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Managing Process Hazards in Lab-Scale Pilot Plant for Safe Operation

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Abstract: In spite of the OSHA Laboratory and Hazards Communication Standards, incidents which result in injuries and property loss continue to occur in the research and teaching locations. Application of Process Hazard Analysis (PHA) of OSHA Process Safety Management (PSM) to laboratory pilot plant operations has the potential to further reduce risk associated with this location. However, a major challenge is unavailability of the easy and effective system to comply with PHA requirements. This study presents a system to manage the implementation of PHA in pilot plant namely Process Hazards Management for Lab Scale Pilot Plant (PHM-LabPP). It provides organized strategies to manage and track information, documents, recommendations and corrective actions related to the process hazards. Application of PHM-LabPP at High Gravitational Natural Gas pilot plant as a case study is examined and discussed. The implementation of this system could help end users to overcome inadequate of managing and controlling process hazards in pilot plant that had contributed to numbers of accidents.

Key words: Process hazard management, process hazard analysis, pilot-plant, process safety management, process hazards

INTRODUCTION

Generally, the volumes of hazardous chemicals in lab-scale pilot plant are lower than commercial plant and considered to be safe without requiring extra precautions. However the novel operations and processes used, high operation density of equipment, unproven or changing technology, lack of safety related information due to developmental stages, waste generated by the operation, use of sophisticated instruments gives a significant hazard impact that can cause injuries, fatalities and property damage (Reinart, 2003; Langerman, 2008; 2009).

As hazards are considered minimal in the lab, the lab safety is not given a top priority due to the perception that small quantity of materials would not give a significant hazardous impact to people and the environment. It is, therefore, not surprising to know that rate opportunity of lab accident in schools and colleges is 100-1000 times greater than at Dow or DuPont as estimated by James Kaufman (Banderly, 2009). Three examples of the accidents at pilot plant are summarized by Langerman (2009) including phosphorous oxychloride release due to gasket had failure which causes inhalation injuries of the technician, cumene hydroperoxide detonation due to the inefficient heat transfer of catalytic reactor which destroy the pilot plant and the release of hot tetrahydrofuran and odium potassium catalyst due to reflux apparatus failure which immediately ignite upon contact with air. It was resulting fire destroyed part of one laboratory and caused water and smoke damage throughout the building. Another accident was reported in laboratory at Ogden where 3 people injured when a 5 gallon container of the petroleum ether appeared to be bulging. As they attempted to move it, there was an explosion and a fire (Penrod, 2009).

Hazard recognition in laboratories and pilot plants is generally managed under either OSHA Laboratory standard CFR 1910.1450 or Hazard Communication standard CFR 1910.1200. Both of these standards emphasize communication of hazard information via a Material Safety Data Sheet (MSDS) and a product label. Unfortunately with the guidance of these standards, incidents resulting in injuries, fatalities and property damage continue to occur in pilot plants. Many institutions may have their internal guidelines for controlling hazards or risks in chemical laboratories such as Chemical Hygiene Plan (Hendershot, 2007). However, such internal guidelines may have limitation to manage process hazards in the lab-scaled pilot plant.

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According to (Mason, 2000) lab-scale pilot plant is dedicated to the development of a potential new production process which is specifically exempted from the OSHA Laboratory standard because it fails to meet the definition of 'laboratory'. West (1999) in his studies classified that pilot plant and full scale production has similarity in terms of typical stages of assessment of chemicals.

Investigation of the pilot plant incidents reveals that the underlying causes are similar to those found in real process plant accidents and should be addressed by applying the established guiding principle of OSHA Process Safety Management (PSM) to these facilities (Langerman, 2009). OSHA PSM is designed to provide the specific guidance needed to manage operational safety, particularly related to process hazards without excessive operational interference. OSHA PSM has been recognized as one of the established standards available in the process industries. Many have been written on implementation of PSM on the Chemical plant scale (DeWolf, 2003; Kwon, 2006; Shariff *et al*., 2011). But PSM does not yet apply to lab-scale pilot plants.

OSHA PSM 29 CFR 1910.119 was introduced in 1992 and contains out of 14 elements. Process Hazards Management (PHA) CFR 1910.119 (e) is one of the OSHA PSM elements, focusing on process hazards management (OSHA, 1992). Langerman (2009) indicates that application of PHA approaches to manage process hazards associated with the operations in the labs have a potential to provide the excellent guidelines with the reduction of incidents and losses. Review of the above issues shows that the underlying causes should be addressed by applying the guiding principles of PHA to lab-scale pilot plants.

