This portion of the process supports the goals of incorporation of HFE principles and guidance, pertinent system design requirements, technical accuracy, easy to use, safe operation of the plant, and the content that is both explicit and comprehensive. Additionally, this communication and feedback link helps to ensure that procedures are maintained and updated as the plant is modified.

(5) Training input into the procedure development and revision process, and feed back from the procedure revision process back to training, ensures alignment between the two processes. The personnel generating the training materials and operators who are to be licensed for the ESBWR can identify procedure improvement issues during pre-operational training on the plant simulator. The full-scope simulator has the same display interface and procedures as the actual plant. It is expected that the newer areas of the HSI design have a significant potential for improvement. This portion of the process supports the goals of incorporation of HFE principles and guidance, technical accuracy, easy to use, safe operation of the plant, and the content that is both explicit and comprehensive. Additionally, this communication and feedback link helps to ensure that training is maintained up to date as procedures are modified.

(6) The V&V input into the procedure revision process, and input from the procedure revision process to V&V, ensures alignment between the two processes. The personnel performing validations of procedures through full-scope simulation receive final procedures for evaluation and can identify procedure improvement issues requiring procedure revision. This portion of the process supports the goals of incorporation of HFE principles and guidance, technical accuracy, easy to use, safe operation of the plant, and the content that is both explicit and comprehensive.

(7) HPM works with a good operational safety culture from the COL applicant and encourages the continual identification of issues for improvement including further reducing the potential for human errors. The potential for improvements to the HSI and procedures continues into the operational phase. Thus, when the plant is turned over to the COL applicant, improvements to the HSI and procedures are still sought, evaluated, tracked, and resolved. This portion of the process supports the goals of incorporation of HFE principles and guidance, technical accuracy, easy to use, safe operation of the plant, and the content that is both explicit and comprehensive. Additionally, this communication and feedback link helps to ensure that procedures are maintained and updated as the HSI, plant, or other factors impacting operation are modified.

4. IMPLEMENTATION

4.1 PROCEDURE DEVELOPMENT PLAN IMPLEMENTATION

The HFE design team generates writer's guides and plant specific technical guidelines, typically developed from Generic Technical Guidelines (GTGs). Procedures are then generated using the writer's guides, GTGs, and the procedure outlines generated in operational analysis. The procedure writers take into account the HSI structure, controls, displays, automations, and other attributes. These procedures are used in the training development and V&V processes where feedback and procedure revision needs are generated. After revision and validation, procedures and their use are monitored and revised over time through the HPM process.

4.1.1 Assumptions

- ESBWRs are operated as a standardized fleet of nuclear plants.
- The training program and procedures are generic to the ESBWR. All plants in the ESBWR fleet use the same training program, procedures, staffing, and qualifications.
- All normal, abnormal, and emergency operating procedures use the same names and numbering of plant equipment and controls used by the plant operators.
- All ESBWR plants meet the standards developed and upheld by the fleet-wide owner's group.
- The ESBWR is designed to operate with many passive systems.
- The control systems for the ESBWR have a high level of automation. Systems are automated unless regulation or HFE analysis results dictate otherwise.
- CBPs are accessible anywhere the HSI can be accessed.

4.1.2 Inputs

Inputs to the HFE procedure development process include the following:

- EPGs
- Writer's guides
- HSI design
- The determination of significant operator actions by the HRA/PRA
- The completion of functional analyses, function allocation, and task analyses

From these, the controls, displays, and alarms needed by the main control room (MCR) operators are determined. Normal, abnormal, and emergency operating procedures for carrying out the operational strategies are considered in HRA/PRAs through their impact on pre-initiator events, initiating frequency evaluations, and post-initiator events. For each of these elements, qualitative evaluations and supporting calculations are made to evaluate the probability of human error. In the initial HRA/PRA screening, HEPs were determined based on the time available assuming that procedures and training were globally available. The PRA results are used to identify risk-important human actions. These actions provide a starting point for review of procedures that can impact system availability, trigger events, and impact accident management through the pre-initiator, initiating event analysis, and post-initiator evaluations. In this way risk-important human actions from the HRA/PRA are used as input to the evaluation of normal, abnormal, and emergency operating procedures.

(1) Operational Analysis

Operational analysis combines its inputs, which include HRA/PRA significant operator actions, vendor document requirements/recommendations, system design specifications, OER/BRR analysis results, and other design requirements, to develop lists of specific actions. Functional analysis breaks down desired changes in plant or equipment status into the required functional manipulations. Allocation of function distributes the functions between automation and human action as appropriate. Task analysis breaks down these functions into discrete tasks, defines the tasks, sequences them, and identifies needed controls, indications, communications, supplemental information, etc. The output of this process is a task based procedure outline for the function being analyzed. This procedure outline is a direct input to the procedures development process.

(2) HSI Design

The controls, displays and alarms needed by the MCR operators are determined as a result of the following:

- Analyses of operation strategies given in the ESBWR EPGs
- The determination of significant operator actions by the HRA/PRA
- Completion of functional analyses, function allocation, and task analyses

The HSI design process evaluates these requirements and uses them to select and configure equipment and software. Additionally, this process evaluates human factors and human-machine interfaces to ensure that HFE principles are built into the HSI. The final HSI design including controls, component identifiers, indications, VDU screen format, human interaction mechanisms and options, queues, alarms, etc., is a direct input to the procedures development and procedure revision process.

(3) Writer's Guides

HFE design team produces writer's guides to address all the procedure development requirements and HFE considerations for both paper and computer based procedures. Sources of guidance include documents such as:

- 10 CFR 50.34
- NUREG-0899
- NUREG/CR-6634
- NUREG-0711

- NUREG-0800
- EPG/SAG Rev 2 (incorporated into the EOP writer's guide)

The completed writer's guidelines (approved by the HFE design team) support a structured approach for developing and refining procedures that support the ESBWR design and operating philosophy. Writer's guides are a direct input to the procedures development and procedure revision process.

(4) BWROG EPG/SAG Rev 2

EPGs that have been applied in previous BWR designs, such as the ABWR, are adapted to the ESBWR to develop the EOPs and SAMGs. The EPGs are based on analysis of transients and accidents that are specific to the ESBWR plant design and operating philosophy. Thus, the EPGs provide guidance for the ESBWR EOPs in both content (e.g., strategies and intent) and form of presentation.

