HUMAN FACTORS ON THE POINT LEPREAU REFURBISHMENT PROJECT

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ABSTRACT

This paper describes the Human Factors Engineering Program Plan (HFEPP) being executed as an engineering activity during the Point Lepreau Generating Station refurbishment project. The scope includes human factors reviews/assessments of plant refurbishment design packages, design changes to the Solid Radioactive Waste Management Facility (SRWMF), and equipment design to support the fuel channel retubing process. The Point Lepreau Refurbishment (PLR) design work was screened to determine the Human Factors Engineering (HFE) level of effort required to adequately address the associated human/system interfaces. This paper explains the methodology for screening work package activities associated with each level of effort as well as specific activities related to the SRWMF and design of Retube equipment.

INTRODUCTION

In July 2005, NB Power Nuclear received approval from its Board of Directors and the Province of New Brunswick to proceed with the project to refurbish the Point Lepreau Generating Station (PLGS). Over the next 2 1/2 years, the project will proceed with detailed engineering and procurement activities in advance of an eighteen-month shutdown referred to as the Refurbishment outage. The major activity is the replacement of all 380 Fuel Channel & Calandria Tube Assemblies and the connecting feeder pipes. This activity is referred to as *Retube*. NB Power will also take advantage of this outage to conduct a number of repairs, replacements, inspections, and upgrades (such as rewinding or replacing the generator, replacement of shutdown system trip computers, replacement of certain valves and expansion joints, inspection of systems not normally accessible, etc). These collective activities are referred to as *Refurbishment*. This will allow the station to operate for an additional 25 to 30 years. The date for the start of the Refurbishment outage is April 2008.

This paper describes the Human Factors Engineering Program Plan (HFEPP) being executed as an engineering activity during the PLGS refurbishment project. The refurbishment scope includes plant refurbishment design packages, design changes to the Solid Radioactive Waste Management Facility (SRWMF), and Retube equipment design.

The HFEPP documents the means by which human factors considerations are integrated into the Point Lepreau Refurbishment (PLR) project to ensure designs and evaluations are performed in accordance with established human factors principles and practices. The purpose of the HFEPP is to identify the organization, responsibilities, Human Factors Engineering (HFE) activities, sources of HFE design criteria, and the tracking and resolution of HFE issues in the PLR project. This ensures compliance with CNSC Regulatory Policy P-119 *Policy on Human Factors* [R-1] and help ensuring that human capabilities and limitations are appropriately incorporated into design and operations.

BACKGROUND

Condition assessments of the PLGS systems have been performed and documented in condition assessment reports. The assessments included reviews of the station Unplanned Event Reports for each system. Combined with other evidence from operating documentation and operating experience, the condition assessment reports concluded with recommendations for correcting degradation of system components or general performance. All recommendations from condition assessments are being tracked to final dispositions and ranged from system modifications to operational changes.

The Point Lepreau Refurbishment (PLR) project initiates selected design changes to the plant, as identified by the PLR condition assessment process supported by Safety & Licensing assessments and approved by New Brunswick Power Nuclear. These changes range from straight-forward equipment replacement to more complex design improvements requiring substantive changes to the plant (examples are given in the later part of this paper). The HFEPP for the PLR project ensures that human factors will be integrated as part of the design work for these changes to the required level of rigor, ensuring that all PLR changes include appropriate HFE considerations.

Basis of the HFEPP

The PLR HFEPP was developed based on industry practices, guidance documents, and regulatory requirements. More specifically, its development was based on the following three documents, constituting a mix of standards and guidance documents:

1. IEEE Std. 1023-2004, IEEE Recommended Practice for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations and Other Nuclear Facilities (a standard) [R-2]
2. NUREG-0711, Human Factors Engineering Program Review Model (an internationally-adopted guidance document) [R-3]
3. G-276, CNSC Regulatory Guide – Human Factors Engineering Program Plans [R-4]

These three documents provide the HFE methods and design criteria for implementing the HFEPP. Specific PLGS design guides were also developed to provide project specific guidance to designers.

