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Environment Design for Digitalized Main Control Room in Nuclear Power Plant

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Abstract : The purpose of the Environment Design (ED) for Main Control Room (MCR) of Nuclear Power Plant (NPP) is to provide and create an optimal working space to be free from physical, physiological and mental stress as well as environmental discomfort, based on the previous environment design experiences and to recommend the best ED including the color, the lighting and the interior design.

Environment Design consists of three main areas: Human factor engineering design, Interior design with color design, and Lighting design. These design areas have been interactively cooperated in a way that each design specialist would share the objectives and concepts of the Environment Design for MCR.

The specialists for Human Factors Engineering design had a corporative role in such a way to provide the guidelines for MCR design suitability of Interior and Lighting design considering the Human System Interface (HSI) safety concerns.

This paper describes fruitful efforts to create the best fit for MCR ED among several design proposals with the design recommendations, impacts, and contributions to NPP environment.

Key Words : Main Control Room, Nuclear, Environment Design, Human Factors engineering

1. INTRODUCTION

There are three main areas for the Environment Design: Human factor engineering design, Interior design with color design, and Lighting design. As shown at Figure 1, these three design areas are interactively cooperated in a way that each design specialist would share the objectives and concepts of the Environment Design for BNPP 1&2. Human factor engineering design had a critical role of the cooperation in such a way to provide the guidelines for MCR design suitability of Interior and Lighting design

In order to assure quality product within limited resources and times, we had a design process with top-down and iterative steps as shown at Figure2.2. Each process step had a feedback after the debriefing session until the consensus

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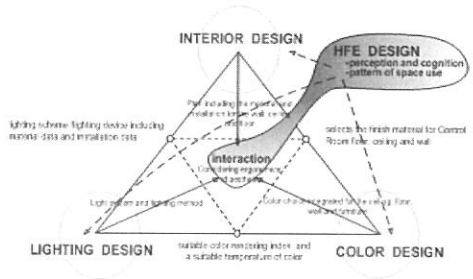

Figure 1. Three areas of Environment Design

has been achieved among the technical groups.

BNPP 1&2 MCR should be an emulated model of APR1400 which is an advanced type of digitalized MCR such as SKN3&4 in Korea. Many issues involved in emulating APR1400 were collected and used to build the concept of BNPP1&2 MCR. In order to get the design fidelity of the resolved issues of BNPP1&2 MCR design, technical surveys and anthropometric data collection in UAE have been performed.

Based on the collected data and concepts, Interior design and illumination design alternatives for BNPP1&2 MCR were proposed by each technical group. The MCR design suitability for the proposed designs was evaluated by the HFE specialist according to the human factor engineering guidelines which were developed with the integration of NUREG based HFE guidelines. Finally, the best alternative design was selected after considerable iterative steps with safe-concerned feedbacks from debriefing session of technical groups

2. HFE Design

A Human Factors Engineering (HFE) for Main Control Room (MCR) of Nuclear Power Plant (NPP) has been applied to optimize the design and operation of Man-Machine Interface (MMI) between operators and their equipment in consideration of physical, psychological and cognitive aspects. However, it has been observed that operators complain about environmental discomfort in the MCR since the operators in the MCR experience excessive stress due to the environmental factors such as inappropriate interior and lighting system.

Since the HFE is an essential factor for the high fidelity performance of operators in the MCR, the adequate MCR environment design with HFE rules and guidelines is as much important to enhance the operability and reliability of the MCRs. Therefore, there has been a strong need to design a pleasant environment for the MCR to improve human performance of the operators.

The purpose of the Environment Design (ED) for the MCR of NPPs is to create an optimal working space to be free from physical, physiological and mental stress as well as environmental discomfort, based on the previous environment design experiences and to recommend the best ED of the color, the lighting and the interior. To pursue the user-friendly design, the preference survey and anthropometry measurement were conducted in the ENEC office in Abu Dhabi by the KEPCO E&C HFE expert team to optimize the BNPP 1&2 MCR design. A number of ENEC employees participated in the questionnaire survey and anthropometric data collection, which will be valuable inputs to the MCR design and be utilized as licensing defense for the BNPP 1&2 MCR design.

It is necessary to validate the survey results to apply them to the ED of BNPP 1&2 MCR. Fortunately, the anthropometric data collected from UAE people showed that there were not significant differences of anthropometry between UAE people and Korean so that we could employ and implement the reference plant' s MCR physical configuration design into BNPP

1&2 with a slight design change. This chapter describes the detail results of the survey and anthropometric data collection.

3. HFE Evaluation

HFE guidelines have been developed as a Verification & Validation tool for system design suitability and the style guidance tool for system design process. NUREG-0800 chapter 18 in NRC Standard Review Plan (SRP) describes the requirement for employing the evaluation model of NUREG-0711 as shown at Figure 2. NUREG-0711 recommends the use of HFE guideline such as NUREG-0700 for the verification and validation of NPP system design suitability.