Deterministic requirements for actions that need to be included in emergency procedures are developed during the system functional requirements analysis, the functional allocation, and task analysis. Probabilistic requirements based on reducing risk are developed through interaction with the HRA/PRA. Design choices that impact procedures are made by selecting the display system for monitoring plant status, the display interface for computer based procedures, and software interfaces to support feedback on actions taken and the degree of support for decision making within the procedures.

BWROG EPG/SAG Rev 2 is a direct input to the procedures development and procedure revision process.

(5) Training Program Feedback

Completed procedures are input into the training process for development of training material and ultimately for the training of personnel. The personnel who are to be trained for the ESBWR identify procedure improvement issues during pre-operational training on the full-scope simulator. The full-scope simulator has the same display interface and procedures as the actual plant. It is expected that the newer areas of the HSI design have a significant potential for improvement. These procedure improvement recommendations are a feedback input into the procedure revision process.

(6) V&V Feedback

Once the ESBWR procedures are written, they are validated and verified using talk through, walk through, mock-ups, part task simulators, and ultimately, the full-scope simulator. These procedure improvement recommendations are a feedback input into the procedure revision process. The resulting revised procedures are then put through the V&V process again to validate the adequacy of the changes.

(7) HPM Feedback

During the design process, HFE addresses a wide range of potential causes of human error to produce procedures that match the HSI. However, a good operational safety culture from the COL applicant encourages the continual identification of issues for improvement and the reduction of the potential for human errors. The potential for improvements to the HSI and procedures continues into the operational phase, so that when the plant is turned over to the COL applicant, improvements to the HSI and procedures are still sought, evaluated, tracked, and resolved through the HPM process. These procedure improvement recommendations are a feedback input into the procedure revision process.

4.1.3 Process

The procedure development process follows the top down approach to MMIS HFE shown in Figure 2. The process results in the creation of the IOPs addressed in the HFE implementation plan, which is an integral part of the MMIS and HSI development for the ESBWR. The IOPs are provided in the form of instructions, charts, and figures in combinations of paper and computer based forms that are validated through simulator testing. They include the following:

- GPPs for normal operation
- SOPs for system level operations
- Calibration, inspection, and testing procedures for surveillance testing
- ARPs to help operators respond to alarms
- AOPs to help operators restore abnormal plant variable indications to normal conditions
- EOPs for mitigating the consequences of accident conditions and minimizing radioactive release
- SAMGs for mitigation of events beyond the scope of the EOPs
- Radiation control procedures
- Maintenance and modification procedures for performing preventative and corrective maintenance

Of these procedures, the EOPs and SAMGs are the most important for protecting the defense in depth barriers in the ESBWR. Using the processes described throughout this implementation plan, the following EOP/SAMG development actions will be performed:

- ESBWR specific Appendix C calculations will be developed from the BWROG EPG/SAG, Rev 2 Appendix C using ESBWR plant specific design input, analyses, instrument set points, vendor input, and other system data.
- ESBWR specific EPG/SAGs will be developed from the BWROG EPG/SAG, Rev 2 using the ESBWR specific Appendix C calculations, ESBWR plant specific Design input, PRA input, ESBWR philosophy of operation, and HFE operational analysis.
- ESBWR specific EOP writer's guide will be developed using EPG/SAG Rev 2 guidance, industry examples, HFE design team input, and ESBWR HSI design inputs. The ESBWR EOP writer's guide will provide details of the specific methods for translating and transcribing the ESBWR specific EPG/SAGs into EOPs and SAMGs.

- ESBWR EOP and SAMG flow charts and supporting emergency procedures will be generated using the ESBWR specific writer's guide, EPG/SAGs, and Appendix C calculations discussed above.

Inputs to the operational analysis include experience from previous BWR and ABWR designs through the OER/BRR, technical guidance-derived from plant design bases, system-based technical requirements and specifications, and critical human actions identified in the HRA/PRA. During operational analysis, detailed FRAs, AOFs, and TAs are performed. The results of the operational analyses are input into the HSI design process and the procedure development process governed by this plan. Using the appropriate writer's guide, procedures developed serve as input to the V&V and training processes.

These processes identify any procedure enhancements needed and feed this information back into the procedure revision process. Final procedures are generated and are again input into the V&V and training processes. Once V&V is complete, the validated procedures are issued for use. ESBWR procedures continue to be revised over time as the HPM analysis process identifies enhancements necessary for safe operation of the plant. The procedures are also maintained and updated as the plant is modified.

4.1.3.1 Writer's Guides

Writer's guides are developed for all classes of procedures. Common writer's guides govern procedures of similar content and structure. Development of the guides starts with similar procedures from previous BWRs and ABWRs. These initial writer's guides are refined and updated by the HFE design team to ensure they address all the procedure development requirements for both paper and computer based procedures. Writer's guide requirements and guidelines will insure that CBP and hard copy procedures are developed and written in a coordinated manner to facilitate the smooth transition between the two presentation mediums. The completed writer's guides approved by the HFE design team support a structured approach for developing and refining procedures that support the ESBWR design and operating philosophy.

The writer's guides establish the process for developing technical procedures that are complete, accurate, consistent, and easy to understand and follow. The writer's guides contain objective criteria so that procedures developed in accordance with them are consistent in organization, style, and content. The guides are used for all procedures within the scope of this element. The guides provide instructions for procedure content and format including the writing of action steps and the specification of acceptable acronym lists and terms for use in ESBWR procedures.

Some of the groups of procedures governed by the writer's guides described in this section include:

(1) EOPs for mitigating the consequences of accident conditions and minimizing radioactive release.

(2) GPPs for normal operation, including startup, power, shutdown, and refueling operations, and SOPs for system level operations.

(3) AOPs to help operators restore abnormal plant variable indications to normal conditions.

(4) Calibration, inspection, and testing procedures for verifying equipment is operable and reliable.

(5) ARPs to help operators respond to alarms.

(6) Maintenance and modification procedures for performing preventative and corrective maintenance.

(7) Radiation control procedures for monitoring and release of solids, liquids, and gasses, access controls, area radiation monitoring, and the ALARA program.

4.1.3.2 Procedure Format

The basic content and format of both paper and CBPs used in the ESBWR are set forth by the applicable writer's guide and include, as applicable, the following:

(1) Title and identifying information, such as number, revision, and date

(2) Statement of applicability, purpose, and level of use

(3) Precautions, including warnings, cautions, and notes

(4) Prerequisites

(5) Limitations and actions

(6) Important human actions

(7) Acceptance criteria

(8) Check off lists

(9) Reference material

In addition to the requirements set forth above, the EOPs and SAMGs are symptom-based with clearly specified entry conditions.

