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The Contribution of Management of Change to Process Safety Accident in the Chemical Process Industry

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Management of Change (MOC) is a process for evaluating and controlling modifications to facility design, operation, organisation, or activities. It is one of the most important elements of Process Safety Management (PSM). In chemical process industries (CPI), MOC is required to ensure that safety, health and environment are controlled. In recent years, the number of accidents related to MOC failure is significant and caused by the lacks of MOC management, organisation safety culture, design failure, incompetency, human factor and etc. From the accident statistics published by Chemical Safety and Hazard Investigation Board (CSB-US), European Major Accident Reporting System (EMARS-European), Failure Knowledge Database (FKD-Japan) and Accident Reporting Information Analysis (ARIA-France), MOC contributes significantly to the occurrence of accidents and its percentage contribution to accident rate is not decreasing over the past 20 years. In this paper, the contribution of MOC failure to accidents and their main failure factor are identified from the study of over thousands of accident cases and analysed with data mining method. Study revealed the major factor of MOC failure are the lack of organisation commitment, lack of experience, limitation of resources, inadequate of HAZOP study, human factor, safety culture and etc. Good practice of MOC has to be inculcated in CPI through learning from past accident and continuous improvement of MOC system.

1. Introduction

Chemical Process Industries (CPI) is often challenged with their operational excellent practices priority in safe operating process. Due to the amounts of dangerous substances handled in CPI and plants complexity, they are characterised with a major accident potential. Many major process accidents take place directly or indirectly related to process safety management elements and a lot of these accidents are in some way related to inadequate and / or inappropriate management of change (MOC) which is one of the Process Safety Management (PSM) elements. Due to the existence of ineffectiveness in managing changes, many organisations in CPI suffered tremendous losses. The mismanaged changes could have caused significant impacts on safety, environment, finance, community, integrity and delivery schedule. It is a matter of fact that for business survival and continuity, changes are unavoidable in the workplace which can affect facilities, organisational structure, processes or systems. A comprehensive consideration is required to determine whether implementing the change can improve good safety sense and safety program. Management of change if successfully carried out can avoid the consequence of unforeseen hazards through careful planning and close monitoring in the implementation of facility change. In United States, Occupational Safety and Health Administration (OSHA) believes that planned changes on a process must be evaluated comprehensively in order to fully assess their impact on employee's safety and health and to identify necessary changes to operating procedures (OSHA, 2000). It is mandatory to establish and implement the procedures to manage changes on process chemical, technology, procedures and equipment. The procedures must take into considerations on the technical basis of the proposed change, modification of the operating procedures, impact on the change of employee safety and health, necessary time period for the

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change and authorisation requirements for the proposed change. Employees in maintenance or operation work and contract employees working with the change in their job task must be informed of and well trained prior to the startup of the process or startup of the affected part of the process. The change in process safety information must match with the change of operating procedure. It is necessary to update the information accordingly. In the U.S., MOC is required by number of agencies including PHMSA, the EPA, and most commonly OSHA (Rainer, 2012). Based on incident investigation reports, it was indicated that one of the major contributing factors that result in catastrophic incidents in the chemical process industry is ineffective MOC. A study has found that 80 % of all large scale incidents are traced back to failure in MOC (Gambetti et al., 2013). Uncontrolled changes are capable of causing both a catastrophic event and disruption of the manufacturing operations (CCPS, 2008). Though MOC has been acknowledged and efforts in the regards have been done accordingly, the current practice of MOC is still insufficient towards the betterment of process safety (Kitajima et al., 2010).

The research on case histories accident investigation report revealed that 9.1 % of all accidents and precursor events in the CPI are MOC related. The significance of MOC or lack of it was never more apparent than in the Flixborough accident. The temporary modification to piping between cyclohexane oxidation reactors failed causing catastrophic accident in June 1974 resulting 28 employees killed and 89 employees injured which the accident was largely due to a mismanaged of change (Chosnek, 2010). Concerning the MOC, US-CSB (2001) has discussed two incidents that occurred in the United States in 1998. The first incident in November 1998 involved a fire at an Equilon Enterprises oil refinery in Anacortes, Washington. The fire in the delayed coking unit caused six fatalities. The second incident in October 1998 involved a reactor vessel explosion and followed by fire at the CONDEA Vista Company detergent alkylate plant in Baltimore, Maryland that injured four people and caused extensive damage. There is a need for CPI to have MOC policies that include abnormal situations, changes to procedures, and deviations from standard operating conditions.

