DEVELOPMENT OF A HUMAN FACTORS ENGINEERING PROGRAM FOR NEW CANDU PLANT DESIGNS

J.S. Malcolm and J. Pauksens
AECL CANDU
Sheridan Park Research Community
Mississauga, Ontario, Canada
L5K 1B2

ABSTRACT

The Human Factors Engineering Program Plan (HFEPP) concept, which is relatively well established in the military systems domain, offers a systematic approach for the incorporation of human factors data and design practise into the nuclear power plant life cycle. The objective is to identify areas and methods for achieving enhanced human performance in diverse aspects of plant design, construction, commissioning, and operation. The view taken of Human Factors is much broader than in the past, and includes consideration of operational factors such as station staffing arrangements and operating procedures, as well as more traditional aspects of human/machine interface design. A generic HFEPP which is being jointly developed by AECL CANDU and OH provides a broad general model for HFEPP's in the CANDU power plants. The CANDU 3 experience with the HFEPP concept indicates that special attention to project specific circumstances and requirements is necessary and appropriate for practical cost-effective implementation.

INTRODUCTION

The life cycle of a nuclear power plant involves many complex phases, each requiring attention to the specific Human Factors (HF) issues relevant to various project personnel (e.g., operators, maintainers, construction, commissioning and decommissioning personnel). It also includes an ongoing process of change as technology evolves, as new requirements emerge, and as experience reveals new challenges and opportunities to maintain or improve performance. In order to meet these wide-ranging and ongoing requirements, a comprehensive, but flexible program is needed that is established and committed to early in the course of any project or any major change or refit during the life of the plant. Such an approach has been developed in the form of the Human Factors Engineering Program Plan (HFEPP).

Purpose of a HFEPP

The purpose of a HFEPP is to define, at a level appropriate to the job concerned, the extent of the required program in human factors. The

HFEPP approach is applicable to human factor-related activities in every stage of station design, and sets requirements for documenting these activities. A HFEPP can apply to any job, whether it be a new design, retrofit, an operational change to an existing plant or any other significant undertaking.

In the Canadian nuclear industry, human factors have been an important part of control centre design for many years and have also been directly applied to occupational health and safety, operator selection, and human reliability analysis. However, despite these applications and despite a general sensitivity to human factors in some other design areas, there has been no broadly based integrated human factors program; and, in many aspects of station design/operation, there has been no formal application of human factors.

The HFEPP concept originated in military systems design and is a relatively well-established approach in that domain. There is a growing awareness now in the power industry, both within Canada and abroad, of the potential for human performance improvements through the HFEPP. A systematic approach to the incorporation of human factors data and design practice will help alleviate a number of design issues where humans are involved. For example: reducing information overload during plant transients, integrating new technology such as soft, VDU-based control, into the human/machine interface,or enhancing maintenance of difficult-to-access equipment, a problem often exacerbated by radiation protection clothing.

Benefits of HFEPP Approach

The HFEPP offers potential benefits in at least three main ways:

1. It identifies at the outset of a job all the areas where human performance can be usefully enhanced through the application of human factors - making human involvement safer, more efficient, more productive, more reliable - and establishes a consensus between all affected groups as to the required scope of human factors in the job and the methods to be used.

2. It encourages an integrated application of human factors to the areas identified and agreed on, so that overall objectives are clear and so that the approaches to meeting them are consistent and/or complementary from area to area, rather than being determined separately and in isolation.

3. It encourages a broad approach to decision-making and to the assessment of operating experience, so that the most appropriate and effective solutions can be found without being limited by

individual group responsibilities. Thus, the investigation of an incident at an operating station could include a review of broad organizational, training, and communication issues as well as more specific design and procedural issues.

International Perspective

Internationally, there have been several developments that point to the need for systematic incorporation of human factors in power plant design. For example: IEC 964 (Design for control rooms of nuclear power plants, IEEE 1023 (Guide for the application of human factors engineering to systems), equipment and facilities of nuclear generating stations), and EPRI 4350 (Human engineering design guidelines for maintainability). These documents vary in the degree to which requirements are prescribed, but the general message is the same - develop a program for the systematic and timely inclusion of human factors and document it.

The external documents are providing an impetus and useful direction for the integration of human factors within our designs. However, we have found them to have various shortcomings in meeting the unique requirements of particular projects such as CANDU 3. For example, IEEE 1023 lays down a valid general design philosophy but does not provide detailed guidance about design methodology. IEC 964 does provide quite detailed methodology recommendations, but prescribes a very extensive and costly plant function analysis which is predicated on the assumption that the control system design is a totally new one, rather than one which inherits a great deal of proven technology, functionality and architecture from earlier, operationally proven CANDU designs. Because of such considerations, we have found that more detailed human factors engineering guidance, tailored to the particular needs of particular projects, is necessary for cost-effective implementation.

