# An Ergonomic Evaluation of the Illumination Level and the Management Plan to Improve the Working Environment of Nuclear Power Plants

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## 1. Introduction

Illumination in the working environment is one of the crucial factors that affect worker's psychological status as well as the physiological condition according to each task. Sometimes it affects the results of worker's cognitive, perceptual work performance. In pathicular, illumination may become a triggering factor to human errors in visual tasks due to visual fatigue through direct influence of vision in NPPs. Illumination includes several visual conditions such as uniformity factor, light distribution, glare, SPD (Surge Protector Device), flicker, illumination system, daylight and window control, in addition to the simple physical aspects of illumination and luminance. These conditions may affect operators' visibility and disillusion level, cause stress, attention, emotion, etc. and they finally affect workers' performance and errors as a result.

From the many illumination conditions mentioned above, current work environment evaluation items on illumination are mainly based only on the intensity of illumination, and there is yet no systematic way with evaluation criteria for other factors such as luminance, flickering, etc. In addition, research and development on illumination emphasizes mainly the physical characteristics of illumination, and it is insufficient for the influence studies on human error or work performance that are caused by these factors.

## 2. Methods and Results of Illumination Level Review

### *2.1 Illumination management in nuclear power plant*

High-reliability industrier like nuclear power plants maintain very high level of work performance, and make various efforts to eliminate the causes of human error generation. Maintaining a correct work environment also han an important role. As the results of the main control room's working environment

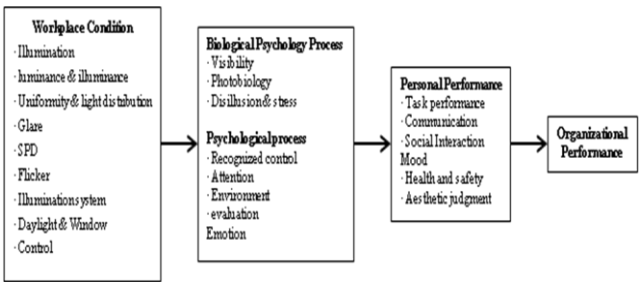


Figure1. Conceptual model for the relationship between illumination and human behavior (Veitch, 2001)

maximum level was 1234 lx from 20 measuring points based on a vertical control panel and horizontal control panel. Light sources are installed on the ceiling and cause average illumination levels of the vertical control panel, which is lower than a horizontal control level, but it was considered that vertical control panels contain mostly indicating meters and have little influence of operational tasks. Also, the illumination measured over 1,000 lx can be controlled by using six dimming switches installed in the control room, which indicates that the illumination level is maintained properly during the operation.

But those fluorescent lamps installed a as light source in the ceiling may lose their lighting power over the time periods and have a unique flickering effect. These two phenomena may give a negative influence on worker performance and physiological disillusion, and it has been suggested to prepare technical ways to compensate them. In addition, it is required to evaluate other conditions like luminance, flickering, control, etc.

### *2.2 Illumination standards and an evaluation*

An illumination standard in the work environment of nuclear power plants is listed in NUREG-0700, and KAERI has suggested Korea's Work Environment Directions within HFMP. NUREG-0700 indicates proper illumination level according to work type, and HFMP Work Environment Directions indicates illumination intensity and reflectivity standards. NUREG-0700 mostly indicates illumination level and reflectivity, and HFMP added more recommendations based on the considerations of visual characteristics and, especially, the visual fatigue.

Table1. Reflectivity standard in nuclear power plant control room (HFMP-T104-104 Work Environment Directions)

| Surface | Reflectivity | |
|---|---|---|
| | Recommended Reflectivity | Allowed Reflectivity |
| Ceiling | 80% | 60~95% |
| Upper Wall | 50% | 40~60% |
| Lower Wall | 15~20% | |
| Meter Panel | 80~100% | |
| Console/Cabinet | 20~40% | |
| Floor | 30% | 15~30% |
| Furniture | 35% | 25~45% |
| Upper wall that is 1~2 feet under the ceiling is recommended to use same color paint as ceiling. | | |