This study presents a system namely Process Hazards Management for Lab Scale Pilot Plant (PHM-LabPP) towards managing the implementation of PHA in the pilot plant. A framework for system has been developed to prevent inadequate hazards review and fulfill the PHA requirements. A computer database prototype system is developed for effective implementation of the system and also easy explanation.

MATERIALS AND METHODS

Compliance with PHA requirement: The PSM standard as specified by OSHA requires employers to meet certain documentation and hazards analysis requirements. However, OSHA does not specify any methods for industries to follow in order to comply with the standard requirement.

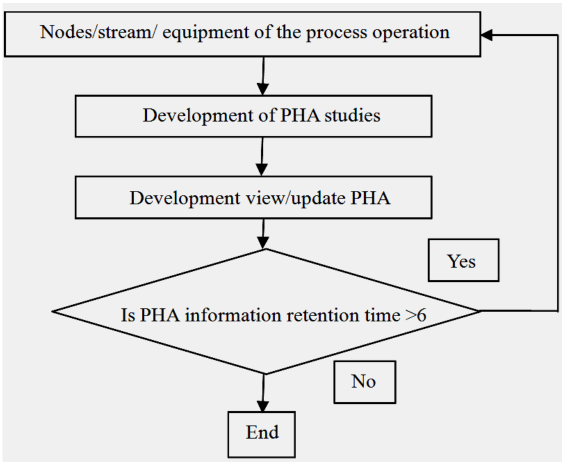

Fig. 1: Framework of PHM-LabPP

Focusing on regulatory compliance, the proposed system assists end users to close any identified gaps and ensure that the requirements are practiced as intended. The framework shown in Fig. 1 summarizes vital information and clear strategy of PHM-LabPP for PHA implementation in pilot plant as required by CFR 1910.119 (e).

Using P&ID as a Foundation for PHA information management: PHM-LabPP proposes the PHA studies by following the node system based on Process and Instrumentation Diagram (P&ID). Once hazards information has been updated for the equipment or stream, end user can choose other equipment within the selected node. The compiling and updating information process will continue until all nodes in the P&ID are completed.

Implementation of PHM-LabPP: The implementation of this concept will assist with computer technology for managing and communicating the information of PHA. PHA study development consists of schedule for conducting PHA, PHA methodology, PHA team members, PHA outcomes and validation of PHA information. PHM-LabPP system interfaces lay down the mandatory requirements for employers to fulfill with the description and evidence location. The checklist system is used to ensure data is sufficiently captured and verified. Any incomplete information and conditions will be remarks by authorized personnel for further improvements.

RESULTS AND DISCUSSION

To demonstrate the capability of the PHM-LabPP, a case study was conducted in High Gravitational Natural

Gas Unit (HGNGU) at UTP. Since the pilot plant is handling a flammable gas at a high pressure condition it is a compulsory requirement of the university that test rig is subjected to hazard assessment. The research team used PHM-LabPP that follow PHA of PSM to manage possible hazards associated with the operation.

PHA team members have conducted PHA for HGNGU following divided nodes system based on plant P&ID. Since P&ID represents the detail equipment and auxiliary in the pilot plant, missing of hazard information is prevented and also enhanced plant personnel acceptance since it is commonly used.

For demonstration, only one of the conducted PHA is presented in this study. A selected node for this case study is node 3 consist of the filter separator (V490) with inlet and outlet streams. Filter separator having the operating condition with a temperature of 38°C and a pressure of 49.6 barg. The diameter and height for filter separator is 39 inch and 15 inch respectively.

Figure 2 shows the selected node for this case study. The PHA assessment process for V490 is guided by the main interface of PHM-LabPP if the process hazards information is available. If there is no data available, the project leader is required to take necessary actions to establish the PHA.

Checklist of PHA requirements based on PSM standard: Figure 3 shows the main interface of PHM-LabPP that consists of 'Sub-standard', 'Description', 'Complete' and 'Remarks' columns. Following the framework in Fig. 1, all the requirements of PHA can be assessed and monitor easily using data captured through computer forms that can be stored in a centralized database. The interface follows exactly the PHA requirements for schedule of conducting PHA, PHA methodology, PHA team members, PHA outcomes and validation of PHA information. The system ensures data is sufficiently captured using a systematic checklist. Any comments such as specific incomplete information and conditions can be included in 'Remarks' column. From the comments, end users can take any required actions in order to improve the safety of pilot plant and comply with PSM standard. From the Fig. 3, most of the PHA requirements are complied except for PHA outcomes. The reason of not complying is due to the incompleteness of PHA Outcomes.

