Enclosure 10

Technical Report MPWR-TECR-005006 (Redacted)

B&W babcock & wilcox nuclear energy

Human Factors Engineering Integration of Human Reliability Analysis

MPWR-TECR-005006

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B&W mPower™
a progressive energy solution

B&W mPower™ Reactor Program
Babcock & Wilcox Nuclear Energy, Inc.
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Lynchburg, VA 24501

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ABSTRACT

This technical report describes the integration of the human reliability analysis (HRA) with the human factors engineering (HFE) program specifically, and also generally, into the overall design. HRA is a structured approach used to identify potential human failure events and to systematically estimate the probability of those events using data, models, or expert judgment. HRA is one of the technical elements of a complete probabilistic risk assessment. The HRA considers the types and mechanisms of individual human actions, and therefore, it is important to analyze this information within the HFE program. The HFE program's goals of minimizing personnel errors, allowing error detection, and providing recovery capability benefit from the insights into human error probabilities documented within the HRA. This document describes the integration of the HRA with the HFE program and how this information is used to develop comprehensive mitigating strategies that address the issues identified in the HRA. HRA and HFE together form the basis for implementing a risk-informed design program. HFE facilitates a thorough analysis and consideration of performance shaping factors found in HRA methodologies. Therefore, the use of the HRA data within the HFE program provides a complete process that provides greater emphasis upon those plant scenarios, human actions, and human-system interfaces that are identified as being important to plant safety and reliability.

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RECORD OF REVISION

Revision No.	Date	Preparer	Description of Changes
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TABLE OF CONTENTS

List of Figures

1. INTRODUCTION

1.1 Applicability

This document is applicable to all human factors design activities for the Babcock & Wilcox (B&W) mPower™ reactor. This includes all B&W employees and contractors assigned to design activities of the B&W mPower reactor within the scope of the human factors engineering (HFE) program described in this report.

1.2 Scope and Objective

This technical report provides methods, criteria, and guidance to incorporate human reliability analysis (HRA) results into the human factors engineering (HFE) process. The report also provides a process for the incorporation of detailed design information back into the HRA. These looped processes ensure the following:

- Human-error mechanisms are addressed in the design of the HFE related aspects of the plant to minimize the likelihood of personnel errors that may affect plant safety.
- The design permits the detection of, and recovery from, errors.
- The HRA and the probabilistic risk assessment (PRA) effectively integrate with the HFE program.
- Operational experience is incorporated into the HRA process through its integration with the HFE program.
- The HRA uses performance shaping factors that concern:
  - Details of human-system interface (HSI) design
  - Functional allocation
  - Personnel qualifications and staffing

This technical report describes the process that ensures that HRA analysis results are integrated with the HFE program and design in accordance with the practices and guidelines established by NUREG-0711. By evaluating the potential for human error and the mechanisms of human error, HRA results can be utilized to positively affect plant safety.

1.3 Responsibilities

Work performed within the scope of this technical report is under the direction of the Unit Manager of the Integrated Design Process and Human Factors Engineering Program. The individuals performing the work are selected from the HFE design team. These HFE team members include, at a minimum, operations and systems engineering experienced personnel.

Engineers outside of the HFE team may be consulted on an as-needed basis. Other engineering personnel may be assigned to work within the bounds of the functional requirements analysis (FRA)/function allocation (FA) process and follow the direction of the FRA team members.

2. BACKGROUND

The HRA is one of the technical elements of the PRA process and constitutes a structured approach for identifying potential human failure events and systematically estimating the probability of those events using data, models, or expert judgment. There are several HRA methodologies, with some methods better suited for evaluating specific types of human errors. Many methods rely on the expert judgment of the analyst performing the HRA calculations. Different methods are capable of evaluating the influence of performance shaping factors (PSFs) that can impact the human error probabilities (HEPs). Although there are many methods of HRA, some are more suited for screening instead of detailed analysis. The following analysis attributes help to ensure the quality of the HRA:

- HRA meets all applicable 10 CFR 50.34(f)(1)(i) requirements.
- A multidisciplinary team analyzes human actions (HA) within the context of PRA.
- Available information related to those factors that affect human performance includes:
  - Accident analysis (determining time available for actions)
  - Task analysis (also determining staffing and qualification)
  - Procedures
  - HSI design details
- The effect of new technology on human performance is considered.
- Detailed analysis is performed of HAs with an emphasis on human error mechanisms.
- Appropriate sources of human error data for the types of HAs that are modeled are available.
- Sensitivity and uncertainty analyses are used to evaluate HEP estimates.
- PRA and HRA are integrated into design activities.
- The HRA process is thoroughly documented.