LEVEL OF HFE EFFORT

The level of HFE design effort assigned to each PLR design activity is based on an iterative evaluation against objective design criteria at various points in the design. An initial assessment of each design job for the level of HFE effort was conducted at the onset of PLR design work and included refurbishment Fixed Scope (FS) packages, SRWMF changes, and Retube tooling (including reactor face platform design).

The screening for HFE level of effort was conducted in accordance with AECL internal procedure for integrating HFE into design. This screening process resulted in design packages being placed into one of three levels of effort categories, these are:

- None – no HFE effort required
- Minor – small or restricted HFE effort and Minor Change Worksheets required
- Consultation – consultation with HFE specialist required to determine effort

To accomplish this initial screening assessment, HFE staff completed screening checklists for each refurbishment FS package by conducting interviews with the responsible branch managers, section heads, and system designers as appropriate. Note that the level of HFE effort assigned to a design activity can always be revisited/verified if changes to the original scope emerge, additional complexities or issues arise during detailed design, or new design packages are added to the project. Each level of HFE effort is described below.

None

When a design package is screened as “none”, no specific HFE activities are required. The lead designers of such packages may, if needed, contact the HFE specialist if they believe HFE design issues exist as they conduct the design.

Minor

Design packages requiring minor HFE involvement have all of the operational and maintenance design issues handled by the lead system designer using the HFE design guides (DGs) and the AECL HFE Minor Change Worksheets. The process of completing the HFE Minor Change Worksheets has been developed in consultation with other industry partners, including the CNSC. This ensures a generally consistent approach is applied across the CANDU industry that is cost effective and comply with regulatory documentation. HFE Minor Change Worksheets cover all human factors activities outlined in the next section.

Support from HFE specialists is also available throughout the design process to assist in completing the worksheets. Lead system designers received a combination of classroom training and on-the-job training. This on-the-job training occurs as part of completing the worksheets for their respective design packages.

Consultation

System designs requiring consultation HFE level of effort will have direct involvement of the PLR HFE team members. Specific HFE activities to be conducted for consultation design packages are outlined in the next section in a generic fashion, describing what may be done for any given FS package, dependant upon the complexity and safety significance of the human-machine interface.

HUMAN FACTORS ACTIVITES

Figure 1 illustrates the structured process within which the HFE activities will occur. Element 1 is the activity of developing the HFEPP. Activities for Elements 2 through 10 are identified below.

