JESK J Ergon Soc Korea 2017; 36(1): 1-7
http://dx.doi.org/10.5143/JESK.2017.36.1.1
http://jesk.or.kr eISSN:2093-8462

A Case Study of Ergonomic Evaluation for the Control Rooms of a Petroleum Complex

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Received : August 18, 2016
Revised : August 29, 2016
Accepted : December 12, 2016

Objective: Two control rooms of a petroleum complex were ergonomically evaluated for this study using diverse drawings of the rooms. The objective of the study is to show the evaluation process and its results, assessment method and essential elements for drawing-based ergonomic evaluation.

Background: Ergonomics can enhance the working environment and safety for a control room when implemented effectively. A control room design was examined by ergonomists based on ergonomic principles and well-practiced standards. This study was conducted because a construction consortium wanted to perform an ergonomic evaluation of the control rooms before the construction.

Method: A simple evaluation process, composed with a pre-evaluation, an evaluation and a post-evaluation, was employed to carry out the study. ISO 11064, NUREG-0700, NUREG/CR-6150, and CRIOP were reviewed to evaluate the control rooms. The assessment ranges over the control room layout, workstations, display and control, environmental requirements and safety. Three ergonomists participated in the study and performed the evaluation for two months.

Results: An experienced consortium of construction companies designed the petroleum complex and control rooms. No significant ergonomic design problems were detected. Quantitative recommendations were provided for the layout and workstation dimensions. Specific design directions were also proposed for environmental requirements and safety.

Conclusion and Application: Design advice and minor potential problems were reported as results of the drawing-based ergonomic evaluation. More practical suggestions could be additionally provided if an on-site assessment was conducted. However, the ergonomic evaluation used in this study could be helpful and applied to designing and evaluating other various control rooms prior to their construction.

Keywords: Control room design, Ergonomic evaluation, ISO 11064

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1. Introduction

Ergonomics has a crucial role in designing control centers and control rooms (Aas and Skramstad, 2010). A control room is composed of functional properties and a physical structure where operators are stationed to carry out centralized control, monitoring and administrative responsibilities (ISO 11064-1, 2000). Current 3rd generation control room design supports advanced supervisory control and data

acquisition with state-of-the-art computers (Walker et al., 2014). The control room will have a calm, attractive, distraction-free and functional working environment when designed ergonomically. Efficiency and safe operation are key benefits of ergonomic design and evaluation.

Ergonomic evaluation was performed, in this study, for two control rooms of a petroleum complex based on the electrical, instrumental, fire safety, and architectural drawings. One control room is located in the main control building and the other control room is placed in the workshop building away from the main building. The main control building is a single story building designed to accommodate the site's process control facilities and personnel including panel and field operators, supervisors, administrators, engineers and visitors. The workshop building has facilities connecting petroleum pipes to oil transportation ships. The petroleum complex was designed and planned to be built by a consortium of construction companies in Vietnam. The consortium developed the initial design and requested an ergonomic design evaluation to produce a functional and usable working environment. The owner and consortium also wanted to ergonomically examine the material selection, accessibility, lighting, furniture, visibility, etc.

Three ergonomists participated in the assessment to complete the evaluation in two months. The control room design was examined especially focusing on layout, workstation specifications, display orientation, environmental requirements and safety by comparing and checking with ergonomic design principles such as ISO 11064, NUREG-0700 (U.S. NRC, 2002), NUREG/CR-6105 (O'Hara et al., 1994), and CRIOP (Johnsen et al., 2008).

ISO 11064 is a widely used standard to design and evaluate control rooms and aims to improve safety and working conditions and reduce the potential for human errors (Aas and Skramstad, 2010; Duarte et al., 2012). Human-System Interface Design Review Guidelines (NUREG-0700) provides the instructions to evaluate the interface between operators and systems. Human Factors Engineering Guidance for the Review of Advanced Alarm Systems (NUREG/CR-6105) describes guidelines for alarm system review. Crisis Intervention and Operability (CRIOP) analysis was studied to evaluate the operation of the control room under abnormal situations.

