원자력 발전소 환경 디자인 설계를 위한 인체측정에 대한 연구

차우창

금오공과대학교

Anthropometric Data Collection for MCR Environment Design of Nuclear Power Plant

Woo Chang Cha

Department of Industrial Engineering Kumoh National Institute of Technologyy, Yangho Dong 1 Gumi-City, Kyoungbuk 730-701

Abstract

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.

Key Words : Environment design, Anthropometry, MCR, Nuclear Power Plant

1.0 Introduction

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

* Corresponding Author : chaw@kumoh.ac.kr

measurement were conducted to optimize nuclear power plant MCR design for ENEC in UAE. 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 MCR design.

It is necessary to validate the survey results to apply them to the ED of 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 without any design changes. This paper describes the detail results of the survey and anthropometric data collection.

2.0 Anthropometric Data Collection

2.1 Purpose

The objective of this anthropometric data collection program is to collect sample data for an anthropometric measurement of the future UAE operation crew in the MCR, which will be used for the evaluation of the reference plant's MCR physical configuration design to verify whether it is suitable for the UAE operation crew or some modifications are required for the MCR.

2.2 Selecting Preliminary sampling size

Once the survey goals and methods of collecting the information have been decided, the groups and the number of people for each group is selected for interview and measurement. There are special considerations when choosing a sample for anthropometric assessment of future crew in the MCR, because there are constraints on conducting a survey within a limited time frame with a limited number of people. A sample is a small part of the group that has been chosen to represent the whole group through sampling methods.

Sampling procedures fall into two classes: formal or probability methods and informal or non-probability methods. Formal sampling methods are based on probability sampling theory. This requires two things: (1) that every sampling unit has a known probability of selection into the sample so that we can calculate the number of sample with confidence level and sampling error (sometimes called precision), and (2) that random chance be the controlling factor in the selection of sampling units which lead to the assumption of normal distribution with a large sample, say n>30.

Informal sampling methods include a number of approaches that are based on other than probability principles, such as the heuristic problem solving method. Although the general intent is often to make inferences to some larger population, methods of selection tend to be more subjective. In most cases, it is assumed that the person(s) making the sample selection is/are knowledgeable about the survey and measurement, i.e., human factors specialists but in most of the cases, this cannot be guaranteed.

From the formal sampling methods, we can calculate the number of sample n based on the formula: $n = Z\alpha^2 * \sigma^2 / E^2$,where $Z\alpha$is the Z-score corresponding to the degree of confidence, σstandard deviation, Esampling error. Generally, most surveys for human resource employ 95% confidence limit, ±3% sampling error, and σ=0.25, which produce the sample size n = 1,067 persons (n= 384 persons with ±5% error) from the above formula.

The primary difficulty in using the above formula is that it requires information on the standard deviation of the indicator being used in the sample size computations. The preferred solution to this problem would be to use values from a prior survey that had been undertaken in the setting in which a program under evaluation is being carried out. If such data are not available data from a neighboring country with similar characteristics may be used.

From the heuristic problem solving method, we may get the approximate number of sample. HFE specialists demonstrated the appropriate human sampling number from their various experiments. Nielsen and Landauer (1993) showed the proper number of evaluators to find the usability problem considering the tradeoff of cost and efficiency. Their evaluators(subjects) demonstrated that more than 10 evaluators showed about 90% error detection power but that did not significantly increase efficiency in problem identification. This means small data samples such as the anthropometric sample for BNPP considering limited resources can show somehow confidence level for the measurement.

In selecting the appropriate number of sample of survey or BNPP anthropometric measurement with the limited resources and constrained time frame, about 30 persons would be good and fairly necessary number to be collected based on both the formal sampling method and the heuristic method.

2.3 Measurement Procedure

From the above academic research background for selecting sample size, we decided that the necessary number of subjects to estimate the standard deviation of the UAE population would be about at least 30 UAE males aged between 25 and 50 if the collected data showed the appropriate normality(the actual result with 32 UAE males showed normality with confidence level, see the 2.4 measurement results).

For the measuring tools and equipment for anthropometric data collection, we used one calibrated Martin type measuring tools which were generally used for anthropometric data collection. The measuring place was located at the conference room at the 9th floor of ENEC building at Abu Dhabi of UAE. There were 4 measuring personnel involved in the data collection process. Two persons measured already designated 18 points of their body size, one person wrote down the actual size on the data collection sheet, and the other one person supervised the whole process and explained the current process to the UAE subjects.

Considering the impact of the collected anthropometric data to the environmental design, we selected 18 measuring points of subjects' body which were basically required to measure for the MMI design and described in the MMI review guidelines; Human Factors Engineering Guidelines and NUREG-0700. The 18 points of body to be collected are as follows and shown at Figure 1.