Table2. Nominal illumination levels for various tasks and work areas

| Work Area or Type of Task | Task Illuminance level, (in footcandles) |
|---|---|
| Panels, primary operating area | 50 |
| Auxiliary panels | 50 |
| Scale indicator reading | 50 |
| Seated operator stations | 100 |
| Reading: | |
| - handwritten(pencil) | 100 |
| - printed or typed | 50 |
| - VDU | 10 |
| Writing and data recording | 100 |
| Maintenance and wiring areas | 50 |
| Emergency operating lighting | 10 |
| Source: adapted from NUREG/CR-5680, Tables 6.2 and 6.3) | |

However no standard has been established for other detailed visual conditions (luminance, flicker, color temperature, uniformity, etc.) other than illumination level and reflectivity. It requires various compensations to evaluate the illumination level such as additional consideration for the differences between the standard and its application according to the light sources (incandescent, fluorescent, LED lamp, etc.) and the field working conditions.

## 3. An Ergonomic Plan for Illumination Management

### *3.1 Directions for illumination management*

Suitable illumination is essential for field workers who do their job indoor, and is an important factor that affects work efficiency and performance. If work is performed continuously in a mis-controlled illumination environment, it will cause psychological, physiological unstable state, lowering work performance and causing human errors. Especially for works required to maintain the high reliability on task performance such as NPPs, it should be carefully controlled so that any unstable state does not happen in operating conditions. Currently, some ergonomic studies are not made actively for human emotion, psychology, physiological and behavior reaction caused by illumination conditions. But illumination influence should not be overlooked, and a has direct relationship with visual information processing that acquires the most of task information. Also, a greater variety of ergonomic studies on the illumination should be conducted to understand the relationships between illumination, work performance, the efficiency, and performance rate to ensure the work performance, lower the human error potentials, and provide an optimal working environments for the personnel in NPPs.

### *3.2 An Ergonomic plan for illumination management*

In a NPP, ergonomic working environment standards should be formulated as follows:

First, the guidelines should be modified. At present, KOSHA, NUREG-0700 and FSAR stipulate the working environment including lighting. The problem is that none of the guidelines issue ergonomic standards of lighting, not physical standards.

Second, the objects of management should be clearly defined. As lighting management should be based on the characteristics of environments and workers, the objects of management should be departmentalized.

Lastly, the methods of management should be clarified. As mentioned, lighting should be installed in light of surrounding environments, operating accuracy and body characteristics such as age and eyesight, not to mention physical values such as luminance. In addition, they should be periodically retested in addition to visual acuity test. In addition, there is a need to evaluate worker satisfaction. The following are a proposed guideline for the management of the visual environment including ergonomic considerations relation to lighting conditions.

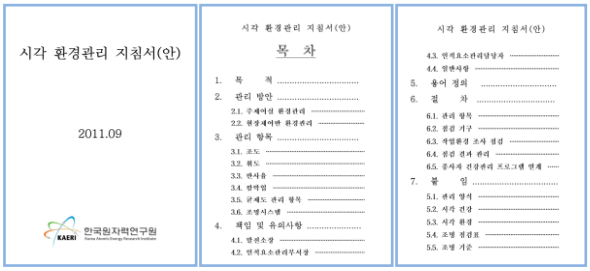


Figure2. Visual Environmental Management Guideline (draft)

## 4. Conclusions and Discussions

Illumination has been managed only in a physical aspect by the fixed criteria of luminance level values. More importantly, however, the human visual integrity should be managed rather than the lighting level itself, and the eyesight should be protected under all lighting conditions. Thus, it needs to evaluate and manage the lighting conditions in a more comprehensive and integrated manner for operating NPPs, wherein workers' conditions should be reflected to the management of working environments. Moreover, a long-range plan is required to carry out the foregoing due to the nature of eyesight and its degradations. Given the fact that most information should be taken in through the visual organ, eyesight is closely related and crucial to the work efficiency and reliability. Particularly in a nuclear power plant that requires high reliability, the protection of eyesight and visual integrity of personnel might be a primary measure to prevent the human errors caused by visual fatigue and problems.

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