Since most HRA methods considered individually cannot fulfill all the criteria specified above, it is necessary to combine this program with the HFE program. The ability to perform a thorough analysis of individual actions is part of the HFE core competencies. The integration of HRA insights into the entire design process is completed through the HFE program. By focusing on the human element and the human interaction with the system, the HFE process seeks to utilize the HRA to minimize personnel errors, improve the likelihood of detection, and provide an

avenue for recovery should they occur. The HFE program assists in the analysis of the HEPs in relation to HSI. During testing of the HSI design, the assumptions (made in the calculation of the HEPs, thereby impacting PSFs associated with those assumptions) are evaluated.

3. METHODOLOGY

3.1 Responsibility

This plan is executed by a multidisciplinary team formed by members of the HFE group and the PRA group. The minimum skill sets include: plant operations, system safety engineering, reliability/availability engineering, and systems engineering. Other personnel are involved on an as needed basis to resolve specific issues and develop specific solutions to those problems related to the HSI. Procedure and training specialists participate during the emergency procedure guideline (EPG) development and ensure that the needs of the EPGs are fully considered within the HRA development process.

3.2 Approach

HRA is integral to the PRA process. The HRA results are shaped by the HFE process. The integration of these programs together forms the basis of a risk-informed B&W mPower design process. Both PRA/HRA and HFE are integrally involved in EPG development. Figure 1 describes the relationship of HRA within these elements. Arrows within the figure describe the normal flow of information and feedback within the process elements. This drawing is not meant to be a comprehensive explanation of all possible information flowpaths, but rather the general process flow. The results of HRA analysis are considered at all stages of HSI development from the FRA down through the workload assessment sections.

The level of detail of the PRA is commensurate with the identified uses and applications of the PRA. The HRA analysis results, including anticipated operator performance, form part of the basis for risk-informed decisions. [