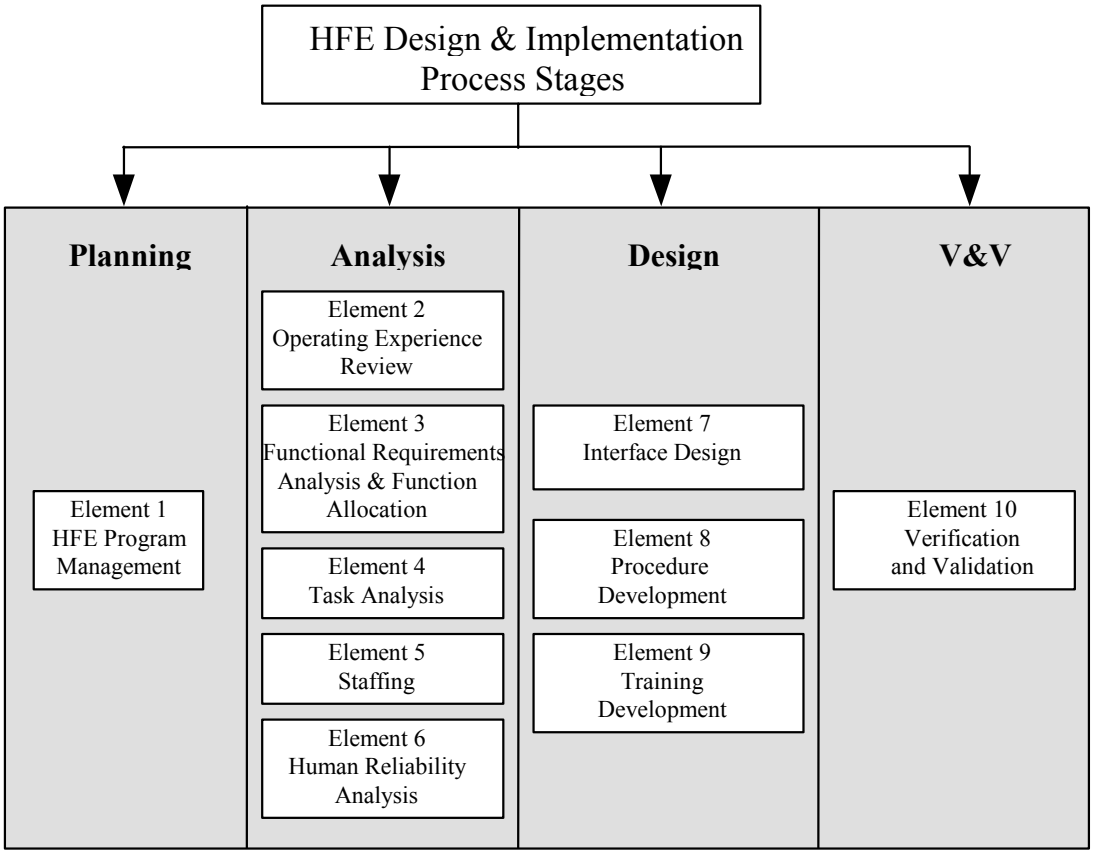

Figure 1 Human Factors Engineering Program Review Model (from NUREG-0711, p. 1-8) [R-3]

Element 2 - Operating Experience Review

An Operational Experience Review (OER) is performed to identify HFE-related issues as required to augment detailed design work. OER information is included in the selection of design changes as described in the background section. If OER is required as part of detailed design, the intent is to review documentation and survey personnel to obtain operating experience related to existing Human-System Interface (HSI) issues so that they may be addressed in the design change.

Element 3 - Functional Requirements Analysis and Function Allocation

Functional requirements analyses is performed as required to provide the framework for the HSI design, and for completion of detailed task analyses. Functional allocation is the analysis of the requirements for plant control and the assignment of control functions to:

1. personnel (e.g., manual control),
2. system elements (e.g., automatic control), and
3. combinations of personnel and system elements.

Element 4 - Task Analysis

Task analyses is developed to identify HSI requirements and potentials for human error associated with operating and maintaining systems under change. In some cases formal task analyses may not be completed although task requirements will always form a design consideration.

Element 5 – Staffing

There is no intent to alter the staff structure at PLGS as a result of PLR design changes. Where HFE analyses suggest altering staff roles and responsibilities, these are identified and forwarded to site staff for consideration.

Element 6 – Human Reliability Analysis (Safety Analysis and Risk Assessment)

The Point Lepreau Human Reliability Analysis (HRA) report is part of the Point Lepreau Probabilistic Safety Assessment (PSA) and the Point Lepreau Safety Report. Any changes to human-credited actions in these reports are forwarded to HFE for consideration.

Element 7 – Interface Design (HSI)

The results of the HFE analyses (Elements 2 through 6) are applied in the detailed design stage. The PLR Design Guides, which capture existing practice, are followed whenever possible. At times, it may be necessary for HFE staff to inspect the Point Lepreau control room or field panels, and/or interview operations and maintenance personnel to establish

existing practice or the impact of a unique design change not specifically covered by the DGs.

Elements 8 and 9 – Procedure and Training Program Development

Relevant HFE reports (e.g., task analyses, HSI designs, etc.) are provided to PLGS staff as input to support required procedure and training program modifications and developments. PLR HFE will meet with these personnel (e.g., System Responsible Engineers writing procedures, and Training Department staff) to ensure the content of HFE reports are clear, and requirements are understood.