Aas and Skramstad (2010) conducted a case study to evaluated ISO 11064 and suggested potential improvements on its scope and application adaptation. Walker et al. (2014) surveyed a third of all North Sea oil complexes and identified well known issues such as alarm systems, emergency situations, and usage of the control room.

The goal of the study is to identify and report ergonomic problems for this complex. In addition, ergonomic assessment processes and method would be introduced. The evaluation report was composed of evaluation scope, method and process, results, and annexes. The Annexes included general considerations, specific and quantitative recommendations, and design principles.

2. Method

The performance of the ergonomic evaluation process consists of pre-evaluation, evaluation, and post-evaluation phases (Figure 1). Azadeh et al. (2007) suggested the ergonomic design approach for a control system consist of identification, evaluation, and optimization phase. The approach was employed but simplified for the study since the evaluation was carried out on the construction documents rather than an on-site evaluation. We performed the ergonomic evaluation, indicated potential problems, and suggested better designs based on the drawings before the construction started.

The pre-evaluation phase clarifies 1) the purpose, context, and resources of the assessment and 2) the structure and functions of the control rooms and supportive facilities. The ergonomic evaluation phase analyzes 1) the control room layout, 2) the layout and dimensions of the workstations, 3) the displays and controls, 4) the environmental requirements, and 5) safety. The post-evaluation phase includes the post commissioning review and presentation to identify the ergonomic requirements and

recommendations in order to positively influence the subsequent construction process.

