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Changing the World's Energy Future

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Dynamic Instructions for Lock-Out Tag-Out

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Abstract. Lock-out tag-out (LOTO) instructions protect personnel from unexpected re-energization or start-up of equipment that is under maintenance. Even though there is rigorous training associated with LOTO activities, incidents still occur. Idaho National Laboratory is researching and developing dynamic LOTO instructions, which supports automatic place keeping, personnel working on multiple instructions, and multiple work groups completing the same instructions. Researchers identified user needs through subject matter expert interviews, observations, and classroom training. Failing to identify potential hazards during LOTO can cause injury or death to personnel. Dynamic instructions help to guide the user seamlessly through the instructions. Combining planning and record keeping may lead to clearer, more applicable instructions which addresses the reason for compliance issues with current paper-based procedures.

Keywords: Dynamic instructions · Lock-out Tag-out · Computer-based procedures

1 Introduction

Lock-out Tag-out (LOTO) instructions are used to protect employees servicing machines and equipment from the unexpected startup or release of hazardous energy that could cause serious injury or death to personnel. Lock-out can be described as the use of devices to lock equipment in a safe position during equipment maintenance. Tag-out can be characterized as using warning devices to inform personnel that equipment is under maintenance and not safe to operate. The United States Occupational Safety and Health Administration (OSHA) established LOTO as a part of workplace programs for personnel protection from workplace hazards in 1989 [1]. Despite rigorous training it is one of top 10 all-time most OSHA cited workplace violations and was the fourth most cited OSHA violation in 2018 [2]. Compliance violations for LOTO are failing to complete all steps as required by policy, failure to identify hazardous energy sources, and lack of personnel training on equipment procedures. Failure to implement LOTO in manufacturing was a contributing cause of 8% of fatalities and 15% non-fatal catastrophic injuries investigated between 2005–2014 [3]. Compliance prevents over 50,000 injuries and prevents over 100 deaths [4].

Many industries currently use paper-based procedures for LOTO activities. Even though paper-based procedures have kept industries mostly safe they have contributed to human errors due to missed or skipped steps, compliance issues, and managing

multiple procedures [5]. LOTO's purpose is to protect personnel completing maintenance on equipment or systems from unexpected hazards or startup.

Phases of the LOTO workflow are planning, recording, activities for workgroups involved, and completion. The planning phase is where the authorized employee puts a work package together which lists procedures, equipment, and previous maintenance performed on the equipment or system. The employee then records LOTO information, locations of hazardous energy on record sheets, and describe how equipment should be isolated. Record sheets are used to record hazardous energy conditions, maintenance personnel signatures, independent verifications that equipment is off or closed, and supervisor approvals.

Once the planning is completed a supervisor will give final approval to begin the LOTO. The authorized employee will contact additional personnel to independently verify the equipment is off or closed. Once the independent verifier confirms the equipment is off or closed, they will install LOTO on the system or equipment. Multiple personnel will begin to work on the LOTO after the equipment has been independently verified as off or closed. Multiple work groups may all be assigned to the same instructions based on their expertise such as electrical, plumbing, or maintenance. Once the work groups have completed their tasks, they will sign the record sheet as completed. Once all activities are finished, the supervisor will give permission to an authorized employee to close out and remove the LOTO.

Paper-based LOTO instructions work well for record keeping and confirming verifications are off or closed equipment have been completed before work begins. However, missed or skipped steps, compliance issues, and managing multiple procedures could be improved for more efficient workflow.

1.1 Dynamic LOTO Instructions

Some industries have switched to Smart PDFs which allow for limited user inputs and adding additional information, such as photos, drawings, and equipment information. However, smart PDFs function similarly and remain static documents. Research into dynamic procedures could offer improvements to the LOTO workflow process. Dynamic procedures help to guide the user seamlessly throughout the use of the procedure [5]. Human performance features can be added such as displaying only relevant steps, easy to access information, and guiding the user through the procedure.

Researchers at Idaho National Laboratory (INL) designed a dynamic LOTO instruction which can support planning and compliance by addressing communications between workgroups, using automatic place keeping, record retention, printing tags, and improving the overall user experience. INL has created extensive design guidance for dynamic instructions that incorporate branching questions, field notes, notes, cautions, and warnings to guide personnel through the entire LOTO process [6]. The design of the dynamic LOTO instruction was based on the design concepts previously published by INL. By doing so the researcher ensured ease of use of the dynamic LOTO as well as improved means to communicate between work groups

The objective of this research was to gather user needs and requirements for the creation of a dynamic LOTO instructions that will combine planning and record

keeping in a manner which will reduce workload, increase efficiency, and increase administrative compliance.