Element 10a – Design Verification

Design verification is performed as stated in the PLR design verification plan. HFE designers review and comment on design documents from approved FS packages categorized as consultation. Design documents with a 'minor' HFE level of effort are reviewed when requested to do so by the PLR designer. HFE documents, on the other hand, are reviewed by a human factors specialist.

Element 10b – Design Validation

HFE design validation is accomplished through tabletop walkthroughs and/or desktop Main Control Room (MCR) simulator based trials with subject matter experts. Tabletop validations use drawings, photos or static mock-ups.

All design packages receive a standard site review, which includes operations personnel. Wherever practical, a walkthrough with a suitable user expert is conducted in addition to the standard document reviews described above.

A HFE Summary Report (HFESR) will be prepared to summarize all HFE activities for all FS packages on the PLR project. The HFESR is a mandatory document to satisfy project reporting and regulatory reviews.

IMPLEMENTATION OF THE HFEPP

Refurbishment Packages

Twenty-five FS design packages are part of the HFE design work for the PLR project. These range from shutdown system trip improvement to new turbine instrumentation and controls. Each of the 25 packages was classified according to a HFE level of effort. Table 1 gives a general overview of the preliminary screening for design packages with a 'consultation' level of HFE effort.

Table 1 Preliminary screening for design packages with a 'consultation' level of HFE effort

Consultation
Replace Programmable Digital Comparators (PDC)
SDS1 Trip Coverage Improvements
SDS2 Trip Coverage Improvements
Main Control Room HVAC Filter System
New Turbine Instrumentation and Controls
UPS Inverters and Rectifiers Replacement
Probabilistic Risk Assessment
Main Generator and Auxiliary Systems
Modifications for SRWMF
Production of four Human Factors Engineering Design Guides

Example #1: Main Control Room HVAC Filter System

The function of the MCR HVAC system is to provide safe and comfortable conditions under a controlled environment for the personnel inside the control room. These systems must also ensure the operability of control room components during normal and emergency conditions such as Loss Of Coolant Accident (LOCA), Loss Of Emergency Core Coolant (LOECC), and Loss of Containment. To maintain these objectives, the main control room area must remain habitable even in the event of accidental radioactive material release to the outside atmosphere. Hence, a MCR HVAC filter system will be added to the current HVAC system.

Human Factors will be considered in the design modification of the HVAC system. The Control Equipment Room (CER) HVAC panel will be modified as required to accommodate new controls of the new filter unit. The information regarding system operating parameters and component status will be presented as a mimic and will be reviewed to ensure consistency with current station's conventions, and clarity of presented information. Human Factors will also be considered in the design of the air filter unit to ensure proper maintenance, inspection, and testing can be conducted through effective equipment layout and adequate maintenance envelopes.

Example #2: Replacement of Turbine Instrumentation and Controls

The present turbine control systems and instrumentation supplied by the turbine-generator Original Equipment Manufacturer (OEM) has been in operation since 1983 and is now, by modern standards, obsolete. The refurbishment work on the turbine instrumentation and controls will (1) Replace the existing analog Electro-Hydraulic Governor (EHG) system with a modern digital EHG system; (2) Replace the existing Turbine Supervisory Equipment (TSE); (3) Replace the mechanical over-speed system with a modern electronic system; and (4) Update digital control computer (DCC) software and the MCR panel to interface with the new EHG and TSE.

The replacement of turbine instrumentation and controls has been categorized as a "consultation" package. As a result, HFE work will be considered in the design modifications of the system. MCR control panels will be modified as required to accommodate new control systems supplied with the digital EHG and TSE systems. The new controls will provide an operator interface with the turbine-generator that will include a soft control workstation (colour CRT or LCD display) with the appropriate control input device (e.g., keyboard, mouse/trackball, touch-screen) and printer. The screens will include mimic displays and will have the ability to display EHG/TSE alarms and to trend parameters. The turbine-generator EHG/TSE annunciations will be incorporated into the existing MCR and DCC annunciation system. The annunciation warning systems will conform with existing plant annunciations procedures. The CER workstation will be designed to duplicate the MCR workstation controls and in addition, provide on-load valve testing and fault diagnostic capabilities. Since this work is part of a refurbishment project, it is important that the MCR and CER control panels be designed to minimize the removal of existing controls while enhancing the human-machine interface (e.g., minimize errors associated with sequential operations, mental conversions etc.).