2. Research Approach

From this research study of over 1,000 accident cases in CPI, 630 accident cases are related with PSM after the screening process. The data are collected from the sources provided by Chemical Safety and Hazard Investigation Board (US-CSB, 2015), European Major Accident Reporting System (EMARS, 2015), Failure Knowledge Database (JST, 2015), Central Major Accident Notification System (ZEMA, 2015) over the period from 1990 to 2015.The research methodology employed data mining process through data cleaning, data integration, data selection, data pre-processing, data transformation, data mining, pattern evaluation and knowledge presentation. First of all, the accidents cases are categorised under different PSM elements. Subsequently, the percentage contribution and ranking of different PSM elements are determined. Finally, accidents are categorised under different MOC typology.

3. Result and Discussion

A total of 630 chemical process industry related accidents cases were reviewed for this research. Based on the statistic on PSM elements accident occurrence frequency, a frequency of 149 out of 1,633 accidents are contributed by MOC due to multiple~~s~~ causations.

3.1 MOC Accident Ranking

Preliminary result shows that the contribution of MOC failure to CPI accidents is found to be 9.1 %. It ranked top number 6 behind the other 5 PSM elements of process hazards analysis (17.7 %), operating procedure (17.6 %), employee participation (11.5 %), training (11.3 %) and mechanical integrity (10.1 %) as demonstrated in Figure 1. It is worthwhile to study due to MOC related accident cases are not decreasing over the period of study and its potential in contributing to major accidents.

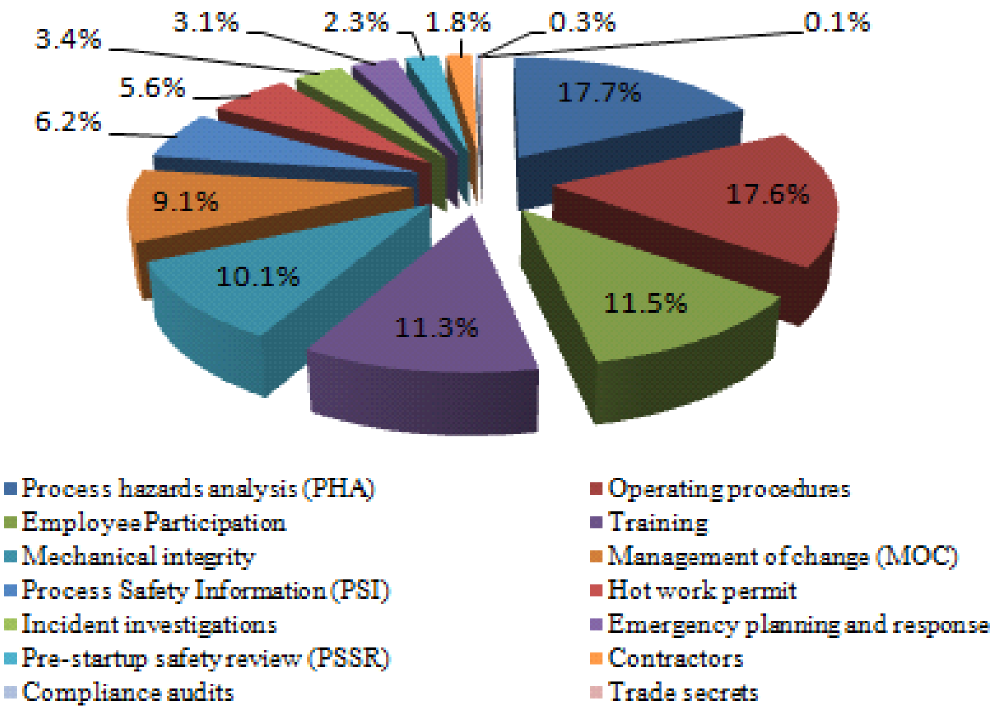

Figure 1: Accident causation percentage by PSM elements

3.2 MOC Typology

Establishing a consistent typology and clear objective is a pre-requisite for effective implementation of MOC system. This research is to categorise MOC under 5 typologies namely requesting system change (process equipment, process control, and safety system and facilities improvement), breakdown / failure system change (system malfunction, safety hazard), temporary system change (specific time, trial period), administrative system change (inspection, testing and preventive maintenance equipment, procedure) and organisation system change (organisational restructuring, staffing, and policy).