2 Method

The researcher identified user needs through three SME (Subject Matter Expert) interviews, observations, and classroom training to research and develop dynamic LOTO instructions. SMEs interviewed were facility supervisors, program managers, and operations LOTO experts. Supervisors review and approve record sheets before and after the work has been completed. Program manager oversees all LOTO operations in their facility. Operations LOTO experts oversees the entire company wide program.

LOTO instructions and record sheet information were reviewed before interviewing SMEs to create targeted questions on how LOTO instructions are used, record sheet information recording, and understanding where human performance errors occur during instruction use. The questions targeted information such as; whether personnel could explain the flow of the record sheet and how it is used, what works well in the paper-based work process, what improvements to the process would have great impact, and how do supervisors approve the LOTO. The researcher attended a demonstration in a training facility where SMEs showed how equipment is locked out, what indications should be observed, and what additional resources are available to the authorized employee. The researcher also participated in a two-day LOTO classroom training to learn more about the planning and performing phases of the LOTO.

Qualitative data and LOTO workflow process information was gathered to understand user needs when completing LOTO. Note taking was used for collecting information from interviews and observations. Previous design guidance from INL on computer-based procedures was used to identify areas for improvement to create dynamic LOTO instructions.

3 Results

Interviews with SMEs found record retention, tag printing, and improving communication between personnel were areas where improvements could have a great impact. SMEs explained how LOTO instructions and paperwork are completed for different LOTO activities. SMEs identified Tag printing and record retention as important for work efficiency by saving personnel time and allowing for record retrieval for future LOTO with the same equipment or system.

Observation of the training showed how personnel are trained on facility equipment and how to identify all potential hazardous energy sources. Classroom training provided information on how LOTO is applied. Instruction provided feedback on completing the training and how the record sheets and forms are completed.

4 Discussion

The LOTO workflow process areas identified as needing improvement were record retention, printing tags, and communication between workgroups. INL's design guidance for creating dynamic procedures has identified additional areas such as field information, notes, cautions, and warnings, branching questions, and automatic place keeping. A prototype is being developed that combines instructions and record keeping with design guidance and identified user needs to address improvements in the LOTO workflow process.

Planning has been combined with record keeping by identifying points in the instructions where tasks and record keeping could be combined to save time. Information can be added to dynamic instructions and allow personnel not to have to carry work packages around for planning. Personnel would begin by identifying the system or equipment and follow the instructions to begin LOTO. By combining instructions and record planning hazardous energy sources can be selected and added to the record sheet while completing instructions. Figure 1 shows an example of following the instructions and completing the record sheet by selecting the equipment or system and possible hazardous energy sources. Branching questions based on design requirements have been added when selecting potential hazardous energy sources for additional personnel safety. Branching questions are used for adding decision points in the instructions that will guide the personnel to the next appropriate step based on their selection. In Fig. 1 if personnel selected electrical hazard the instructions would then direct personnel to additional electrical questions. Combining the planning and record keeping addresses improvements to the workflow process that could help increase work efficiency.

The screenshot displays a mobile application interface for Lockout/Tagout (LOTO) planning. At the top, there is a navigation bar with a menu icon, the title 'Lockout/Tagout', and a settings icon. Below the navigation bar, the main content area is titled 'INSTRUCTIONS' and 'Prerequisites/Planning'. The first step is 'Identify the equipment to be serviced or maintained', which includes a dropdown menu for 'Equipment/ System' currently set to 'Circulating Pump'. There are buttons for 'Get additional equipment', 'Field Information', and 'Continue'. A 'NOTE' section follows, featuring a warning icon and text: 'Energy sources with thresholds that require application of LOTO include but are not limited to assemblies as listed in Appendix C, technical data for Analytical Hazardous Energy Forms and Specific Class Circuits.' Below the note is a section for 'Identify the hazards associated with the equipment to be serviced or maintained.', containing a grid of checkboxes for 'Electrical', 'Pneumatic', 'Mechanical', 'Pressure', 'Radiological', 'Thermal', 'Laser', and 'Other'. A 'Field Information' button is located at the bottom right of this section.

Fig. 1. Example of dynamic LOTO instructions planning and record sheet.

Automatic place keeping is an identified need found based on both the design guidance and classroom training. Place keeping is a human performance tool helping personnel from unintentionally missing or skipping steps [5]. Currently the circle slash

method is the most common method of place keeping in the nuclear industry. Personnel will read a step, then circle it to begin the work, and slash through it when work is completed [5]. Classroom training requires personnel to demonstrate they can perform LOTO without missing or skipping steps. If steps are missed or skipped the entire training must be repeated. Having automatic place keeping as a feature can improve overall human performance by helping personnel to not miss or skip a step unintentionally. This will also help reduce cost of training personnel.

