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Prediction and analysis of human errors on the Boiler operator using PHEA method: A case study in dairy industry

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Abstract

Background: Although advances in technology and increased use of production machinery have decreased manpower role, many industrial sites have exposed human resources to various dangers and a small mistake can often cause irreversible injuries. The purpose of this study was to analyze certain jobs and to detect the possible human errors in the steam boiler room of dairy industry using the PHEA method.

Materials and Methods: In this study data were collected through two steps: In the first step, using observation, investigation, and documentation techniques, all tasks of involved employees in process were identified. Then, with respect to the obtained results, critical tasks were selected to analyze the human errors. In the second step, the error description (and consequences resulted from it) were determined. Several action plans for mitigation and elimination of human errors are also recommended.

Results: The results have shown that most errors were characterized as "control is not true," with 110 repetitions, and the second type of errors "does not do the control" were obtained with 108 repetitions. For identified errors, 11 cases with 453 frequencies were identified. Most human-error causes were found as the forgotten, negligence and busy factors with the frequencies of 117,111, 111, respectively.

Conclusion: The results showed that PHEA technique can be used as an effective method to detect human errors and assess the consequences of the hazards resulted from the errors in the complex tasks.

Keywords: task analysis, human errors, steam boilers, Milk Co, PHEA

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Introduction

Since humans are inherently fallible and human errors could be expectable, it is necessary with the possibility of applying the methods to detect errors and make appropriate conditions for practical guidelines to prevent the incidences. According to a study by Heinrich (1973), performed on 75,000 events, it was identified that human factor accounted for the majority of accidents (88%). Unsafe conditions, 10% and the unpredictability of the causes were 2% of the incidents (1). Examples catastrophic events and disasters that have occurred in recent decades due to human errors are the accidents of Felix board (1971-UK), Three Mile Island (1979-America) and Chernobyl (1986-USSR) (2). Among the methods of risk assessment there are lots of methods to be considered for human errors and unsafe acts such as THEA, HEART AND HUMAN HAZOP methods, noting that the most suitable current method is the Predictive Human Error Analysis (PHEA). The advantage of this method is that it shows the combined method of treatment and pain. In this method, human errors are also identified and the causes of these errors are contemporary discovered and eventually lead to solutions to reduce or eliminate the errors. PHEA is an effective method that can apply the results of this research to reduce human errors and increase the safety matters (3). The aim of PHEA method is to predict human errors and to provide the practical solutions to prevent such errors. Addle and Jahangir (2003) studied the human errors caused by noise interference in the Isomax communication department in Tehran Refinery. Most errors identified by the researchers were unclear and ambiguous. Furthermore, the exchanged information that was sent or transmitted to the receiver caused the operator not to react at all or based on his speculation carried out the act in the possible wrong way; the first case did not work properly and in the second case, the unsafe event operated and led to occurred incidence. It was concluded that the incidence probability of accidents caused by predicted human errors was high. Especially in emergency incidences such as leaks of gas and steam which produce a loud noise in the environment, the occurrence of the errors would probably be more likely. As a result of those actions, if necessary measurements are not in place on time to prevent leakage of flammable and explosive gases, the events of fires and explosions would be inevitable (4). In another study conducted by the same researchers in 2004 identifying and analyzing predictable human errors during licensing process in Tehran Refinery, it was found that despite the lack of human errors and accidents recorded system in the refinery, it seems that certain events have occurred in Tehran Refinery which were caused by detected errors through the PHEA method and therefore, there is always the incidence possibility (2). Barry *et al.,* in 2000 and Gordon *et al.,* also in 2004, in separate studies with the issue of applying the risk identification to air traffic control systems concluded that this technique (PHEA) was a valuable aid in the design, development and performance of air traffic control duties in the UK and had the usability of air traffic control in America and Britain, which greatly reduced the potential risks (5). Embrey and Zayed (2009) in a study titled "The means of predicting and preventing human error in organizational performance in relying on computers" explained the safety of some techniques including PHEA with emphasis on computer software and aiming to prevent and predict the human errors in a gas plant (7 and 6). Finally, "Berger *et al*. (2010) applied PHEA method to identify and control human errors and confirmed that PHEA is a useful method (8). Since the boiler rooms in the dairy industry are potentially the most dangerous places in the company so they were selected to be evaluated in this study. Yet, no previously-

reported severe accident crises have been occurred in these places. However, this does not mean that it never happens. The present study examined the possibility of minor severe incidents many of which have never occurred, although the cause of these accidents exists and can be provided according to the present working conditions. Needless to mention that absence of an error and its cause do not mean that it will never take place during the project. However, expecting the incidence and its possible incidence should always be born in mind. The purpose of this study was to do a job analysis and identification to detect the possible human errors and causes as well as consequences in room boilers and eventually introducing the recommendations to address them.