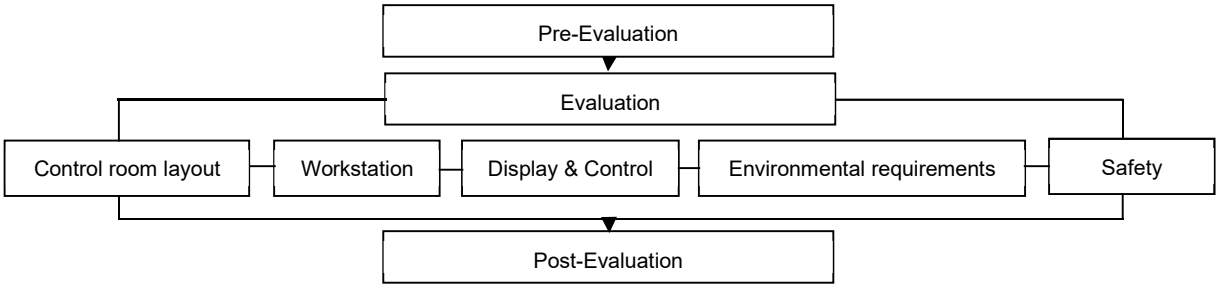


Figure 1. Ergonomic evaluation process

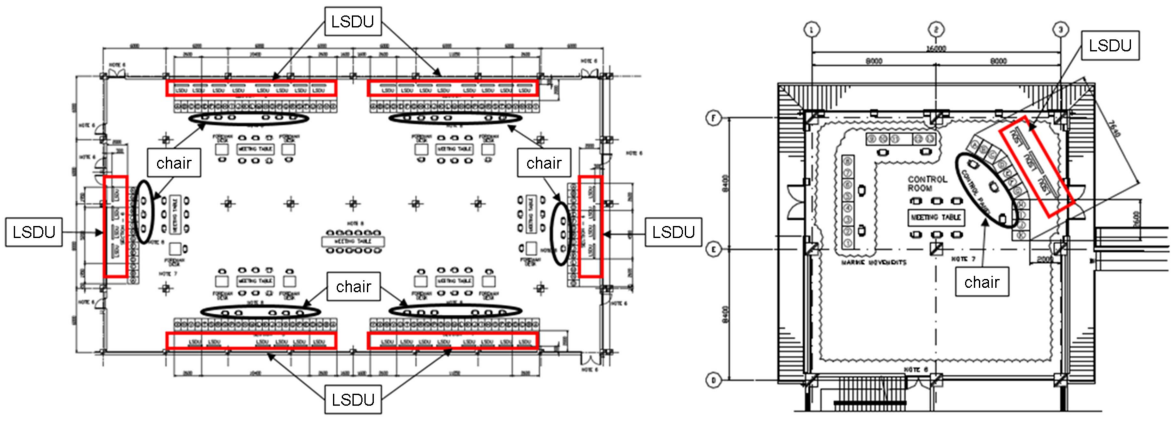
3. Results

3.1 Control room layout

The requirements, recommendations and guidelines of ISO 11064-3 (1999) were referenced in order to evaluate the layout of the control rooms. In addition, checklists of CRIOP and Part 3 of NUREG-0700, workstation and workplace design, were reviewed in the evaluation.

No significant contraries to the general considerations of ISO 11064-3 were found in the control room design. The considerations include architectural considerations, workstation arrangements, a LSDU (Large Screen Display Unit), and the circulation of personnel.

The current control room design could allow enough space for each working position and additional staff for normal and abnormal operations (Figure 2). The main doors are properly positioned and offer acceptable openings for the operators and visitors with disabilities.



(a) Control room A (b) Control room B

Figure 2. Control room layout

The LSDUs located directly in front of the operators are positioned within a horizontal visual field and all LSDUs could be easily monitored by a simple rotation of the chair (Figure 2.a). Operators can effectively share all LSDUs in the control room B (Figure 2.b). The drawing shows operators can watch information displayed on the LSDU from a normal working position for vertical planes.

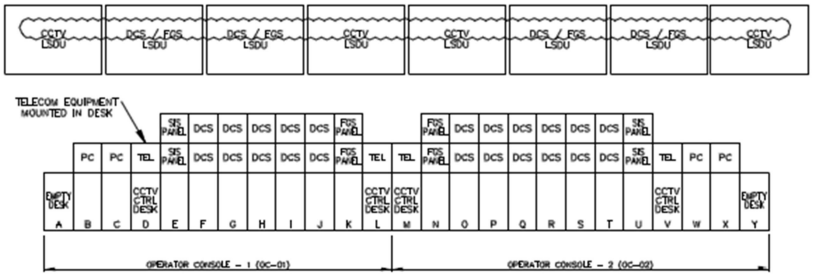
The layout of the control rooms was verified to permit the general circulation and the orderly evacuation of the room. Enough space has been provided for passage during an emergency evacuation as well. Door sizes are wide enough for emergency evacuation of wheelchair users.

Quantitative analysis was also performed providing recommendations for ingress/egress, window layout, space layout, meeting room location, LSDU specification and operator console specification.

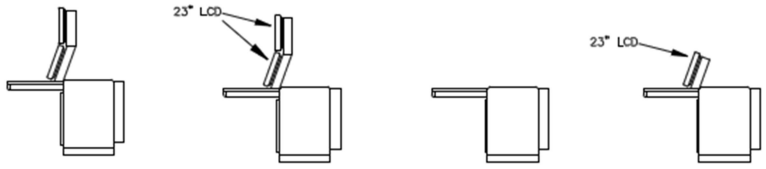
3.2 Layout and dimensions of workstations

The ISO 11064-4 (2013) aligns toward ergonomic principles for the layout and dimensions of the process control workstations. The requirements, recommendations and guidelines of ISO 11064-4 were studied to evaluate the workstation design.

Anthropometrical analysis was performed on the workstation designs and resulted in accommodating from the 5th to the 95th percentile of the operators (Figure 3). Both man and woman aged between 20 and 50 were assumed as target population. International anthropometric data offered by the standards were applied to the analysis. The design, however, was not proper for the users presenting extreme anthropometric dimensions. The arrangement of displays and adjustable chairs was confirmed to supply the users with comfortable and safe working condition.