] **[CCI per Affidavit 4(a)-(d)]**

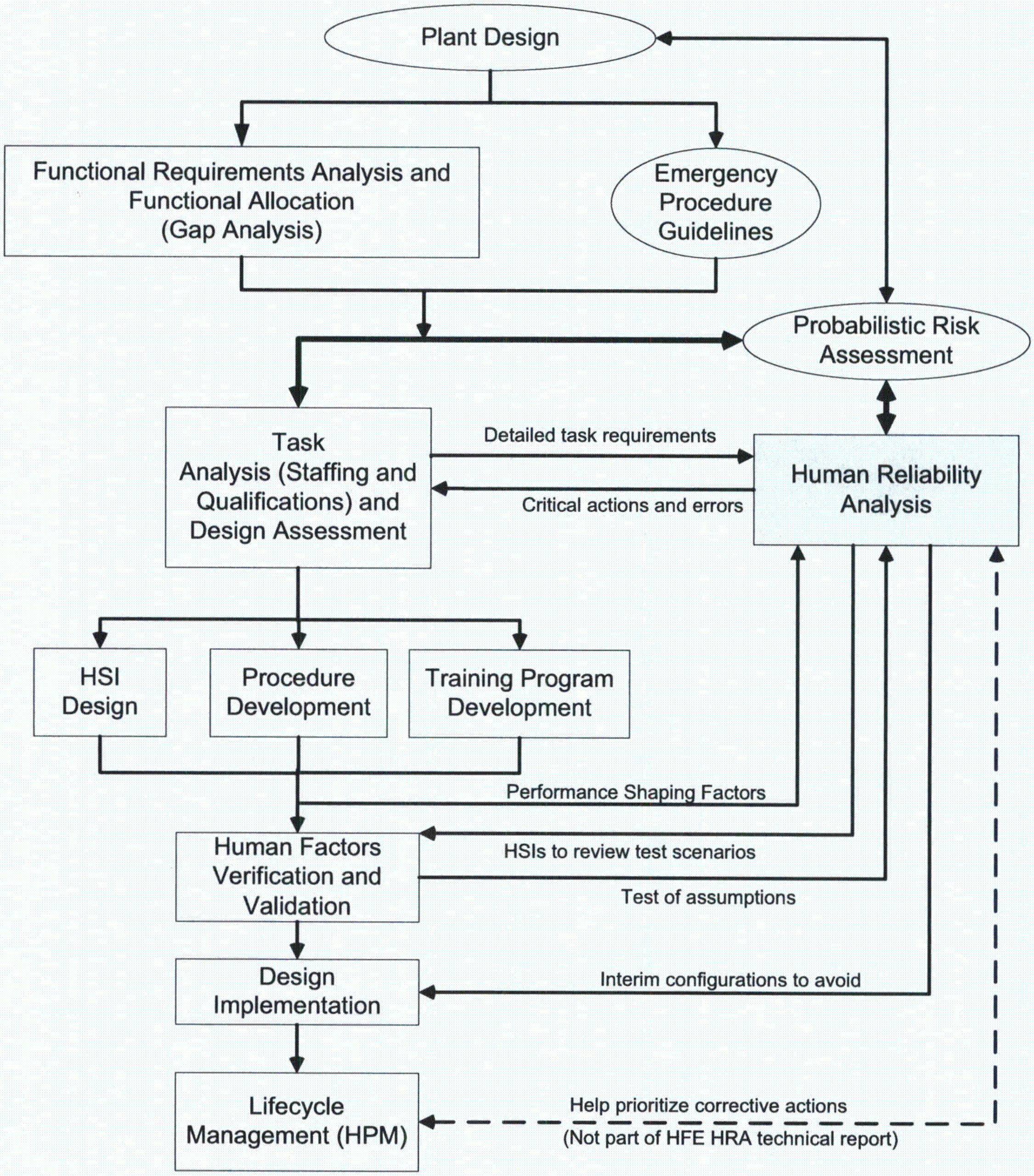

Figure 1. HRA Integration into HFE

Risk-important human actions are specifically addressed during each part of the HFE process. The HFE verification and validation (V&V) process completed at the conclusion of the design process shows that the B&W mPower design supports the successful completion of risk-important HAs. Successful completion of the HFE V&V proves that the design is within acceptable human performance capabilities and that all the functional requirements are met through the designed HSIs.

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[CCI per Affidavit 4(a)-(d)]

3.3 Risk-Important Human Actions

PRA identifies accident scenarios and considers the impact of HAs on these scenarios through the HRA process. The PRA/HRA identifies both pre- and post-initiator actions for analysis. Pre-initiator actions are those actions that, if not performed correctly, can leave equipment or systems unavailable to fulfill their function during an initiating event. Post-initiator actions are those actions that are taken in response after an initiating event.

The HEP contributions to these accident sequences are the focus of the HFE program. The risk-important HAs and their associated tasks are addressed within the operational analysis portions of the HFE program. This integrated linking of the HFE to the PRA/HRA is formed through both qualitative and quantitative means. The identification is done quantitatively using standard risk important measures derived from risk analysis and qualitatively from various criteria such as task performance concerns based on the consideration for performance shaping factors. This includes the FRA/FA for changes to the overall functions or their allocations for execution. The task analysis portion reviews risk-important HAs and their scenarios for mitigation strategies or elimination of the HA. HSI, procedures, and training improvements and any function allocation changes are also considered during the review of all risk-important HAs. These taken together provide for a design that supports human capabilities and attempts to remove human weaknesses. This forms the basic process of clarifying the operator requirements through the systematic examination by the operational analysis section of HFE. HRA methods typically identify errors of omission. To the extent possible, the design process identifies potential errors of commission (EOC). The risk-important HAs that are considered through this process are those actions that reach or exceed the established thresholds from the quantitative methods described within this document. The list of overall HAs considered for risk-importance is derived from individual lists modeled in the level 1 (core damage frequency [CDF]) and level 2 (large release frequency [LRF]) PRA analysis. These overall CDF and LRF risks are derived from the integration of individual PRA hazard groups (e.g., internal events, fires, flooding, etc.).