Formatting requirements relating to computer based procedures are specified in applicable writer's guides and include any automation, auditory cues, visual cues, supplemental information, screen presentations, plant equipment controls imbedded or linked to procedure steps, and feedback presentations. CBP and hard copy procedures are developed and written in a coordinated manner to facilitate the smooth transition between the two presentation mediums.

4.1.3.3 Procedure V&V

The purpose of the V&V process is to verify that the procedures are correct, meet HFE requirements, and can be carried out as stand alone procedures. Additionally, it is verified that they do not conflict with other procedures and processes that may be taking place in parallel with the tasks governed by the procedure being validated. All normal, abnormal, and emergency operating procedures are validated through simulator testing, where applicable, or through talk/walk through. NUREG-0711, Rev 2 sets forth test objectives and testbed validation requirements that are discussed further in Reference 2.1.2 (10), ESBWR HFE Verification &Validation Implementation Plan.

As shown in Figure 1, the V&V process supports HFE evaluation of the HSI design, all normal, abnormal, and emergency operating procedures and their CBP equivalents, and the output of the training plan. V&V is performed using a variety of means including part-task simulators, talk through evaluations, walk through evaluations using mock-ups, and full-scope simulators. In addition to testing stand-alone procedures, a test process is developed to verify that the separate procedures have been converted into an integrated set of procedures. These procedures have a common language and the names of systems and components are consistent throughout the procedure set. The test process includes dynamic simulation of startup, power operation, and shutdown. During power operation in the simulator the ARPs and AOPs are simulated to verify that trained operators can respond properly.

V&V testing and evaluations insure that both CBPs and hard copy procedures can be effectively performed as written. CBPs and hardcopy procedures for the same tasks are verified to be similarly written, presented, and performed. The philosophy and methods of transitioning between CBPs and hardcopy procedures that are built into the HSI are verified to support smooth transitions. This verification includes both planned transitions to and from CBPs and unplanned transitions from CBPs to hardcopy procedures due to CBP system degradation or failure.

Any issues identified during the V&V process are provided as feedback to the originating process for resolution. Based upon the nature of the issue, one or more of the following solutions may be implemented:

- Procedures may be revised.
- HSI design is either modified to address the issue by changing the procedure interface content, display, or software decision support.
- An issue becomes an input to the training program so that operators are taught the conditions they need to consider in selecting a procedure path.

The priority for modifying the procedure interface design, in response to a human factor discrepancy, is guided by an assessment of risk impact from the HRA/PRA interface.

If a V&V issue cannot be resolved using the iterative processes shown in Figures 1 & 2, then it is input into the HFEITS process for resolution.

Resolutions to procedure issues are developed using the same processes and writer's guides used in procedure development. The V&V process is again used to evaluate the revised procedure.

4.1.3.4 Computer-Based Procedures

The ESBWR plant design and operating philosophy support the use of CBPs. Unless the iterative operational analysis, HSI design, procedure development, training, and V&V processes shown in Figure 2 dictate otherwise, CBPs are the normal presentation medium for plant procedures. Duplicate paper based procedures are created and used as back up in the event CBPs are not available. Both CBPs and paper-based procedures are created, revised, and validated using the same processes presented in this document.

If during the HFE process it is identified that the use of paper based procedures for a particular task or evolution improve procedure utilization or reduce operating crew errors related to procedure use, then the analysis is documented and paper based procedures are generated for normal performance of the evolution. Analysis of plans and alternatives put in place in the event of loss of CBPs is performed and documented. Specific HSI requirements supporting CBP presentation are specified in the ESBWR style guide discussed in Reference 2.1.2 (8), ESBWR HFE Human System Interface Implementation Plan, while the CBP formatting and content requirements are specified in the appropriate writer's guide.

Computer based presentation of procedures produces a wide range of aids and enhancements. One example is the use of a tracking system while implementing EOPs. The objective of the EOP tracking system is to provide a listing of unresolved conditions to help the operators organize their verifications of the plant status, so as not to take any decision making control away from the operator. In simulator tests of an early BWR EOP tracking system, human errors in using the large chart procedures were reduced by about 50% (NUREG/CR-6634). Development of such a system requires identification of errors in using the EOPs, a desire by the COL applicant to reduce the errors, and verification of the EOP tracking systems ability to reduce specific types of human error. If an EOP place-keeping system is cost effective in reducing errors, then it becomes part of the HSI software design. Similar analyses and decision making precedes the use of other enhancements including supplemental information displays and calculation aids.

4.1.3.5 Procedure Maintenance

HFE addresses a wide range of potential causes of human error during the design process to produce procedures that match the HSI. However, a good operational safety culture from the COL applicant encourages the continual identification of issues for improvement, including further reducing the potential for human errors. The potential for improvements to the HSI and procedures continues into the operational phase. Thus, when the plant is turned over to the COL applicant, improvements to the HSI and procedures are still sought, evaluated, tracked, and resolved. Additionally, the operators who are to be licensed for the ESBWR can identify procedure improvement issues during pre-operational training on the full-scope simulator.

The full-scope simulator has the same display interface and procedures as the actual plant. It is expected that the newer areas of the HSI design have a significant potential for improvement. For example, in the area of EOP tracking, a simple tracking system lets the operators know when responses to action statements (e.g., IF A & B or C, Then take X, and Y actions) have effectively been resolved. When entry conditions exceed given parameters, a list of text messages appears on a VDU and remains until the condition is resolved.

Similar feedback is received from the training program on an on going basis. Each issue undergoes the same type of analysis. If the issue is risk-important or is worthwhile, then a procedure enhancement or changes in the HSI are evaluated and incorporated as appropriate.

An administrative procedure dictates the administration and control of ESBWR procedures. This procedure outlines the process for procedure maintenance and control of updates to ensure that they are integrated across the full spectrum of IOPs. This integrated approach ensures that alterations to a particular procedure, or set of procedures, do not generate conflicts with other procedures.