PHA Schedule: End users need to provide a schedule of activities for PHA process. PHA schedule of PHM-LabPP is shown in Fig. 4. The system allows lab manager easily plan, monitor and updates the PHA information.

All PHA information needs to be updated at least every five years as stated in CFR 1910.119 (e). However, for pilot plant the validation should be carried out every year due to rapid changes of research work. The revalidation allows the pilot plant to have an updated PHA, which is consistent with the current plant operation.

PHA methodology: Development of PHA can be done by any established methods such as "what if?" Scenarios, checklist, Hazard and Operability study (HAZOP), failure mode, fault tree analysis and other equivalent or a combination method.

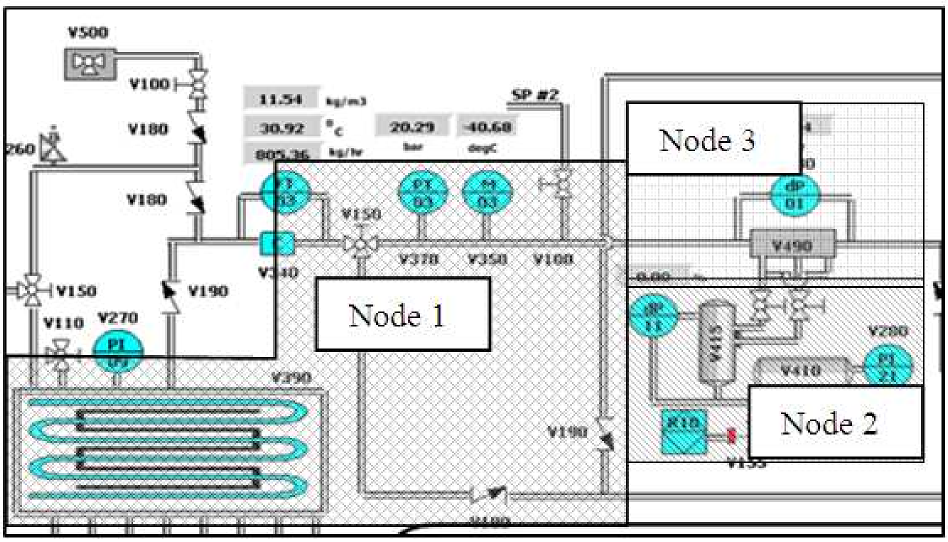

Fig. 2: Part of overall P&ID diagram for HGNGU

Fig. 3: Development of PHA studies

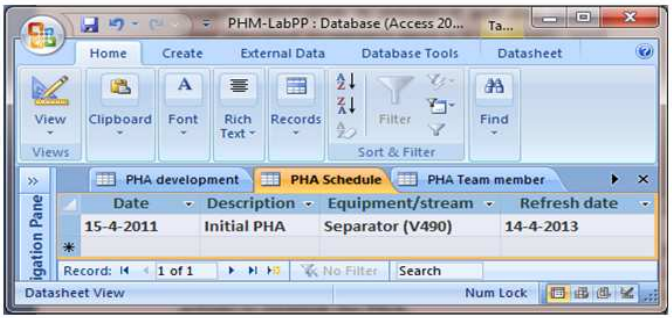

Fig. 4: PHA Schedule in PHM-LabPP

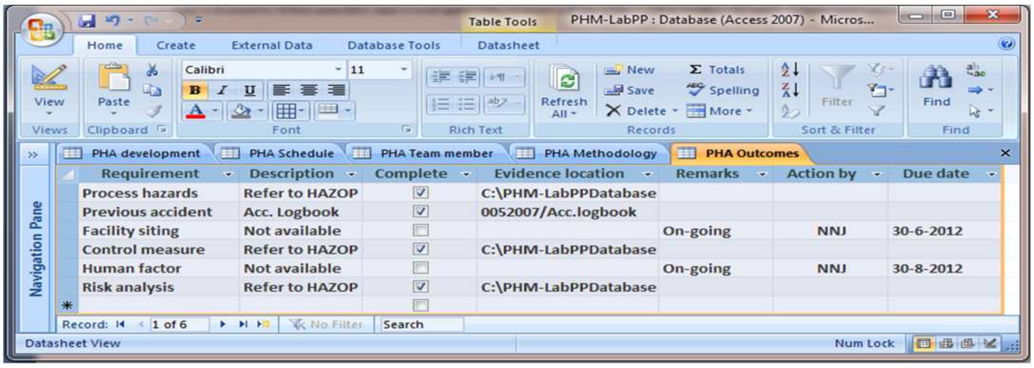

Fig. 5: PHA Outcomes in PHM-LabPP

However, HAZOP is the frequently the method of choice because it was developed within the chemical industry specifically to improve the operating characteristics of new processes. HAZOP method has been utilized to analyze process hazards of V490. Information about HAZOP study for selected node is stored in PHM-LabPP database as shown in Table 1.

PHA team member: PHA needs to be performed by a team member with specific expertise. The team must include at least one researcher familiar with day to day operations and one member knowledgeable in the specific PHA method to be used. In this case, a PHA study for V490 has been done by team members lead by process safety experts who is also well verse with HAZOP procedures. Other team members are involved with the pilot plant operation.

Table 1: HAZOP review and risk ranking study of filter separator

Item	Study node	Process parameters	Deviation (Guide word)	Possible causes	Possible consequences	Risk CC	LL	RR	Safeguards	Recommendation	Assigned to:	Reply Date (D/M/Y)	Completion
1A	Gas inlet	Flow	More	i. Increased pressure ii. Running two pumps iii. Control valve trim changed	i. Pipe leaks ii. Explosion iii. Loss of cooling	4	3	A	i. Safety relief valve	i. Control the pump ii. Periodic maintenance	i. NHM ii. NNJ	30/05/10	24/05/10
1B			Less	i. Partially plug and leak ii. Valve partially closed	i. Less pressure ii. Unfavorable outlet	1	3	B		i. Periodic maintenance ii. Open the valve	i. NNJ ii. NHM	31/12/10	3/8/2010