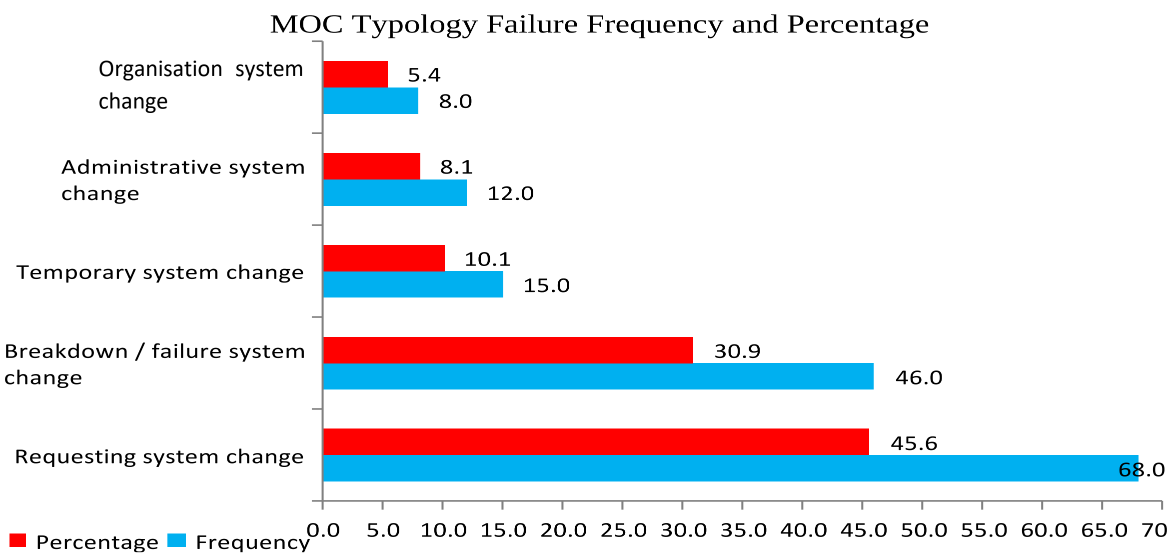

Figure 2: MOC typology failure in frequency and percentage

From the results of study, requesting system change demonstrated the highest percentage contribution of 45.6 % in MOC typology failure frequency. Breakdown / failure system change ranked number 2 contributing to 30.9 % followed by temporary system change of 10.1 %, administrative system change of 8.1 % and organisation system change of 5.4 % as shown in Figure 2.

3.3 MOC accident main factors

An important aspect of MOC related accident cases study is to identify main failure factors for preventing similar event from recurring. Table 1 shows the three major common main failure factors namely the lacking in management involvement, inadequate in procedure and risk assessment. Other main failure factors are personnel competency, resources limitation, human factor, inadequate tools and equipment, lack of supervision, cost control, pressure and stress from management which can directly or indirectly contribute to MOC failure.

3.4 Requesting system change

Requesting in system change ranked the highest MOC failure frequency because it involves more activities and the nature of complexity in the process. Other shortfalls are resources limitation such as insufficient competent personnel (in the areas of process, maintenance, safety, risk assessment and etc.), absence in detailed changes review and revise of procedure, no training and lack of communications after system changes. Improper supervision during system change is another issue leads to the use of sub-standard tools and equipment that may cause system failure. When request system change is planned, there should be careful consideration of the process safety implications. The organisational responsibility for approving such changes should be carefully defined, and approval should be given after appropriate review by competent personnel has been completed.

3.5 Breakdown / failure system change

Breakdown / failure system change is ranked number 2 of the MOC failure frequency. It is mainly caused by time constrain, time limitation and urgency to resume operation. The study revealed that some of the common malpractices are by-pass or improper MOC practices in executing the change by simplifying the risk assessment, without continual review and updating of procedure, inadequate training after the change, and the replacement of sub-standard equipment as a substitution due to urgency.

