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Investigation of Lockout/Tagout Procedure Failure in Machine Maintenance Process

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Abstract: Lockout/tagout (LOTO) refers to specific practices and procedures to stop the release of hazardous energy and turn off machinery and equipment during service or maintenance activities. An effective LOTO system will make sure the workers are protected from the unexpected conditions during maintenance activities. This paper focuses on incidents of LOTO system failures in the electric power industry. LOTO system had implemented for many years in the company, but many incidents of LOTO system failure still happened. The purpose of the research was to investigate cases of the incident caused by LOTO procedure failures. The research was conducted using descriptive analytical approach to analyze cases of the incident to find the causes and develop the solution. Main data used in the research was the document of incidents and was analyzed by Systematic Cause Analysis Technique (SCAT). The result of the investigation showed the root causes of LOTO system failure were caused by personal, job and management factors. Based on SCAT chart synthesis, the control actions were identified. The identified control movements were improved operational procedure of LOTO and proposed job description of supervisor. Evaluation of control action concluded that basically the suggestions were feasible to carry out and some adjustments were needed due to implementation.

Keywords: Investigation, logout/tagout, SCAT.

Introduction

Lockout/tagout systems (LOTO) are a set of special procedures and practices to prevent workers from releasing energy or operating machinery and unexpected equipment or occurrence of hazards during ongoing maintenance or maintenance activities (OSHA [1]). The LOTO system is designed for non-activation mechanisms. It is also designed for the termination of energy sources' flow into machinery or equipment before any corrective or maintenance action is taken. Therefore, in this system, some persons have the authority to lock and tag symbol for the energy isolation process to prevent the release of hazardous energy and ensure that energy has been effectively isolated. Locking equipment works to enable energy insulation equipment in a safe condition, i.e. the 'off' position. This mechanism prevents the machine and equipment from getting energy supply and always in a controlled position because no one can remove without a key or have to go through a unique unlocking mechanism using a particular tool. The marking equipment is a prominent warning sign that indicates that the device has been locked and alerted other workers not to activate the machine during the repair or maintenance process. Implementation of a right and correct LOTO system is expected to prevent accidents, injuries or casualties during the maintenance process.

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Lockout/Tagout procedures are implemented to protect workers, especially maintenance workers in manufacturing or service industries which involving machines or processes with hazardous energy. The implementation of the LOTO system is not difficult, but often industry faces problems in its implementation. The problems that occur mainly because of human failures in running the procedure and lead to the system working failure (Campbell [2], Bulzacchelli *et al.* [3], Mehrgani *et al.* [4]). A review of earlier studies related to the LOTO system, grouped into two focuses, i.e. research on the LOTO system implementation analysis and research on the optimization of production systems that apply the LOTO mechanism. Analysis of the LOTO procedure implementation was done in eight sawmills in Canada to identify their respective advantages and disadvantages (Poisson and Chinniah [5]). In the implementation of the LOTO procedure, employee attitudes and supervision are significant factors that affect its success, so it is important to be noticed (Hapsari and Ardyanto [6]). Charlot *et al.* [7] developed a manufacturing system optimization model with a preventive maintenance system using LOTO procedure and without LOTO procedure. Mehrgani *et al.* [4] developed a model for minimization work in process and inventory costs due to engine breakdown with LOTO procedures on the maintenance process. The stochastic optimization model was developed by Badiane *et al.* [8] for the optimization of production during the machining process reduction due to the LOTO mechanism.

This study focused on the incidence of LOTO system failure in a power plant company. The LOTO system had been running for several years in this company.

Nevertheless, several times there were failures in its implementation and caused work accident. Previous researches have analyzed similar conditions.

This study aimed to investigate cases of workplace accidents due to LOTO system failures. We evaluate the investigations' results to find the root causes of LOTO system failures and to find the solutions as the control actions. We might use the results of the investigation and synthesis as a control pattern model for the other similar companies.

Injuries attributed to improper LOTO are often severe or fatal. Similar conditions have been done elsewhere as the comparator to this research. Anggraeni [9] evaluated the implementation of LOTO in a manufacturing company in Indonesia. The investigation method used critical incident approach by observation of mechanical supervisors, mechanics, and electricians. The results showed the implementtation of LOTO was not optimum caused by less understanding of worker about the LOTO procedure. Periodically refreshment was proposed to improve the LOTO mechanism. Aghenta [10] analyzed the cause of failures of LOTO implementation in an electric company in Nigeria. The study determined the risk(s) associated with LOTO of hazardous energy and proposed a new LOTO procedure which tracks the implementation of LOTO to mitigate against identified risks as a basis for the promotion of safety.