For the evaluation of the human factor design suitability for BNPP1&2 Environment Design, 65 human factor items of 22 categories in 4 design areas were selected and evaluated. 4 main design areas for the human factor evaluation are general design, illumination design, interior design, and color design. Details are as follows.

General design: 6 categories, 21 items
- Layout(6)
- Document organization(2)
- Storage(5)
- Supervisor Accessibility(2)
- Communication (5)
- Comfort(1)

Illumination design: 7 categories,14 items
- Illumination level(3)
- Task area luminance ratio(1)
- Ambient illumination(4)
- Material reflectance(1)
- Reflective glare(1)
- Surface color(1)
- Luminaries(3)

Interior design: 7 categories, 26 items
- Consoles ergonomics(7)
- VDU layouts(3)
- Furniture(7)
- Interior design(1)
- Ambient noise(4)
- Thermal & humidity (2)
- Ventilation(2)

Colors Design: 2 categories, 4 items
- Color coding(2)
- Colored illumination(2)

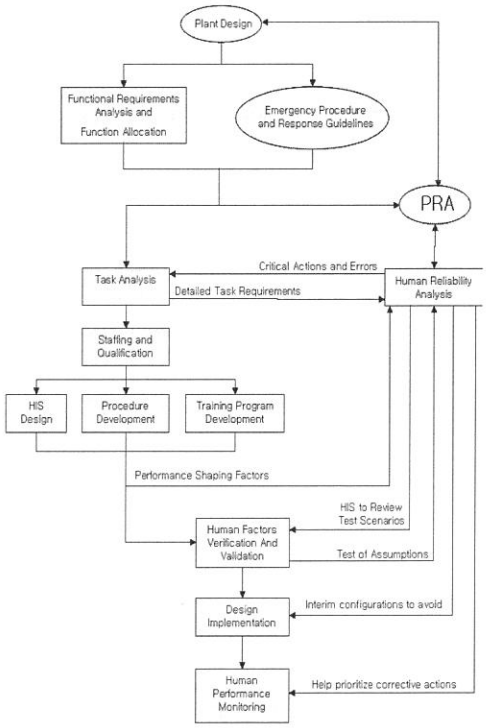

Figure 2. NUREG HFE Evaluation Model

The general methodology of design evaluation is to compare the HFE characteristics and functions with the criteria provided in the HFE guidelines. 65 items from 22 categories in 4 designs were selected for evaluating the design

suitability for the proposed environment design of BNPP 1&2 MCR.

Corresponding HFE criteria for each design area was reviewed and a decision made with a check mark and comment. There were four types of decision after HFE evaluation: OK, Discrepancy, N/A, and Return as follows:

- OK - This indicates that the aspect of HFE evaluation is acceptable. This evaluation should be given only if there is total compliance, i.e., only if every instance of the item being reviewed is fully consistent with the provisions of the guideline.
- Discrepancy - This indicates that the aspect of HFE evaluation under review is discrepant from the guideline: i.e., there is less than total compliance with the guideline.
- N/A - This was checked for individual guidelines that do not apply to the particular review.
- Return - This box was checked when a guideline is applicable but the information needed to make the evaluation is not available. In this case, it make a comment of what is needed to complete the evaluation

HFE design suitability of proposed BNPP 1&2 MCR environment design was confirmed with the top-down evaluation in terms of general design configurations. 21 evaluation items in 6 categories were selected. Evaluation items include general layout, document organization, storage, supervisor accessibility, crew communication and comfort.

3. DISCUSSION

In order to evaluate the appropriate number of HCI issues on information display on VDT and its environment, tremendous guidelines and technical papers related to evaluation issues of information display has been collected, analyzed and transformed to electric database forms and then built on database management system to retrieve the appropriate issues for information display on VDT.

From the DBMS system, the relevant evaluation issues and its hierarchy has been finally developed and validated through guideline integration based on the concept of human cognitive model process.

It is necessary and confident to consider the result of the suggested evaluation issues which are suitable for the design of the system with advanced information displays such as Computer Based Procedure (CBP) and information on Large Display Panel (LDP).

The design issues and resolutions from the finding may provide the cues for the designers and evaluators of the specific man machine interfaces of the system environment using digitalized devices.

In fact, as for the human factors guidelines of CBP in KNGR (Korea Next Generation Reactor) main control room, the items related to the issues has been assigned and analyzed.

And another contribution of this research is that it would consider the new issues of VDT information display from the current Korea NPP evaluation guidelines such as Nureg0700 Rev.2 or HF010, which needs to be updated

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