Retube activities

The main Retube activity consists of replacing all 380 fuel channels and calandria tubes during the PLR. This will include replacement of the pressure tube, annulus spacers, end fitting assemblies, and calandria tube. Several HFE considerations must be taken into account for tools, reactor face work, and the Retube Operations Centre (ROC).

Tools

Several specialized tools and numerous standard/common tools will be required to complete the retubing work at PLGS. Specialized tools may be custom designed with motor driven components and controlled by operators using dedicated pendant control/display HSIs, while more common/standard tools will be used such as hand tools. HFE aspects of tool design will be handled using the Minor Change Worksheets and associated DGs. This approach was taken because there is a large number of tools and the HFE level of effort required to complete each design may vary considerably. Additionally, the worksheets provide a standard format for the HFE design work and documentation.

In order to apply the Minor Change Worksheets in an effective and efficient manner, the following process will be followed:

The tools were evaluated by HFE and tool designers. Each tool was placed into one of three categories, as follows:

1. Established tools – these are commonly used tools and have a successful operating history. These tools will be used "as is" and no further engineering

work on their design is planned (e.g., positioning assembly tool). For these tools, no HFE design effort is required and worksheets will not be completed.

2. Similar tools – These tools require some level of HFE design effort and regardless of HFE effort, are similar and can have their HFE design managed with a single worksheet. The degree to which HFE supports the design of these tools will be discussed with each tool designer and recorded on the HFE worksheet.

3. Specialized tools – These tools require some level of HFE effort and are unique. A worksheet will be completed for each tool in this category. The degree to which HFE supports the design of these tools will be discussed with each tool designer and recorded on the HFE worksheet. The use of the Minor Change Worksheets for tools is not a strict classification of level of effort. Both similar and specialized tools may require significant HFE input. The categorization is applied in order to achieve an economy of effort in documentation.

Reactor Face Work

Design for reactor face work constitutes work platforms, communication systems such as headsets and telephones, and environmental aspects such as lighting. The reactor face is also the location where operational tasks are integrated into jobs. Each of these areas of reactor face work will have their HFE design handled in the following way:

- Platforms: civil designers will apply Retube HFE DG and HFE will participate in review and comment of design documentation.

- Communication equipment: the need for communications will be established as part of completing the design of each tool and included as part of Minor Change Worksheets.

- Integrated tasks: HFE will perform a task analysis of a typical removal operation sequence and of a typical installation operation sequence to identify issues arising from the use of tools in combination and to ensure workspace and communication provisions adequately support personnel. The analysis of integrated tasks combined with task analyses of individual tools and the integrated validation will provide assurance that the design will support personnel in accomplishing their operational goals.

Retube Operations Centre

The ROC is a centralized monitoring facility that will accommodate several people who have monitoring responsibilities for Retube operations. For HFE aspects, the ROC will be treated as a “Consultation” design package, requiring specific definition of HFE activities against the program elements described earlier.

Validation of Retube Equipment

HFE validation work will be conducted as part of completing Minor Change Worksheets and additional validation activities will be incorporated into trials planned using a full-scale Retube mockup located at Sheridan Park. This mockup will provide a test-bed for testing the functionality and operability of Retube tools and HFE aspects will be incorporated into the trials.