Materials and Methods

The technique of PHEA was applied in this study. This study was conducted in two phases: data collection was the first one; through observation technique, the methods and procedures as well as the documents were scrutinized**.** In this phase all the personnel duties involved in the related tasks were selected through multiple visits to identify the most critical functions for the system for analyzing human errors. Describing the error and explaining the outcome of the due to an error was the second phase (2) which finally led to a control strategy. While overall assessment of the work sheets, specific suggestions were also provided to improve the safety of individuals (9). The procedure is detailed as follows:

1- Identifying the critical and vulnerable job functions with respect to human errors: At this stage, all personnel job duties were examined in all units of the dairy industry. Based on the recorded reports on occurred incidents, interviews and consultations with the head of units as well as the consultation with the company officials were performed. In addition, the vulnerable safety-sensitive job duties were carried out for the human errors.

2- Analysis of job duties in vulnerable and sensitive jobs in terms of human errors: Each work was divided into tasks or work procedure and in the first part of the risk analysis; every stage of the work was divided in terms of the situation of the staff in which they were doing their jobs. Then, the sufficient information was examined to describe each job function.

3- Forecasting errors and their consequences: Human errors in any of the job functions using the method of classifying human errors were performed through SURRY method and human errors were divided into 16 categories.

4- At this stage the attempt was to classify the causes of errors and their causes.

5- Control strategies to prevent human errors: The necessity of control strategy methods to reduce the predictable human errors in each job tasks were introduced in terms of training, preparation instructions, hardware changes and others.

Results

The most distinctive boiler room operators' tasks were determined as surveillance and inspection. Generally, 17 job tasks were identified for the boiler room operators. Table 1 shows the job tasks in the form of PHEA for each job. After analyzing the job PHEA sheets for the boiler operator 441, human errors were identified in different locations. In boiler room, the error No. 15 was the most common error type with 110 times recurrence, meaning that the "inspection" was not carried out properly. The second degree of incidence errors in the boiler room was error No. 13 with 108 times recurrences meaning that "the visit stage has not being performed." The error numbers 11and 5 were obtained with 101 and 100 times recurrences, respectively, which means " sending or receiving information was incorrect" and "operation was performed less than deemed necessary." These two errors in the boiler room in terms of recurrences were placed in the third and the fourth positions (Table 2). According to the

investigations carried out on boiler operator's duty and the classification of errors for the curator; 11 errors were detected with the frequency of 453 cases (Table 3). Forgetting factor with the frequency of 117 was the most common type. The second concerned factors were identified as negligence and full of activity with the prevalence of 111 cases. In rushing was ranked on third position with 100 recurrences. Other factors were identified with a frequency of 14 cases.

Table 1. Job tasks for boiler operator

	Job Tasks
1	blouses, pants, safety shoes, wearing job uniforms
2	Study of previous shift reports about defects or repairs needed before the next shift
3	Writing emergency office reports
4	Inspection of all unites and equipment
5	Checking the stock oil pumps and, if necessary, replacing or supplying the shortages
6	Entering the revived filter in the boiler circuit feed water
7	Checking the boiler pressure gauge
8	Inspection of water boiler gauge
9	Checking the safety valve
10	Checking the mechanical and electrical systems of firing boiler tanks
11	Checking the gas supply system and replace the inlet gas filter
12	Checking the magnetic water softener and the filter system in the path of the incoming feed water.
13	Checking the boiler tanks flames
14	Checking the under boiler tank water system
15	Checking the exhaust steam pressure
16	Checking the boiler feed water system
17	Checking the Pump pressure hydrofoil gauge

Table 2. Frequency percentage for boiler tank operator tasks errors

Error	Boiler Tank	Frequency
Operation is not performed.	4	0.9
Operation is performed earlier than fixed time.	0	0.0
Operation is performed later than fixed time.	2	0.5
Operation is performed more than necessary.	0	0.0
Operation is performed less than necessary.	100	22.7
Duration of operation performance is too short.	0	0.0
Duration of operation performance is too long.	0	0.0
Operation is performed on the wrong track.	1	0.2
Proper operation is performed on the wrong case.	1	0.2
Incorrect operation is performed on the right case.	3	0.7
Sending or receiving information is incorrect.	101	22.9
Cannot send or receive needed information.	5	1.1
Inspection is not performed.	10.8	24.5
Inspection is performed on the wrong case.	0	0.0
Inspection is performed incorrectly.	110	24.9
Inspection is not performed on time.	6	4.1
Total	44.1	100.0