Methods

The study was analytical descriptive by examining the accident cases to find the root causes of failure and proposed solutions. The primary data used were the accident incidents documents related to the failure of the LOTO procedure during the last three years. For each case of the incident was investigated in more detail with in-depth interview technique on the informants involved in each case. Research in this field use supporting data, i.e. machine data, the working procedure of LOTO practice, LOTO equipment, data of personal protective equipment, secure work permit and supporting photograph documentation.

Data processing was done on cases of work accident due to LOTO procedure failure by using Systematic Cause Analysis Technique (SCAT). SCAT is a systematic method for determining the root causes of an event (Livingston *et al.* [11]). Systematic of SCAT is expressed in a diagram (SCAT chart) which consists of 5 (five) blocks, adopting from accident cause elements of the domino theory. The five blocks are: (1) the event description; (2) the categories of common causes of events, such as electricity, heat, cold, radiation, and the like (3) direct causes of events, consisting of unsafe act and unsafe condition; (4) fundamental causes, consisting of individual factor and job factors; and (5) safety management actions for events prevention. The SCAT chart structure is a series of five blocks as shown in Figure 1. The last block in the SCAT diagram involves solution as the control action based on the causes of the accident identified from the previous blocks. Control actions are developed by identified fundamental causes for individual factors, work factors, and management factors as well. The documents and brainstorming with the managers support the deployment process.

Results and Discussions

Cases of Accident

The result of the examination of accident documents identified 6 (six) cases of accidents due to LOTO procedure failure. Table 1 shows the results of the identification of the six cases of accident. The victims were maintenance workers who were running a repair or maintenance process.

In the identified six events, there were five types of machines or installations carried out maintenance and repair processes, namely: ejector, steam turbines, separators, transformers and main pipes. Based on the effect on the victim, all incidents are categorized as minor accidents because they did not cause the fatal effect like disability or death. The victim mostly just suffered minor injuries and did not have any workday loss due to the accident. However, actions for control should be taken to avoid more severe accidents. More detailed investigations were carried out for each accident case by reviewing the documents related to the occurrence and interviewing the victims and workers involved in each process performed during the event. Subsequently, the search results are used as the basis for constructing SCAT charts.

SCAT Analysis

Investigation of events was done by developing a SCAT chart for each identified case. This paper explains the analysis for case K1. Figure 2 shows the SCAT chart for case K1. In the 4th block of the SCAT chart, identified the cause of the incidence of individual factors, work factors, and management factors. Based on each case, the control actions were determined in the 5th block by considering supporting data and brainstorming with the company's OHS management. The causes of individual factors were less skilled workers in energy isolation on ejector machines and less awareness of using PPE when working. Control action for this factor was to create a training and socialization program

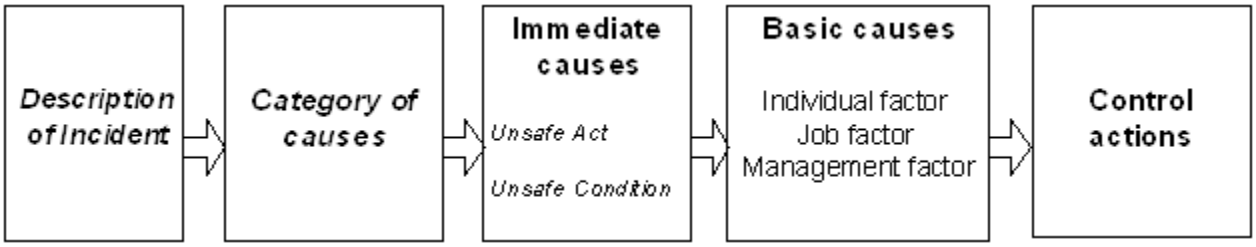

Figure 1. The structure of SCAT chart

Table 1. Identification of Accident Cases

Case	Chronological events	Machine/ device	Number of victim	Parts of the body were injured	Treatment
K1	The worker repaired the ejector, but the energy isolation was not perfect, so the steam was leaking about the workers, the worker was not wearing gloves in both hands	ejector	1	Left palm	First aid / medical
K2	Worker repaired ejector, but not the energy isolation yet, so that exposed to steam heat, the worker was not wearing gloves in both hands	ejector	1	Both palms	First aid / medical
K3	The worker repaired the steam turbine, wearing personal protective equipment (PPE): shoes, gloves, and safety helmets. Suddenly the engine flashed and blew out the hot steam because there was another worker who did not know there was maintenance work and turned the machine on	Steam turbine	1	Right palm	First aid / medical
K4	Worker repaired the separator, but the energy isolation was not perfect, so steam exposed to the worker's body, the worker was not wearing protective shoes	Separator	1	Right foot	First aid / medical
K5	The worker repaired the transformer but the energy isolation was not perfect, resulting in a leaking electric current, the worker was not wearing gloves	Transformer	1	Right palm	First aid / medical
K6	While the worker repaired the main pipe, steam exposed to him due to the main stop valve on the main pipe opened by another operator who did not seem aware of any maintenance activities. The worker was not wearing gloves in both hands	Main pipe	1	Left palm	First aid / medical