4.1.3.6 Procedure Access and Use

The physical means by which operators access and use procedures, especially during operational events, is evaluated as part of the HFE design process shown in Figure 1. The HSI design, the MCR, the RSSs, and risk-significant LCSs are assessed to ensure that procedure plans for the ESBWR adequately address the storage of procedures, ease of operator access to the correct procedures, and the lay-down of paper based procedures. Requirements generated from these assessments are input into the appropriate HFE process for resolution. If a procedure access and use issue cannot be resolved using the iterative processes shown in Figures 1 & 2, then it is input into the HFEITS process for resolution.

When an issue is resolved, the V&V process is applied again to evaluate the procedure and validate the chosen solution.

4.1.4 Outputs

The IOPs addressed in the HFE implementation plan are an integral part of the MMIS and HSI development for the ESBWR. The IOPs are provided in the form of instructions, charts, and figures in combinations of paper and computer based forms that are validated through simulator testing. They include the following:

- GPPs for normal operation
- SOPs for system level operations
- Calibration, inspection, and testing procedures for verifying equipment is operable and reliable
- ARPs to help operators respond to alarms
- AOPs to help operators restore abnormal plant variable indications to normal conditions
- EOPs for mitigating the consequences of severe plant transients and minimizing radioactive release.
- SAMGs for addressing accidents in which predetermined thresholds have been exceeded and strategies beyond the scope of the Emergency Operating Procedures are required
- Radiation control procedures
- Maintenance and modification procedures for performing preventative and corrective maintenance

Normal, abnormal, and emergency operating procedures comply with deterministic rules and explicit probabilistic evaluations. All normal, abnormal, and emergency operating procedures are validated through simulator testing where applicable or through talk/walk through.

These collections of individual procedures become IOPs following successful dynamic task and performance testing in simulators. This testing demonstrates that qualified plant control room crews can effectively use the procedures with the HSI to manage plant operations and safety margins. Testing is performed with dynamically driven real time plant simulation computer models and prototypical HSI equipment.

4.1.4.1 General Plant Procedures

GPPs provide instructions for normal operations of the plant (e.g., startup, shutting down, shutdown, power operation and load changing, process monitoring, and fuel handling). The forms of GPPs include listed instructions, charts, and figures in combinations of paper and computer based forms. They comply with the deterministic rules and probabilistic evaluations. Their use by operators is validated through simulator testing.

4.1.4.2 System Operating Procedures

The SOPs provide instructions for energizing, filling, venting, draining, starting up, shutting down, changing modes of operation, returning to service following testing (if not contained in the applicable testing procedure), and other instructions appropriate for system operation. Only those BWR systems in Regulatory Guide 1.33 applicable to the BWR, as well as specific ESBWR systems, are addressed in this plan. The procedure format conforms to the HFE standards established for the overall plant and HSI interface. They comply with probabilistic evaluations. Their use by operators is validated through simulator testing. Their integration into the IOPs is accomplished during the V&V process.

4.1.4.3 Calibration, Inspection and Testing Procedures

The calibration, inspection and testing procedures provide instructions for operational testing required to demonstrate that systems and components are expected to perform satisfactorily in future service. Operators or computers perform tests while the plant is operating in accordance with written test procedures on redundant standby circuits and systems that involve establishing test alignments, testing, and realigning. The tests are cued by a time interval requirement developed from either reliability or availability goals or from manufacturer recommendations. They protect against failure to start on demand faults in standby equipment. They comply with the deterministic rules and probabilistic evaluations. Selected samples of the calibration, inspection, and testing procedures are validated through simulator testing where applicable or through talk/walk through.

4.1.4.4 Alarm Response Procedures

The ARPs guide operator actions for responding to specifically dedicated alarms that indicate that a measured or calculated plant variable exceeds a pre-determined set point. ARPs are developed for control room alarms that require operator response. These alarms indicate entry into specific procedures or indicate the need for operator action to address conditions that potentially affect plant availability or plant safety. They comply with the deterministic rules and probabilistic evaluations. Selected samples of the ARPs are validated through simulator testing where applicable.

4.1.4.5 Abnormal Operating Procedures

The AOPs specify operator actions for restoring an operating variable to its normal controlled value when it departs from its normal range or to restore normal operating conditions following a transient. Such actions are invoked following an operator observation or warning alarms indicating a condition that, if not corrected, could degenerate into a condition requiring action under an EOP. They comply with the deterministic rules and probabilistic evaluations. Selected samples of the AOPs are validated through simulator testing where applicable.

4.1.4.6 Emergency Operating Procedures

The EOPs direct actions necessary for mitigating the consequences of severe plant transients and minimizing radioactive release. The SAMGs direct actions necessary when it is determined that predetermined thresholds have been exceeded and strategies beyond the scope of the Emergency Operating Procedures are required. Computer support for using the EOPs and SAMGs is considered during the design development. Such support is presented electronically on the VDU in the MCR. Whether they are electronically displayed or are laminated hard copies, EOPs and SAMGs conform to the requirements in Appendix A, unless the use of simulation during V&V reveals deficiencies and the need for implementing improvements.

4.1.4.7 Maintenance and Modification Procedures

Maintenance procedures provide instructions for the repair of degraded or failed equipment and for the performance of preventative maintenance intended to enhance equipment reliability. The manufacturer of the system or component provides basic procedures for preventative and some anticipated corrective maintenance work. These vendor procedures are incorporated into the initial drafts of ESBWR maintenance procedures in accordance with the appropriate ESBWR procedure writer's guide. The writer's guide ensures the procedure format conforms to the HFE standards established for the overall plant and HSI interface. They comply with the deterministic rules.

Maintenance procedures that require operator actions in the MCR, RSSs, or risk-significant LCSs are written in accordance with the appropriate ESBWR procedure writer's guide. The writer's guide ensures the procedure format conforms to the HFE standards established for the overall plant and HSI interface. They comply with deterministic rules and probabilistic evaluations. The portions affecting the MCR, RSSs or risk-significant LCSs are validated through simulator testing where applicable or through talk/walk through.

4.1.4.8 Radiation Control Procedures

Procedures for the control of radioactive releases provide direction regarding actions to be taken to identify and mitigate release sources as well as release controls. These procedures are drafted in accordance with the appropriate ESBWR procedure writer's guide. The writer's guide ensures the procedure format conforms to the HFE standards established for the overall plant and HSI interface. They comply with the deterministic rules.

Procedures for the control of radioactive releases that require operator actions in the MCR, RSSs or risk-significant LCSs are written in accordance with the appropriate ESBWR procedure writer's guide. The writer's guide ensures the procedure format conforms to the HFE standards established for the overall plant and HSI interface. They comply with deterministic rules and probabilistic evaluations. The portions affecting the MCR, RSSs or risk-significant LCSs are validated through simulator testing where applicable or through talk/walk through.