Discussion

Results showed that most of the boiler tank operators' tasks were monitoring and inspection tasks which were carried out on every single boiler tanks. One of the boiler tank inspector duties was to check and inspect the pipes and fittings as well as one-way valves throughout the boiler room and basement of the hall which may exceed 100 cases and therefore makes the possibility of 100 times recurrences for this type of error. This task is one of those which must be of particular interest to improving and reducing predictable human errors. Inspections of such units must be performed in several occasions. Sometimes, the repetition of a task leads to the unwillingness of the inspector to carry out the task. In addition, sometimes no incidence happens for a long time which may result to incorrect inspection. Another reason could be the lack of commitment to the preservation of properties by the workers. Other particular factors were also involved such as job dissatisfaction, forgetfulness, and lack of concentration. Regarding error No. 11, it could be born in mind that the only way to know the correct process within the boiler and automated systems are the markers and pressure gauges. Therefore, if any of them are out of calibration mode or facing a defect, they might provide false information to inspectors. Subsequently, they may lead the inspector to the wrong performance and cause the subsequent consequences. Therefore, they must be calibrated to avoid the incidences. Error No., 5 which was repeated 100 times, could happen due to busy work. For example, inspector must spend more time to read the pressure gauge, but because the pointer of the gauges are inaccessible, or to check the pipes and fittings they require to spend more time to inspect them, such error might occur. In such a case, the operator has little time to inspect other tasks which leads to such an error. Other errors such as performing wrong operations on the correct case have less frequency and therefore, the experienced inspectors commit few mistakes in these cases. However, because of the lack of appropriate instructions and hands-on experiences, there is always the possibility of performance error. Late perform scaling of the boiler tank makes it harder for the next scaling and damages the process, which results in the increased possibility of mechanical damage to the tank body, further decrease in strength of tank body in high pressure, and eventually causing the tank bust. One of the most important causes of human errors that accounted for a large share of the errors was the omission or forgetfulness of operator error in the performance of one of the work procedures which may occur in the majority of job duties, especially the job-related equipment, devices, and inspections. Such conditions especially in critical situations, such as emergency stop units have adverse consequences. Salvandy (2006) stated that if any device for reminding the performing of a task was not in place, the possibility of occurrence of forgetting an operator error is leveled at 0.01. While, the checklist is used or procedures and instructions are in place to carry out the job, the error probability is reduced to 0.003 (10). Therefore, providing and applying the checklists are the most appropriate control option for the prevention and reduction of errors on the equipment installation, compilation and review of procedures as well as development of new procedures. Neglect means that the person is aware of the importance of the task but due to various reasons, he fails to do the task. An example is when the boiling tank operator is preparing a chemical solution and is aware of the importance but due to the fear of being ridiculed by others, refuses to wear safety glasses and gloves. Therefore, the education programs should be developed to change the attitudes towards the operator behavior. Distress can be of two types, one is mental and the other is

occupational. Mental distress includes conflicts between co-workers and family members. While, occupational distress includes complicated process and time intensive tasks which will waste the person's time and will leave some tasks incompletely performed. As such, the incidence of human error in the boiler tank room is mainly due to the boiler operator's distress, forgetfulness, negligence and haste. Therefore, to prevent and reduce the consequences the following suggestions are presented:

1- Developing the specialized training courses for newly boiler operator as internship under the supervision of experienced operators.

2- Instructing new and updated guidelines as well as checklists for operations with operators' participation that are consistently faced with the generated differences in the boilers rooms and availability of guidelines along with the technical inspections.

3- Performing a time study and time measuring to determine the required time for each task.

4- Regulation programs to inspect the pipes and valves in terms of the equipment life span and exhaustion.

5- Teaching the operators how to report a rundown of the top records in the notebooks

6- Substituting the digital pressure gauge with analog ones (and available at the height of the operator).

7- Installing electronic water-view and safety valves in accessible points normally installed under the height of the boiler operator.

8- Developing the safety education courses, changing attitudes towards the safety issues and drawing the attention towards the importance of using safety equipment even in a short time.

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