Place keeping is identified by the blue border surrounding the current step, as illustrated in Fig. 2. Previous and future steps are grayed out for easy identification of the current step. By scrolling personnel can revisit previous steps that have been completed as well as looking at future steps. An arrow button at the top of the dynamic procedure will return the worker to the current step if they have looked at previous or future steps. The tracking of conducted steps via the automatic place keeping can help to reduce the cognitive demands on personnel having to remember previous step completed.

Fig. 2. Record sheet, sending notifications to personnel, and work preview.

Field information which incorporate notes, pictures or additional information has been included based on design guidance for computer-based procedures [6]. In PBPs additional information is included as paper copies in work packages. Having field information section would allow for documentation relating to the current step to be available as needed [6]. Adding pictures of the equipment, drawings, or notes can help personnel identify locations of hazardous energy for easier planning or completion of maintenance. LOTO PBPs record sheet has a space for notes that works for the LOTO process in case of additional information is needed. In Fig. 2 the dynamic instructions have a section to add notes and information in the field information folder in each instruction step [6]. The field notes section is grayed out when there is no current information included. The folder icon will turn blue if information has been added to field information for easy identification. The blue color change indication can help to identify if information has been added to an instruction step.

Notes, cautions, and warning indicators are indicated to the left side of a series of steps for a visual cue to which steps related [6]. Having notes, cautions, and warnings help inform personnel to pay attention to related steps [6]. For example, Fig. 1 has a note to acknowledge possible equipment hazards that should be identified as part of the LOTO instruction step. Having the acknowledgement can help personnel to identify additional information for personnel protection.

Having multiple personnel working on LOTO instructions at the same time can help increase work efficiency. Notifications can be sent easily to different personnel when work has been completed. An example is an electrician could send a notification that they have turned off circuit breakers allowing for maintenance to begin on equipment. In Fig. 2, notifications are sent to the supervisor to approve LOTO planning once the authorized employee has finished planning. The supervisor would receive the notification to review and approve the LOTO and could inform the authorized employee to submit approval. Having the ability to send notifications will help to increase work efficiency by reducing waiting time between maintenance and planning tasks.

Record retention was an identified important user need that is not currently addressed when using paper-based procedures. SMEs stated that if records can automatically be stored after completion it will save personnel time. Records currently are kept as paper copies, but then are transferred to a database after a set period. Personnel must physically scan records into a database for future retrieval. Having automatic record retention built into dynamic procedures to automatically save or send once completed will help increase work efficiency. An additional area for improvement for record retention is the easy retrieval of LOTO information that has been performed on the same system or equipment. This could same time by identifying and locating hazardous energy sources that were isolated in previous maintenance activities.

Currently tags are planned, filled out on the record sheet, and then written out again on the individual tags. Interviews with SMEs said having the ability to print the record sheet tag information will save personnel time from having to complete the record sheet and write out the information on each of the individual tags. In Fig. 2 once the planning phase is completed the supervisor will receive a notification to approve the LOTO. Once approval is granted a notification will be sent back to the authorized employee to print the tags. Dynamic instructions can help with improving the process for printing tags and save time.

The dynamic LOTO instructions prototype has addressed areas for workflow improvement by combining identified user needs with design guidance helping to reduce cognitive workload, increasing work efficiency, and increasing compliance.

5 Limitations and Future Work

The sample size of three SMEs was a limitation of this research. Limited access to SMEs could mean that there may be additional user needs that are not yet identified. More SMEs and users will be needed to identify additional user needs and requirements for creating dynamic LOTO instructions.

A web-based prototype for dynamic LOTOs is under development. The prototype version is intended to be used as a mobile or desktop application and combines planning, documentation, and instructions. Users will be asked to evaluate the functionality by providing feedback on the design, challenges, and errors encountered during user trials. Usability of the prototype will be determined from feedback given after testing to improve the dynamic instruction prototype.

6 Conclusion

Dynamic LOTO instructions are being researched by INL that will combine planning and record keeping reducing workload, increase efficiency, and increase administrative compliance. User needs were identified by interviewing LOTO SMEs, observing facility demonstrations, and classroom training. Identified user needs were record retention, tag printing, and improving communication between personnel. Classroom and facility demonstrations informed how LOTO planning and record keeping is performed. A prototype is under development to address areas for LOTO workflow improvement. Combining these functions may lead to clearer, more applicable instructions which addresses the reason for compliance issues with current paper-based procedures.

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