GENERIC HUMAN FACTORS PROGRAM PLAN

In order to reduce costs and encourage a common approach to the development of HFEPPs for specific projects, a generic HFEPP is being developed jointly by AECL CANDU and Ontario Hydro (Reference 1). The generic HFEPP will be provided as a guide to designers/specialists responsible for developing project-specific plans. The generic plan contains all the various human factors program elements that are relevant to a new nuclear plant design. It also contains reasonable latitude for technical specialists and project managers to provide judgement and innovation consistent with specific projects, in order to accommodate any unique requirements and constraints. In other words, the comprehensive generic plan can be (and normally is)

"tailored" by selecting human factors activities in accordance with project-specific scope, scale, cost and schedule.

General Content

The potential scope of the human factors program defined in the generic HFEPP is much broader than the approach applied to earlier projects. The areas of human factors application include the well-established ones (e.g., those related to control centre design), but they extend as well to many aspects of generating stations where we have not formally addressed human factors in the past. The following outline indicates the proposed scope of the generic HFEPP. Note that the subjects shown against each heading are representative, but the lists are not meant to be restrictive.

1. Design
   - control centre design
     - room layouts
     - control panel arrangement
     - anthropometrics
     - information display
     - operator control devices
     - human-computer interaction devices
     - human factors aspects of supervisory control
     - environmental conditions
     - human reliability analysis (HRA) in safety assessment
     - verification, validation of control centre design
   - plant design
     - equipment accessibility
     - plant layout (e.g., radiation zoning)
     - operability, maintainability
     - labelling, signs
     - human reliability analysis (HRA) in safety assessment
     - environmental conditions

2. Operator selection and training
   - education qualifications
   - selection criteria
   - training philosophy
   - qualifications of training staff
   - training materials
   - use of simulators
   - validation of selection and training

3. Procedures
   - commissioning, operating, testing and maintenance
   - presentation
   - workload assessment
   - validation

4. Station operational management
   - organization
   - job definition
   - reporting mechanisms
   - staff communication
   - policies and administrative procedures
   - shift schedules
   - authorization/responsibility
   - operational records
   - supervisory style and authority gradient

Responsibility

Typically, responsibility for an HFEPP would be split between the design organization and the operating organization. Design ensure that the more traditional human factors engineering areas are satisfied, such as: anthropometry, display and control layout, basic ergonomic features of hardware and operator workload (both physical and cognitive). The operating organization ensures that such issues as training (operators and maintainers), assigned responsibility, teamwork, reporting mechanisms and general plant organization support safe and reliable human operation. It is currently proposed that any given HFEPP will eventually be composed of both these "areas". As a result, plans will most often be started by design organizations in order to deal with the immediate needs of a design schedule, but will at some point (the earlier, the better) be passed to the operating organization for the appropriate additions and be maintained by them over the life of the plant.

CANDU 3

Practical aspects of applying the HFEPP concept to new CANDU plant designs are illustrated by the CANDU 3 experience. In that project, the HFEPP concept is being applied across the plant, but with some practical restrictions. One of these restrictions stems from the fact that the development of a CANDU 3 human factors program began well after the start of design (several years). As a result, human user aspects of the initial plant design were based, following traditional design practice, on the judgement and experience of the designers and on various design reviews which included experienced utility operations personnel as reviewers. This was augmented by new three-dimensional CADDS modelling of plant and equipment layouts, which

facilitates visualization of space and accessibility for service and maintenance. A maintenance assessment review of the civil engineering design augmented the review of space allocations. Further reviews are planned for later stages of design and commissioning.

In the case of CANDU 3 control centres, the design work is done relatively late in the project, making it possible to incorporate human factors more formally into the design process. Control centre development was initially supported by a link analysis of personnel traffic patterns. This was done to assess the merits of various locations within the overall site plan. Following this decision, conceptual room layout was carried out. This involves mapping of the basic plant functions to operator work stations in the control centres. As the design evolves, attention to operator tasks in the control centres will be addressed in several ways. This will include a review of task allocations, i.e., whether tasks have been automated or given to the operator), task analysis, supported by operations feedback, to guide the panel and CRT human-machine interface design, a full-scale, quasi-dynamic mockup of the main control centre for evaluation of selected operator interfaces (e.g., annunciation system) and finally, full procedure development and evaluation in a full-scale simulator by utility personnel, supported by AECL CANDU.

In the design of the control centre, human factors attention is given to all systems. However, recognition is given (Reference 2) to the evolutionary nature of the human/machine interface design relative to earlier, operationally proven CANDU designs. Hence, the principal focus is on those areas of the design which have been found in the past to be operationally limiting, or which are affected by plant design changes or advances in interface technology.

CONCLUSIONS

In summary, recent new international standards and guidelines, and growing awareness of the importance of systematic treatment of human factors have motivated the introduction of the HFEPP concept in CANDU design. A generic HFEPP, which is being jointly developed by AECL CANDU and Ontario Hydro, provides a model for project-specific HFEPPs, and has the objective of reducing program development costs and encouraging a common approach. Our CANDU 3 experience (as well as experience on other projects) indicates that special attention to project-specific circumstances and requirements is necessary and appropriate for practical, cost-effective implementation.

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