Solid Radioactive Waste Management Facility

The SRWMF expansion includes the expansion of the Point Lepreau Phase I and Phase II waste areas and the addition of a new Phase III area, designed specifically to store and manage waste from the Retube and refurbishment. The Phase I expansion and Phase III construction include the completion of new waste storage structures (e.g. vaults and Retube canisters). The Phase II expansion includes only the grading and preparation, as new dry fuel storage containers are not currently required. The scope of the work also includes the means of transport of the waste from the plant to the SRWMF site, and into the storage containers, and site monitoring.

At the time of writing this paper, HFE design work on the SRWMF was mostly complete. Since the SRWMF expansion project was treated as a 'consultation' package, the nine steps related to HFE activities outlined in the previous sections were applied. They are summarized below:

Operating Experience Review

Operational experience (OPEX) was gathered from several sources. The AECL Feedback Monitoring System (FMS) and the COG OPEX databases were reviewed for issues relating to waste storage, dry waste in particular. Operators from PLGS were also interviewed regarding areas of potential improvement on certain SRWMF tests. Designers also drew on individual and expert operational experience

Functional Requirements Analysis and Function Allocation

The Phase I and II expansions will be functionally identical to the existing Phase I and II sites, and formal function analysis was not performed, as OPEX did not indicate any difficulties relating to functional allocation. The Phase III function analysis was performed and documented.

Task Analysis

The operational strategy being considered for the Point Lepreau SRWMF facility task analysis is normal operations. SRWMF also covers abnormal operations, including storage of special (non-routine) waste, damaged waste packages, transfer of waste between cylinders, or loss of support systems. However, specific task analyses were not performed for these situations, as they were less common events, and covered in other

areas of review (i.e., function analysis, document review, validation, etc.). Task analysis was performed on the task involving the transfer of waste to the Phase III canisters.

Staffing

Due to schedule demands, the Retube activities, and thus the transfer of waste to the SRWMF, will proceed 24 hours per day. This means that staff will work in shifts. The duration of these shifts will be determined based on estimated dose following the time and motion study, and taking into consideration all provincial and federal labour requirements.

Human Reliability Analysis

A review of the input to the SRWMF Safety Report due to the expansion indicates that there are no credited human actions impacted by the work being performed under SRWMF.

Interface Design

The means of operator interaction with the various equipments (e.g., loading interface device, curb adapter, transfer flask, etc.) to be used was reviewed and discussed with designers. This includes physical interaction (e.g. how to open the gate) and indications. The exact location and coding of indication has not been determined for all equipment, although annunciation/indication requirements have been reviewed by the HFE team. The final indications will be in accordance with the Main Control Room Unit Panels and Field Control Panels DG, with human factors specialist input as required.

Procedure and Training Program Development

HFE has reviewed the preliminary input to the Operating Manual, and has discussed the procedures for the existing system with subject matter experts. The new systems are based on the current system and procedures are expected to be similar except for the Retube canister. There will be changes to the procedures including the use of the new interface equipment and the ability to work at close proximity to the flask.

Design Verification

All HSIs as specified in the Design Requirements documents will be compared to the final issue of the design description and drawings to ensure the presence and adequacy of the appropriate HSIs. This review will include any significant changes as a result of the Design Reviews.

Design Validation

The SRWMF validation was performed in 2003 at PLGS. The validation was performed using site, structure and support equipment drawings, as well as computer-generated models showing the interaction of the various system components at certain phases of the waste transfer cycle.

CONCLUSION

HFE considerations have been an established aspect of the PLR project starting in the pre-project condition assessment and safety assessments. The integration of HFE in the PLR project has been formalized and carried directly into the project phase via the HFEPP and its associated activities. Implementation of the HFEPP is currently underway and is expected to be completed by mid-2008.

REFERENCES

[R-1] P-119, Policy on Human Factors, Canadian Nuclear Safety Commission, October 2000.

[R-2] IEEE 1023, IEEE Recommended Practice for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations and Other Nuclear Facilities, Institute of Electrical and Electronics Engineers (2004).

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[R-4] G-276, Regulatory Guide – Human Factors Engineering Program Plans, Canadian Nuclear Safety Commission, June 2003.