(a) Layout of operator console



(b) Console assembly

Figure 3. Console of the control room

The layout effectively supports operation and maintenance tasks to be carried out in the control rooms. Both horizontal and vertical planes have been taken into account for the arrangement of the displays and normal operating positions. The workstations

were verified to furnish each operator with enough space and sufficient leg and feet clearance. Frequently used monitors and controls were planned to be positioned in front of the operators.

Ergonomic data and principles for the layout and dimensions of the workstations were also reported in preparation of its future use. More specific directions were also provided such as viewing distance and console workstation dimensions.

3.3 Environmental requirements

The ISO 11064-6 (2005) presents environmental requirements and recommendations for an ergonomic design. We mainly focused on offering recommendations for a proper environment because the environmental requirements could not be checked well with the drawings. An on-site assessment is very necessary to make sure whether environmental requirements are satisfied or not. A practical and detailed evaluation for environmental requirements would be possible by conducting an on-site evaluation.

The thermal environment is considered in the building design, operator activities and climate elements such as the number of operators, shift patterns, heat dissipation, orientation of the control room, thermal transfer from walls, number of doors and windows, etc. The heating, ventilation and air-conditioning (HVAC) systems need to maintain appropriate environmental conditions. A manual control should be possible when HVAC systems are not properly working.

No operators should suffer from air shortages by carefully arranging the air distribution inlets and outlets and well-controlled air flows. The air provision should protect from the ingress of humidity, dust and polluted air. The potential air contamination by external sources and micro-organisms should be taken into account. The control rooms need to be equipped with gas detection sensors, an appropriate fire extinguishing system and separated from equipment releasing pollutants (e.g. photocopiers/ozone, battery rooms).

Access to daylight is recommended with effective shades. Operators should be able to adjust the levels of illumination in order to optimize the operators' performance and comfort. Any operator-controlled lighting should not cause glare for other operators.

Clear quantitative directions were reported for thermal conditions: temperature, vertical air temperature difference, air velocity, humidity. Air quality, lighting level and acoustic conditions were also concretely advised.

3.4 Safety related elements

The architectural design takes into account of the emergency situations. The checklists of NUREG/CR-6105 and CRIOP were reviewed to evaluate the safety related factors. The evaluation presents requirements and recommendations jointly because of the limited information.

A clearly defined scope of the alarm system is imperative. The alarm system could include parts of several systems such as fire & gas, a process control system (PCS) and an emergency shutdown (ESD) system. The control room must show the locations of an activated sensor (pressure, gas, fire, etc.). Operators must recognize and easily read high priority alarm under all alarm conditions. The operational systems, instruments and controls used together should be located adjacently.

The operators must be able to discern between the states of new, acceptable, cleared or suppressed alarms. Both auditory and visual alert signals must be informative, easily understandable and perceivable from all related workplaces under all operating situations. Spurious alarms should be logged to reduce false alarm. The control room operators must have the capability to check the sensor data. Accurate alarm time indications assist the operators in responding to the alarm.

4. Conclusion

The construction consortium and owner requested an ergonomic design evaluation for the control rooms and it was performed based on the drawings. The ergonomic assessment would include visual, thermal and auditory environment and anthropometry for physical work place (Wilson and Corlett, 1990). The ergonomic examination and evaluation checked the control room layout, layout and dimension of the workstations, environmental requirements and safety related elements in the study. Although actual measurement and precise assessment was not performed in the evaluation, the employed standards provided satisfactory and practical guidelines.

The current control room design would have no significant potential ergonomic problems. However, ergonomic design advice and minor potential problems were reported as results of the evaluation. Furthermore, an on-site check was suggested for when the drawings did not provide enough information. For instance, the locations of pillars needs to be reviewed as not to obstruct any operator's vision and the finished ceiling height should be secured higher than 3,000mm, etc.

This case study presents the results of a drawing-based ergonomic evaluation and would be helpful for other drawing-based ergonomic assessments. As well, it is desirable to conduct ergonomic evaluations in the stages of construction, operation and maintenance. An on-site evaluation is especially necessary for supporting a practical and workable ergonomic design.

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