3.4 Review Criteria

At least two different importance measures and HRA sensitivity analyses from the Levels 1 and 2 PRAs (including both internal and external event analysis) are performed. The following criteria are used to identify risk-important HAs. Using several HRA analysis methods provides reasonable assurance that an important action is not overlooked due to the selection criteria or the use of a particular assumption in the analysis.

The HRA importance criteria to be used for risk-Important determinations are the following:

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[CCI per Affidavit 4(a)-(d)]

Similar risk-importance metrics are produced by the Level 2 PRA results, except that the criterion for risk-importance is associated with LRF instead of CDF.

3.4.1 Human Reliability Analysis Best Practices

Inclusion of human failure events, which could lead to support system failures, is considered. Human-induced initiators are not primary considerations of PRA; however, when a significant event is considered, this impact is fed back into the PRA. Although Regulatory Guide 1.200 does not explicitly address EOC, the design process identifies potentially important EOCs. The mPower design process identifies pre-initiator actions within each system where redundant or multiple diverse equipment can be affected by a single HA or through a common failure with similar multiple HAs.

3.5 Human Error Probabilities

HEPs are probabilities for human error actions in accident sequences that contribute to CDF and LRF. The quantification of the importance of HEPs establishes priority for the HSI needs. This risk-informed approach allows for the development of specific design features for the B&W mPower design. The HEPs are influenced by individual attributes referred to as PSFs. By verifying, clarifying, or changing the PSFs, improvements in the HSI design may reduce the value of the HEP.

3.6 Performance Shaping Factors

By analyzing the PSFs, the complexity and severity of the accident can be understood in relation to the HAs within the event analysis. HFE considerations when analyzing PSFs include:

- Are the cues clear from the available HSI?
- Is sufficient time for the action allotted and components arranged in a manner that makes them readily available?
- Are sufficient personnel available?
- Is the context of the accident relevant?
- Are there sufficient procedures available?
- Are the procedures correct for the assumptions?
- Is the training and qualifications of the performers adequate?

These questions denote considerations for changes in teamwork, required personnel skill levels, communication demands, or environmental conditions. The results of these considerations are analyzed through design assessment for possible design changes or improvements.

3.7 Human Action Dependencies

The determination of HA dependency is important and can affect the screening level. When there are many HAs affected by a change in the plant status (e.g., more than two), the likelihood of dependency increases. Dependent HAs are aggregated together for PRA modeling. Industry-accepted methods for evaluating dependency are used in the B&W mPower PRA.

3.8 Human Factors Engineering/Human Reliability Analysis Process Flow

As discussed earlier, the PRA/HRA group and the HFE group collaborate to support the integrated approach to both HRA and HFE. The HFE/HRA Interface process is presented in Figure 2. The process below is shown through a swim-lane structure as an aid in the understanding of the process.

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[CCI per Affidavit 4(a)-(d)]

Figure 2. HRA/HFE Interface Process

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] **[CCI per Affidavit 4(a)-(d)]**

3.9 Modifications

Modifications to the B&W mPower design after the design certification is complete follow the process flow described in this document. The initial HRA is consulted so that the personnel actions resulting from the modification and their interaction with the rest of the plant are considered. These modifications are in the form of upgrades to plant system, HSIs, procedures, or training. The changes can include anything that could change, or modify existing operator actions including operator response times. When analyzing these changes, the following items are considered in the same comprehensive manner as the original HRA. Changes to the CDF and LRF are documented by the PRA personnel.