1. Stature
2. Eye height
3. Acromion height
4. Biacromion height
5. Finger height
6. Wall-finger distance
7. Sitting height
8. Eye height, sitting
9. Shoulder height, sitting
10. Elbow height, sitting
11. Forearm-fingertip, sitting
12. Height of upper thigh when seated
13. Popliteal height
14. Buttock-knee length
15. Buttock-popliteal length
16. Hip breadth, sitting
17. Thigh clearance
18. Knee Height

The total time to measure the 18 points of

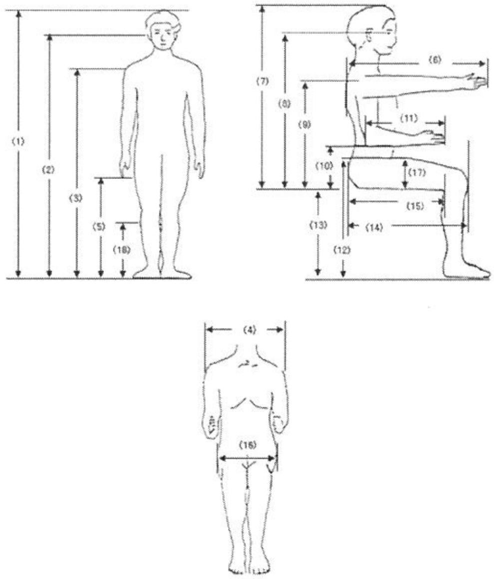

Figure 3 Anthropometric measuring points

each subject was 380 minutes which was 320 minutes for measurement (about 10 minutes for each subject) and 60 minutes for preparations. Detail procedure of measuring each point of body is not described in this report and may be referred to Size Korea web site at .

3. Results

The statistical results for measuring 18 body points of 32 subjects according to the anthropometric measurement procedure described above are shown at Table 1. The figures on the table were obtained from Minitab statistics software package. We found some measurement errors of two body points from two subjects which might incurred from mistyping or measuring mistakes, but these would not hamper the statistical confidence level.

3.1 Anthropometric result

Table 4 **Statistical results for anthropometric measurement**

No.	Physical Description	Ave (cm)	SD (cm)
1	Stature	173.20	6.416
2	Eye height	161.00	5.889
3	Acromion height	141.10	5.465
4	Biacromion height	44.070	1.692
5	Finger height	64.670	2.847
6	Wall-finger distance	83.370	3.798
7	Sitting height	88.880	3.092
8	Eye height, sitting	77.320	3.191
9	Shoulder height, sitting	58.170	3.092
10	Elbow height, sitting	21.200	2.498
11	Forearm-fingertip, sitting	47.880	2.302
12	Height of upper thigh	59.930	3.189
13	Popliteal height	42.140	2.225
14	Buttock-knee length	59.130	3.536
15	Buttock-popliteal length	49.130	4.195
16	Hip breadth, sitting	38.940	3.340
17	Thigh clearance	17.790	1.784
18	Knee Height	46.180	3.149

3.2 Data Analysis for Normality Test

Since the p-values of body point were all greater than 0.05, we would say that the collected data were normally distributed with 95% confidence level. Accordingly, the selection of 32 samples did not show the violation of normality so that we can use the result as an anthropometric data of future crew. But we may try to collect as many samples as possible in order to increase the accuracy or precision of 3% sampling errors if possible.

4. HFE Design Verification for Anthropometry

HFE analysis was implemented by KEPCO E&C to find whether UAE anthropometry causes any impacts on the current MCR design based on reference plant. This analysis is performed in accordance with HFE guidelines, codes and standards to assure that the MCR design is adequate to support safe operation of the plant.

Most of UAE anthropometric data are within acceptable range except the eye height at operators' sitting position. Since the Large Display Panel (LDP) located in front of the operator consoles is an important MMI equipment for providing the necessary information and the status of nuclear power plant (NPP) to the operators, it should be readable from all operators sitting positions in the MCR. HFE review regarding the readability is necessary to justify any possible design deficiencies. Therefore based on UAE people's eye height at the sitting position, we analyzed viewing angle to LDP and investigated any obstacles toward the LDP. The analysis result reveals that no obstacles exist toward the LDP and the viewing angle to the LDP is acceptable because the HFE guidelines stipulate an acceptable limit of 30 degrees off the viewing centerline. In conclusion, the reference plant's MCR design can accommodate UAE anthropometric data without any design changes.

5. Conclusion

The surveys and visits to the ethnographical places in UAE surely provided us with a good opportunity to have a cultural mind to apply it to the MCR environment design in terms of space, color, lighting, materials and styles for the reflection of UAE culture. As we recognized in the surveys, we would try to consider the highly developed technical level of environment design climate of UAE buildings and UAE people's expectation of a reflection of their design mind to MCR. It should be understood that not all of the survey results can be incorporated into the actual design due to the MCR design regulations or policy. Even though there are constraints and limitations, we would surely try to resolve the problems and limitations by all means with our skills, knowledge and the favors to reflect UAE people's expectations. In order to achieve the resolution, we need and expect ENECs' prompt and sincere feedback on this document.

REFERENCES

[1]. Nuclear Regulatory Commission. Human-System Interface Design Review Guideline(NUREG-0700 Rev.2), U.S. Nuclear Regulatory Commission, 2002.

[2] Dept. of Defense Design Criteria Standard, HUMAN ENGINEERING (MIL-STD-1472F), U.S ARMY AVIATION AND MISSILE COMMAND, 1999

[4] Human Factors Engineering of Computer Workstations (BSR/HFES 100,Draft Standard for Trial Use). The Human Factors and Ergonomics Society, 2002.

ACHNOWLEDGEMENT

This paper is partly supported by Kumoh National Institute of Technology.