3.6 Temporary system change

Under this typology, the main failure factor is similar to that of breakdown / failure system change which is caused by time constraint, time limitation and urgency to resume operation. Management always treats it as a short term change without considering carefully the needs to perform a complete risk assessment and analyzing the possible hazard impact. Replacement of a sub-standard equipment or parts as a substitute due to urgency, no review of procedure and communication with regard to the change can happen.

One good example is the reactor modification at Flixborough which was a temporary change for a short period only until the reactor which suffered corrosion was repaired and ready to be reinstalled. One of the major recommendations arising from the Flixborough incident Public Inquiry was that any temporary changes to the hardware should be formally subject to a safety review, and the change implemented as it would be for new permanent installations.

3.7 Administrative system change and organisation system change

Though these two changes are considered as lower threats in causing MOC failure, accidents do happen. Majority of the management under estimate these two changes and is reluctant to carry out MOC practice in risk assessment for procedure revision, process control changes, organisation restructuring, review of policy review, work pattern change, sourcing of alternate contractor or suppliers and etc. As a result, accident can take place if change is not managed systematically.

One of the major problems faced by organisations is that movement of personnel within the organisation is more frequent than changes to hardware. Change in people occurs both at the operational and at management levels. When experienced people leave or being transferred, their knowledge and experience can disappear with them. Before new personnel take over their positions, there is a necessity to have an MOC review in terms of skill and training needs, and provide the necessary competency especially in identifying and managing abnormal situations. The relocation of technical professionals away from plant resulting in their non-availability to provide timely advice during abnormal plant operations was considered as one of the contributing factors to the classical incident of Esso Longford plant in Australia (Dawson and Brooks, 1990).

Table 1: Typology characteristics of Management-of-change (MOC), Objective and main failure factor

Typology	Objective	Main Failure Factor
Requesting system change	• Modification to achieve higher production rate • Modification to achieve better product quality • Change of production type with existing operating facilities and system • Replacing different type of equipment / instruments to achieve higher production rate or better equipment integrity • Operating control system change • Process line change • Start up and shutdown system change • Complete system change involving equipment, instruments, procedures, organisation, process • Setting higher production output without equipment / instruments upgrade (changing operating parameter, higher temperature, pressure, flow, human limitation)	• Lack of Management involvement • In-adequate of Procedure • In-adequate of risk assessment • Lack of Competency personnel • Resources limitation • Human factor • In-adequate Tools and Equipment • Lack of Supervision • Lack of Communication • Cost control
Breakdown / failure system change	• Equipment breakdown / failure change • Piping / vessel or high corrosion effect change • Sudden / urgent shutdown operating change • Change to prevent safety issue	• Lack of Management involvement • In-adequate of risk assessment • In-adequate of procedure • Cost control • Tools & Equipment • Pressure and stress (time constrain)
Temporary system change	• Temporary by pass normal operating system to keep operation process running with part of the system / equipment taken out for service or replacement • Temporary interlock by pass • Temporary safety protective devises by pass • Chemical substitution • Temporary changing different material and or chemical	• Lack of Management involvement • In-adequate of risk assessment • In-adequate of Procedure • Tools and Equipment
Administrative system change	• Changing SOP / work flow for operational and safety issue • Changes in establish training method to software method • Change in operation parameter, limit, control • Change procedure from hard to soft copy	• Lack of Management involvement • In-adequate of Procedure • In-adequate of risk assessment • In-adequate of Training
Organisation system change	• Manpower (work force / reduction / work distribution) • Contractors / vendors change • Work pattern change • Human behaviour change (emotional / feeling) • Cost saving implementation • Restructuring (competency) • Policy change • Stake holder change • Business unit change • Realign audit function	• Lack of Management involvement • In-adequate of Procedure • Human factor • Lack of Competency • Cost control • Pressure and stress

4. Conclusion

The accident rate in the CPI has not been decreasing over the period of study. Learning from historical MOC related accident cases is of vital importance and it is a continual improvement process. This study provides better understanding of MOC system, MOC typology failure ranking and main factor of MOC failure for sharing. Further study in determining the root causes of MOC failure with preventive solution is on-going which will benefit the CPI.

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