5. RESULTS

5.1 RESULTS SUMMARY REPORT

The results of the Procedure Development are summarized in a RSR. This report is the main source of information used to demonstrate that efforts conducted in accordance with the implementation plan satisfy the applicable review criteria of NUREG-0800.

The report contains the following:

- General approach, including the purpose and scope
- Plant procedures derived from ESBWR EPGs
- A description of the plant procedures derived from the ESBWR SAGs, including the technical basis for severe accident management
- A list of writer's guides, procedures, and procedure support equipment developed during implementation of this plan
- Outline of how procedures are utilized, including operator access and use of procedures for both hard copy and computer based procedures
- A description of procedure storage and laydown areas for hardcopy procedure use in the MCR, RSSs or risk-significant LCSs
- A description of the framework utilized for procedure maintenance and control of updates

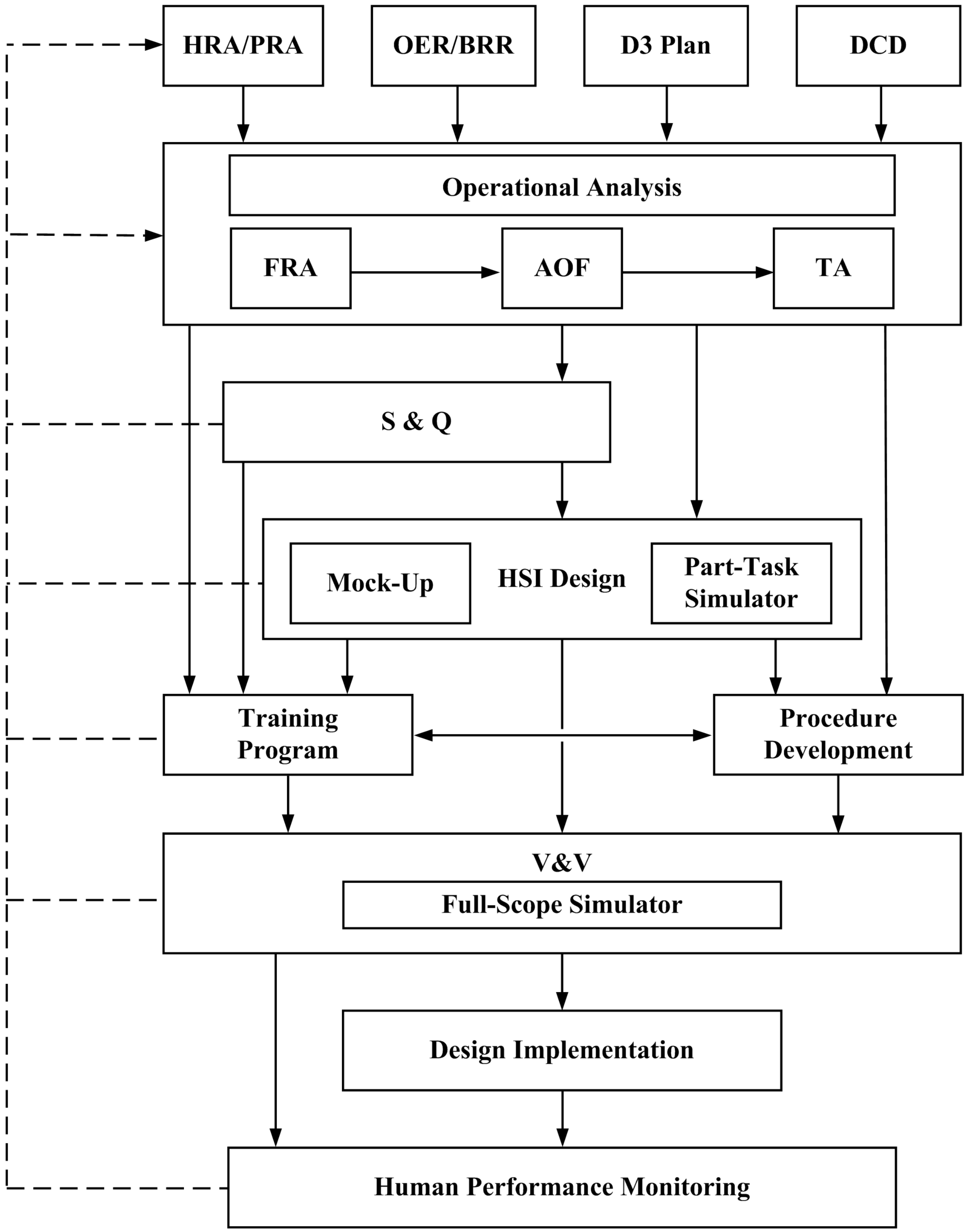

Figure 1 - HFE Implementation Process

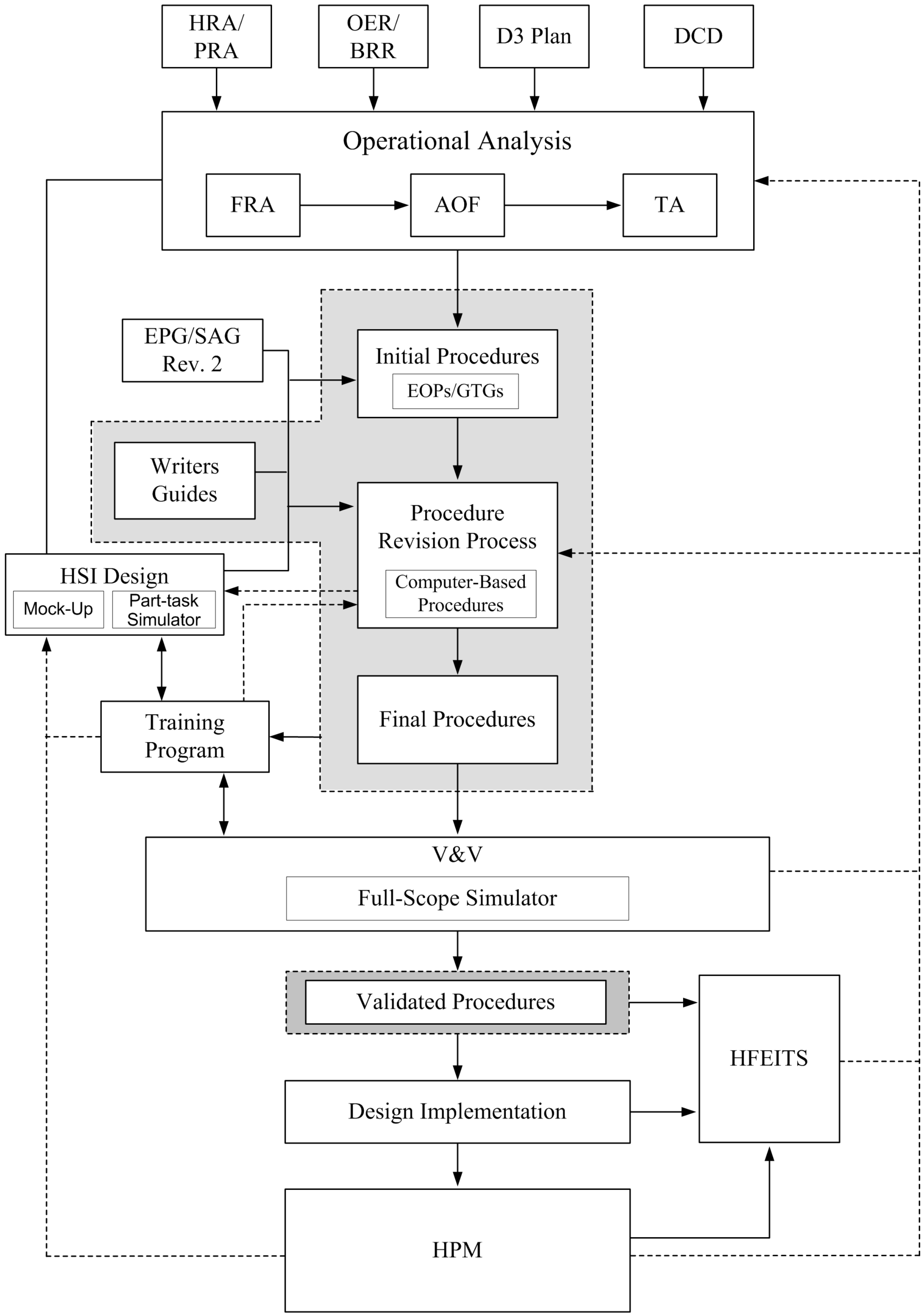

Figure 2 - Process for Development of ESBWR Procedures

Table 1
Example General Plant Procedures

	General Plant Procedures[1]
1.	Cold Shutdown to Hot Standby
2.	Hot Standby to Minimum Load (nuclear start-up)
3.	Recovery from Reactor Trip
4.	Operation at Hot Standby
5.	Turbine Startup and Synchronization of Generator
6.	Changing Load and Load Follow (if applicable)
7.	Power Operation and Process Monitoring
8.	Power Operation with less than Full Reactor Coolant Flow
9.	Plant Shutdown to Hot Standby
10.	Hot Standby to Cold Shutdown
11.	Preparation for Refueling and Refueling Equipment Operation
12.	Refueling and Core Alterations

(1) Regulatory Guide 1.33 Quality Assurance Program Requirements (Operation) Appendix A Typical List of procedures for LWRs

Table 2
Example System Operating Procedures

	System Operating Procedures for ESBWR Systems (1)
1.	Nuclear Steam Supply System
2.	Control Rod Drive (CRD) System
3.	Reactor Cleanup System and Shutdown Cooling System
4.	Standby Liquid Control System
5.	Gravity Driven Core Cooling Systems