- Are the original HRA assumptions still valid?
- Are the human errors analyzed in the existing HRA still relevant?
- Has the HEP for operators or maintenance personnel changed?
- Are there new errors that could be introduced that are not modeled in the current HRA/PRA?
- Are the consequences of errors different from the existing HRA?

4. SUMMARY RESULTS AND DOCUMENTATION

The following are the results of the HFE integration of HRA that are documented in a final summary report.

- The list of risk-important HAs that exceed the risk importance threshold (this includes their description including their assumptions)
- A description of how all assumptions and performance shaping factors were verified and validated
- All EPG assumptions associated with HRA that have been validated
- The list of dominant accident sequences that include HEPs, dominant systems, and how these HAs with their associated scenarios were addressed in the design process
- How risk-important HAs were utilized within the design process in order to:
  - minimize human errors
  - create an error tolerant design
  - provide for a design that allows for error detection and recovery

5. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

5.1 Definitions

Term	Definition
Human action (HA)	A manual action completed by a person in order to accomplish a task.
Human error probability (HEP)	A measure of the likelihood that various failure modes for plant personnel to obtain the correct, required, or specified action or response in a given situation. The HEP is the probability of the human failure event
Human-system interface (HSI)	A human-system interface (HSI) is that part of the system through which personnel interact to perform their functions and tasks. This interaction includes the alarms, displays, controls, and job performance aids (e.g., procedures, instructions, etc.).
Performance shaping factors (PSFs)	Factors that influence human reliability through their effects on performance. PSFs include factors such as environmental conditions, human-system interface design, procedures, training, and supervision.

Risk-important human actions	Actions that are performed by plant personnel to provide reasonable 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 probabilistic design objectives are met. From a relative standpoint, the risk-important actions may be defined as those with the greatest risk contribution in comparison to all risk contributors.

5.2 Abbreviations and Acronyms

B&W	Babcock and Wilcox
CDF	core damage frequency
EOC	error of commission
EPG	emergency procedure guideline(s)
EPRI	Electric Power Research Institute
FA	functional allocation
FRA	functional requirements analysis
FV	Fussell-Vesely importance measure
HA	human action
HEP	human error probability
HFE	human factors engineering
HPM	human performance monitoring
HRA	human reliability analysis
HSI	human-system interface
ISV	integrated system validation
ITS	issue tracking system
LRF	large release frequency
LOCA	loss of coolant accident
MCR	main control room
OER	operating experience review
PORV	pressure-operated relief valves
PRA	probabilistic risk assessment
PSF	performance shaping factor

PWR	pressurized water reactor
RAW	risk achievement worth
RCP	reactor coolant pump
SG	steam generator
SGTR	steam generator tube rupture
V&V	verification and validation

6. REFERENCES

6.1 Code of Federal Regulations

6.1.1 10 CFR 50§34(f)(1)(i), "Energy," Domestic Licensing of Production and Utilization Facilities, United States Nuclear Regulatory Commission

6.2 U.S. Nuclear Regulatory Guidance

6.2.1 NUREG-0711, Human Factors Engineering Program Review Model, United States Nuclear Regulatory Commission

6.2.2 NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition, Section 18.0, "Human Factors Engineering," United States Nuclear Regulatory Commission

6.2.3 NUREG-0933, A Prioritization of Generic Safety Issues, U.S. Nuclear Regulatory Commission

6.2.4 NUREG-1764, Guidance for the Review of Changes to Human Actions, U.S. Nuclear Regulatory Commission

6.2.5 NUREG-1792, Good Practices for Implementing Human Reliability Analysis, U.S. Nuclear Regulatory Commission

6.2.6 NUREG-1842, Evaluation of Human Reliability Analysis Methods Against Good Practices, U.S. Nuclear Regulatory Commission

6.2.7 Regulatory Guide 1.200, An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities, U.S. Nuclear Regulatory Commission

6.2.8 Regulatory Guide 1.206, Section C.I.18.6.1, Human Reliability Analysis, U.S. Nuclear Regulatory Commission

Appendix A. Generic Pressurized Water Reactor (PWR) Human Actions

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[CCI per Affidavit 4(a)-(d)]