for workers about the ejector machine's energy isolation procedure and the importance of PPE for occupational safety. The cause of the job factor was a hazardous installation with high-pressure steam. The control action for this cause was to check the current LOTO procedure. The cause of management reason was the supervision absence during the maintenance process, and there was no standard operation procedure (SOP) for log out/tagout mechanism in ejector machine being repaired. Control actions for this factor were to create a job description for supervision during the maintenance process and create an SOP LOTO for the ejector mechanism.

In the same way, we developed the SCAT chart for the other five cases. Moreover, we also synthesize the result of SCAT chart development for the whole cases in the control actions identified in the fifth block. Table 2 shows the synthesis' results, where 'I' is code for the individual cause factor, 'J' for job factor and 'M' for management factor. The check mark indicates that each case (K1-K6) need the action controls. The consideration for control actions need in every case was based on the case description, SCAT chart and brainstorming with OSH management.

Discussion

Based on the results of the synthesis, we found that fixing the SOP LOTO action of each machine/ installation (M1) and developing the job description of the supervisor (J) as the control actions identified in all cases (K1 - K6). It means that those two control actions are the priority in the application. According to the control actions prevalence in all cases, the next sequence of priority is I2 – I1 –M2. All control actions are not exactly independent. There is an interrelationship between all control actions. The relationship

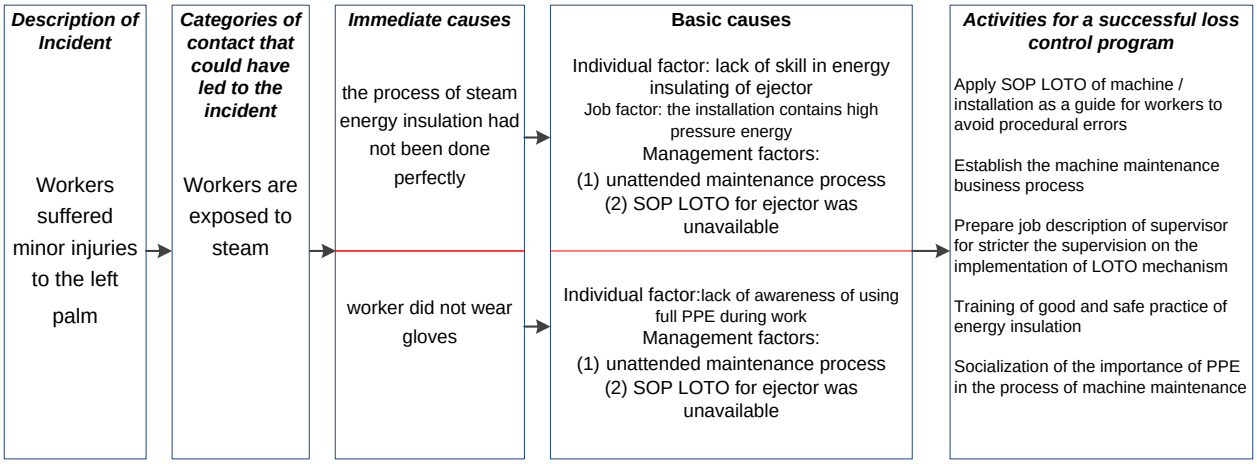

Figure 2. SCAT chart of K1

Table 2. Result of SCAT chart synthesis

Notation	Control action	K1	K2	K3	K4	K5	K6
M1	Apply SOP LOTO of machine/installation as a guide for workers to avoid procedural errors	√	√	√	√	√	√
M2	Establish the machine maintenance business process to prevent communication errors			√			√
J	Prepare job description of supervisor for stricter the supervision on the implementation of LOTO mechanism	√	√	√	√	√	√
I1	Training of excellent and safe practice of energy insulation	√	√		√	√	
I2	Socialization of the importance of PPE in the process of machine maintenance	√	√		√	√	√

diagram (see Figure 3) shows the relationship between all control actions. From the diagram can be seen there are three outgoing arrows from M1, they are to J, M2 and I1. M1 will affect J because SOP LOTO will determine the job description of the supervisor. M1 also will influence M2, which maintenance process business as the essential input for SOP LOTO. Likewise, M1 will bring over I1 as the main focuses in training.