6.	Containment and Environmental Control Systems
7.	Fuel Storage Pool Purification and Cooling System
8.	Main Steam System (reactor vessel to turbine)
9.	Turbine-Generator System
10.	Condensate System (hotwell to feedwater pumps, including demineralizers and resin regeneration)
11.	Feedwater System (feedwater pumps to reactor vessel)
12.	Makeup System (filtration, purification, and water transfer)
13.	Service Water System
14.	Reactor Building Heating and Ventilation Systems
15.	Control Room Heating and Ventilation Systems
16.	Radwaste Building Heating and Ventilation Systems
17.	Radioactive Waste Management Systems
18.	Instrument Air Systems
19.	Electrical Systems
20.	Nuclear Instrument System
21.	Reactor Protection System

(1) From RG 1.33 for selected ESBWR systems

Table 3
Example Calibration, Inspection and Testing Procedures Test Procedures

	Specific Calibration, Inspection and Testing Procedures in BWRs[(1)]
1.	Containment Leak-Rate and Penetration Leak-Rate Tests
2.	Containment Isolation Tests
3.	Service Water System Functional Tests
4.	Main Steam Isolation Valve Tests
5.	Fire Protection System Functional Tests
6.	Nitrogen Inerting System Tests
7.	Core Cooling System Tests (RWCU in the ESBWR)
8.	Control Rod Operability and Scram Time Tests
9.	Reactor Protection System Tests and Calibrations
10.	Rod Block - Tests and Calibrations
11.	Refueling System Circuit Tests
12.	Standby Liquid Control System Tests
13.	Minimum Critical Heat Flux Checks and In-core Flux Monitor
14.	Emergency Power Tests
15.	Isolation Condenser
16.	NSSS Pressurization and Leak Detection
17.	Inspection of Reactor Coolant System Pressure Boundary
18.	Inspection of Pipe Hanger Settings
19.	Control Rod Drive System Functional Tests
20.	Heat Balance
21.	Automatic Blowdown System Tests
22.	Leak Detection System Tests
23.	Axial and Radial Flux Pattern Determinations
24.	Area, Portable, and Airborne Radiation Monitor Calibrations
25.	Process Radiation Monitor Calibrations
26.	Environmental Monitor Calibrations
27.	Safety Valve Tests
28.	Turbine Overspeed Trip Test
29.	Water Storage Tanks-Level Instrumentation Calibrations
30.	Reactor Building In leakage Tests