1C			No	i. Blockage ii. Small leak iii. Closed valve	i. No cooling process ii. Disturbing Process flow	1	3	C		i. Repair the blockage and leakage ii Open the valve	i. NNJ ii. NHM	_	
1D		Pressure	More	i. Valve failed open ii. Blockage iii. Chocked flow	i. Explosion ii. Overpressure iii. High temperature iv. Pipe and unit rupture	4	4	A	i. Safety relief valve	i. Repair the blockage	ii. NNJ	30/05/10	28/05/10
1E			Less	i. Undetected leakage ii. Vessel drainage iii. Condensation	i. Reduce flow rate ii. Longer cooling time	4	2	B		i. Repair the leakage ii. Install auto open-close valve iii. Periodic maintenance	i. NNJ ii. NHM	31/12/10	28/05/10

C-Consequence Class, Risk Class: L - Likelihood Class A- Risk intolerable - needs to be mitigated within two weeks to at least a Class C. If that cannot be - R - Risk Class that cannot be accomplished, the process needs to be shut down. B-Risk undesirable- needs to be mitigated within six months to at least a Class C C-Risk tolerable with controls (engineering and administrative)

PHA outcomes: The PHA outcomes address the direct process hazards, previous accidents, the engineering and administrative controls to ensure the safe operation. Figure 5 shows the interface of PHA outcomes of PHM-LabPP. The completeness of the information is tracked by a checklist in the system. For incomplete data, the condition is directly discovered in the checklist and easily identified by authorized personnel.

In this case, almost all PHA outcomes are completed except for facility siting issue and human factor analysis. The qualitative evaluation is made to safety and health effects of control failure. This evaluation is used as the basis for planning prevention, control, mitigation and emergency response to any release. Finally all the safety issues and required action are resolved following the standard guideline such as OSHA standard. All the PHA information is recorded in PHA database. The database can be assessed by the researchers to view the PHA information of pilot plant.

CONCLUSION

PHM-LabPP is the development of structured techniques to manage process hazards in pilot plant following PHA of OSHA PSM standard. The application in the case study had successfully showed that PHM-LabPP is workable and practicable to manage process hazards in pilot plant since it is easy to implement, effectively manage the process hazards and correct unsafe process conditions. This technique also can be extended to commercial process plant in order to comply with PSM regulation

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