Meanwhile, there are two incoming arrows to I2, and they are from M2 and I1. It means M2 and I1 will influence the control action of I2. Analysis of the relationship diagram reveals that M1 as the critical control measure, which has the most relationships to other control actions. Hence, the control action of M1 becomes the priority in implementation. The next priority is more focused on I2, even though J as the control action which is founded in all cases (K1-K6). From the diagram can be seen that two actions have the relationship to I2. Therefore, I2 will be more prioritized rather than J. Then, the analysis focused on the control action priority, i.e. "Apply the SOP LOTO of machine/installation as a guide for workers to avoid procedural errors".

Figure 4 shows the results of the SOP LOTO proposed improvement. The proposed procedure is divided into two categories: general and specific procedures. The general procedure is used by all stall involved in LOTO mechanism. While the specific procedure is the procedure that used by maintenance staff whilw working in the maintenance process.

This paper presents an evaluation matrix for the proposed solution. Recommendation of control actions was discussed with the OSH management by brainstorming methods. Management evaluated the feasibility of the proposed LOTO procedure in the company and assessed all actions the advantages and disadvantages. The outcomes were an evaluation matrix for the proposed control actions, including benefits, consequences, and explanations of management response to the proposed control actions (see Table 3). It takes time and some adjustments to implement the proposed methods.

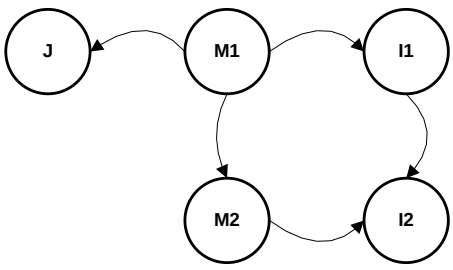

Figure 3. Relationship diagram of control actions for cause factors

GENERAL PROCEDURE

1. Only that person who attaches the tag may pick up the tag
2. The panel in charge person must be listed as a Panel Control Person and must be responsible for controlling and ensuring that the panel is always locked

LOCK OUT AND TAGOUT MECHANISM

1. The maintenance staff conducts a preparatory work plan, i.e., to identify the hazardous energy by using job security plan on high voltage installation form and LOTO checklist
2. LOTO checklist is not required for non-high voltage installation,
3. The maintenance staff should inform all relevant workers that the maintenance activity will be carried out and the LOTO system will be applied.
4. The maintenance staff insulate energy from main disconnect switch or other energy insulating devices
5. The maintenance staff should inform the relevant workers that hazard energy has been insulated from the devices
6. The operator activates the lock out devices and attaches tagging at the workplace. For office and terminal point, the maintenance staff will do those tasks.
7. The maintenance staff repairs and services the machine and equipment until the expected condition of the machine is reached
8. In condition the maintenance process is unfinished in the workday; the maintenance staff should inform the relevant workers and record in the logbook.
9. The maintenance staff reports to the other workers that the maintenance process is finished, and the machine is ready to operate normally
10. The operator turn on the switch and pick up the tagging
11. The maintenance staff fill the LOTO checklist

Figure 4. Proposed SOP LOTO

Conclusion

Based on the case reviewed, the factors causing the LOTO procedure failure in the machine maintenance process was the cause of individual factors, work factors, and management factors. The failure events investigation of the LOTO procedure makes it possible to find the causes of the failure factors in detail and to find the proper solution control actions for each factor. Evaluation of every proposed control actions should be undertaken to assess the feasibility of each proposal. It is necessary to consider the timing and some adjustments to the proposed control actions implementation.

Further research can be done based on the results obtained from this study. Detailed analysis is required to prepare the operational design of each proposed control action by considering the evaluation of OHS management. Analytical research is also possible to examine the correlation between the implementation of control action with the decrease of work accident rate due to the failure of the LOTO procedure in machine maintenance process.

Lesson learned from this case is the importance of investigation and synthesis as the control action of the accident case. Analysis of accident cases caused by LOTO system failure can be used as a preventive system in occupational safety and health management. Similar companies can adopt the model in preventing LOTO failures.

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Table 3. Evaluation matrix of proposed improvement

Proposed control action	Benefit	Consequence	Clarification
Apply general Standard Operational Procedure (SOP) LOTO and specific SOP LOTO for machine and installation	- The existence of SOP LOTO for machine and installation will ensure the maintenance operator's compliance - SOP LOTO on each machine will complete the company document - Valuable for OHSMS certification	- It is needed to inform SOP LOTO to all departments which connected to the maintenance department - An evaluation program is required to improve SOP LOTO per machine to confirm the current machine condition	The company accept SOP LOTO proposals for each machine. SOP LOTO socialization will be done gradually as well as to adjust SOP LOTO with the machine condition

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