(1) Adapted from RG 1.33 for selected ESBWR systems

Table 4
Example Maintenance and Modification Procedures

	Specific Maintenance and Modification Procedures in BWRs[(1)]
1.	Maintenance that can affect the performance of safety-related equipment with the exception of some craft skills such as: 1) gasket replacement, 2) electrical troubleshooting, and some recorder repairs, etc.
2.	Preventative maintenance schedules for lubrication, inspections, filter/strainer replacements, and replacements of limited lifetime parts.
3.	Repair and replacement of Control Rod Drives.
4.	Replacement of important strainers.
5.	Repair or replacement of important safety valves.
6.	Repair or replacement of neutron detectors.
7.	If Operating procedures are not developed for the following, then Maintenance procedures are: • Draining and refilling heat exchangers • Draining and refilling the reactor vessel • Removal of the reactor head • Demineralizer resin replacement
8.	General procedures controlling the conduct of maintenance and modifications including: • Methods for obtaining permission, clearances, and log keeping for work • Factors to be taken into account including the minimization of radiation exposure and the preparation of detailed work procedures

(1) Adapted from RG 1.33 for selected ESBWR systems

Table 5
Example Radiation Control Procedures

	Specific Radiation Control Procedures in BWRs[(1)]
1.	Liquid radwaste collection, demineralization, filtering, evaporating, concentrating, and neutralizing
2.	Liquid radwaste sampling and monitoring
3.	Discharge of liquid radwaste effluents
4.	Spent resin and filter sludge handling
5.	Baling machine operation
6.	Drum handling and storage
7.	Mechanical vacuum pump operations
8.	Air ejector operations
9.	Packing steam exhauster operation
10.	Gaseous effluent sampling
11.	Air ejector, ventilation, and stack monitor
12.	Access control to radiation areas including a Radiation Work Permit system
13.	Radiation surveys
14.	Airborne radioactivity monitoring
15.	Contamination control
16.	Respiratory control
17.	Training in radiation protection
18.	Personnel monitoring
19.	Bioassay program
20.	Implementation of ALARA program
21.	Area radiation monitoring system operation
22.	Process radiation monitoring system operation
23.	Meteorological monitoring

(1) Adapted from RG 1.33 for selected ESBWR systems

Table 6
Guidelines and Contingencies Described in BWROG EPGs / SAGs and Example Parameters for EOP Implementation

Guidelines and Contingencies Described in BWROG EPGs / SAGs
• Reactor Pressure Vessel (RPV) Control. • Primary Containment Control • Secondary Containment Control • Radioactivity Release Control • Contingency#1—Alternate Level Control • Contingency#2—Emergency RPV Depressurization • Contingency#3—Steam Cooling • Contingency#4—RPV Flooding • Contingency #5—Level/Power Control
Example parameters for EOP implementation
• Reactor Pressure Vessel (RPV) pressure • RPV water level • Reactor Power • GDCS, PCCS, and Suppression pool temperature • GDCS, PCCS, and Suppression pool water level • Drywell temperature • Drywell pressure • Drywell water level • Control rod scram status • Drywell oxygen concentration (when monitors are in operation) • Drywell hydrogen concentration (when monitors are in operation) • Wetwell oxygen concentration (when monitors are in operation) • Wetwell hydrogen concentration (when monitors are in operation) • Plant Radiation levels

Table 7
Example Administrative Control Procedures

	Plant Specific Administrative Control Procedures[1]
1.	Procedures review and approval process
2.	Equipment control procedures
3.	Control of maintenance and-modifications
4.	Fire protection procedures
5.	Crane operation procedures
6.	Temporary changes to procedures
7.	Temporary procedures
8.	Special orders of a transient or self-canceling character

(1) NUREG–0800 13.5.1

Table 8
Example Specific Administrative Procedures

	Specific Plant Administrative Procedures[1]
1.	Standing orders to shift personnel[2]
2.	Assignment of shift personnel to duty stations
3.	Shift relief and turnover
4.	Control room access
5.	Limitations on working hours
6.	Feedback of operating experience
7.	Shift supervisor administrative duties
8.	Verification of correct performance of operating activities

(1) NUREG–0800 13.5.1

(2) Includes authority and responsibility of the shift supervisor, senior operator in the control room, control room operator, and shift technical advisor

Appendix A

Summary of the BWROG EPG/SAG and its Application to the ESBWR

BACKGROUND:

The current revision of the BWROG EPGs / SAGs is divided into two discreet sections, Emergency Procedure Guidelines (EPGs) and Severe Accident Guidelines (SAGs). The EPGs define strategies for responding to emergences and to events that may degrade into emergencies until primary containment flooding is required. The EPGs and SAGs will be modified based on the ESBWR system design features, and the HFE design process. The examples discussed within this appendix are documented prior to the implementation of the HFE design review process, and as such are examples of the potential outcomes of the completed and approved accident mitigation products.

A.1 EOP / SAG DEVELOPMENT:

The following generic symptomatic EPGs have been developed:

- Reactor Pressure Vessel (RPV) Control Guideline
- Primary Containment Control Guideline
- Reactor Building Control Guideline
- Radioactivity Release Control Guideline

The SAGs define strategies applicable after containment flooding is required. They comprise two guidelines:

- RPV and Containment Flooding
- Containment and Radioactivity Release Control

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

The Containment Control Guideline maintains containment integrity and protects equipment in the containment with respect to the consequences of all mechanistic events. This guideline is entered whenever suppression pool temperature, drywell temperature, drywell pressure, suppression pool water level, or containment hydrogen concentration is above its high operating limit or suppression pool water level is below its low operating limit. Suppression pool and drywell temperatures are determined by plant-specific procedures for determining bulk suppression pool water temperature and drywell atmosphere average temperature, respectively.

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

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

The emergency procedure guidelines for the ESBWR design address all systems that may be used to respond to an emergency.

At various points within these guidelines, limits are specified beyond which certain actions are required. The bases and calculation methods for these limits are defined in the BWROG Emergency Procedure and Severe Accident Guidelines, Revision 2, Appendices B and C, respectively. While conservative, these limits are derived from engineering analyses utilizing best-estimate (as opposed to licensing) models.

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

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

Each procedure developed from these emergency procedure guidelines (EPGs) is entered whenever any of its entry conditions occurs, irrespective of whether that procedure has already been entered or is presently being executed. When RPV and Containment Flooding are required, the EPGs transition to the Severe Accident Guidelines (SAGs). The EPGs are exited and the operator returns to non-emergency procedures when either one of the exit conditions specified in the procedure is satisfied or it is determined that an emergency no longer exists. After a procedure developed from these guidelines has been entered, subsequent clearing of all entry conditions for that procedure is not, by itself, conclusive that an emergency no longer exists.

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

The ESBWR EPG/SAG was derived from Rev. 2 of the generic BWR Owners' Group Emergency Procedure and Severe Accident Guidelines. Adaptations were required to accommodate the unique design philosophy, plant configuration and specific systems and components of the ESBWR.

A.2 ESBWR EPG/SAG COMPARED TO GENERIC EPG

The ESBWR design has incorporated many desirable features and systems characteristic of earlier generation BWRs. Some common BWR systems have been eliminated or modified and some unique systems and configurations have been added to improve safety or operational characteristics in the ESBWR.

The purpose of this document is to provide information about the ESBWR design philosophy and features relative to other BWRs in limited, but sufficient detail to explain the rationale behind the adaptation of the generic EPG/SAG for use in the ESBWR. BWROG EPG/SAG Rev. 2 is used as the standard for comparison.

A brief summary of those features, which have had significant impact on the development of the ESBWR EPG/SAG is presented below.

A.2.1 ESBWR RPV and Related Features

The ESBWR is a natural circulation plant and has neither jet pumps nor external or internal recirculation pumps. Thus, there are no operator actions specified regarding control of recirculation flow. The reactor core is shorter in height than most of the earlier BWR designs and the reactor pressure vessel (RPV) is much taller, resulting in a much larger vessel volume to core power ratio. As a result, level transients are slower allowing more time for operator recovery actions. The ESBWR also has fine motion control rod drives, so specific operator actions to manually scram the reactor are different from those for the hydraulic locking-piston drives in earlier BWRs. The CRD system in the ESBWR can be operated in the usual (purge) mode or can inject flow into the RPV via the feedwater line (high pressure makeup mode). Where appropriate, a distinction between modes is made in the ESBWR EPG/SAG.

A.2.2 Isolation Condenser

Most operating plants have no isolation condenser and the relative capacities of those plants that have isolation condensers are much smaller than the ESBWR design. Thus, the ESBWR isolation condensers play a larger role for reactor pressure and level control in the ESBWR.

A.2.3 Emergency Core Cooling Systems

Operating BWRs typically have a full compliment of automatically initiated Emergency Core Cooling Systems (ECCS) for both high and low pressure injection, plus an ADS for vessel depressurization. High-pressure systems are typically steam driven (HPCI or RCIC). ESBWR has no steam driven or other high pressure ECC related injection systems.

In contrast, ESBWR has the capacity to gravity reflood the RPV using the ADS and the Gravity Driven Cooling System (GDCS). These two systems comprise the ECCS for ESBWR. The function of ADS is to depressurize the reactor pressure vessel (RPV) sufficiently so that the GDCS can re-flood at very low RPV pressure. Gravity re-flooding of the RPV can be accomplished by draining the GDCS. The RPV must be at essentially the same pressure as the containment for gravity re-flooding to be accomplished.

The ADS in ESBWR consists of 10 SRVs piped to the suppression pool and a set of 8 depressurization valves (DPVs) which discharge directly to the drywell. ESBWR ADS has no start time delay timer, but stages first the SRV openings in two groups of five with a delay in between; then after a further time delay, stages the DPV openings in groups with time delays between the groups.

A.2.4 ATWS Mitigation Systems

Operating plant Standby Liquid Control (SLC) systems are typically pump driven with borated water taken from a supply tank. The ESBWR SLC system is accumulator driven, necessitating that somewhat different directions be specified to the operator. ESBWR has an automatic ADS inhibit feature in contrast to earlier BWRs where manual action is required to inhibit, if needed. In contrast, ESBWR has no manual inhibit feature.

A.2.5 Containment Features

ESBWR has a unique natural circulation driven Passive Containment Cooling System (PCCS). This system condenses steam in the containment and has a vent for transport of non-condensable gases to the suppression pool that is driven by any pressure difference between the drywell and suppression pool. There are no valves or any other device requiring activation and thus no operator actions are specified in the EPG/SAG. The PCCS is mentioned here because of its inherent ability to control containment pressure and remove energy and its high likelihood of being in operation during any event without operator action.

A.3 EXAMPLE ESBWR EOP AND SAMG STRUCTURE AND PRESENTATION

ESBWR EOP writer's guide and ESBWR technical guidelines are developed using the following:

- BWROG EPG/SAG Rev 2
- Generic writer's guides
- Generic Technical Guideline (GTG)
- NUREG-0899
- NUREG-0800
- NUREG-0737

The ESBWR EOP writer's guide and technical guidelines are used to develop EOPs and SAMGs that are legible and intelligible and contain the following basic attributes (as listed in NUREG-0899):

- They can be easily read
- They can be read rapidly without interruption
- They can be precisely understood
- They can be understood without the aid of additional information
- The reader accepts the information presented
- They can be easily learned
- They can be retained
- They can be used easily for instruction
- They are simple, ordered, and pertinent

A brief summary of EOP and SAMG structure and presentation is presented below.

(1) EOPs and SAMGs are in the form of logic or flow charts.

(2) Entry conditions to the EOPs and SAMGs are clearly displayed in the HSI display panel.

(3) EOP and SAMG management parameters and variables are clearly displayed and verifiable in the HSI display.

(4) Sufficient laydown space is provided for hard copies of EOPs, SAMGs, other procedures, and other documents required by the operators during accident management and the performance of their regular duties.

(5) The main control console is equipped with both intra-plant and external communications equipment required to implement the EOPs, SAMGs, and other procedures.

(6) The laminated EOPs and SAMGs provide parameter set points for action. The EOPs may include call outs to other emergency support procedures (e.g., derived from SOPs, AOPs, or ARPs) specifying steps to implement an action or task for reaching safe shutdown. Computer based EOP and SAMG tracking systems provide updated parameters necessary for the operator to make each decision required on the same display as the procedure.

(7) The laminated EOPs and SAMGs provide reference to the control points. Computer based procedures provide the capability for the operator to access those controls needed to carry out the tasks directly from the procedure display.

(8) The laminated EOPs and SAMGs are used to record procedure path decisions. Computer based tracking systems provide information for reminding the operators of unresolved conditions, while the operator retains final control and authority on whether or not to proceed. Automatic logging of resolved and unresolved conditions are also provided.

(9) Operators use the laminated EOPs and SAMGs to record parameter values at key intervals. Computer based SPDSs provide continuously updated plant safety parameters and status presented as part of the procedure displays.

(10) The laminated and computer-based EOPs and SAMGs conform to industry and regulatory guidelines regarding HFE principles.