MARY KAY O'CONNOR PROCESS SAFETY CENTER
TEXAS A&M ENGINEERING EXPERIMENT STATION

19th Annual International Symposium
October 25-27, 2016 • College Station, Texas

Lessons in Process Safety Management Learned in an Explosion Accident in Taiwan

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Abstract

A substantial explosion attributed to thermal decomposition of o,o-dimethyl phosphoramidothioate (DMPAT) resulted in 1 fatalities and 1 injury in Taichung, Taiwan, in 2016. An analysis of this explosion indicated that such an accident could have been prevented, or the consequences might not have been as severe if certain elements of process safety management (PSM) had been applied. Proper execution of process safety management, including process safety information, operating procedures, pre-startup safety review, and process hazard analysis, can prevent the occurrence of such explosion accidents. The impact of this explosion could have been reduced had these process safety management elements, particularly management of change, been executed.

Introduction

In January 31, 2016, a fire and explosions occurred in a plant manufacturing agricultural chemicals resulted in 1 fatality and 1 injury in Taichung, Taiwan. By inspection of the process and causes of the accident, it is found that the consequence of this accident might be not so serious or even the accident might not be happened, if some elements of the process safety management (PSM) were carried out properly.

To prevent or minimize the leakage of highly hazardous chemicals, Process Safety Management of Highly Hazardous Chemicals, 29 CFR 1910.119 [1], was promulgated by the Occupational Safety and Health Administration (OSHA) of USA in 1992 after the Bhopal catastrophe. Processes involving some specific chemicals more than the specified threshold quantities were required to implement the 14 elements of PSM, employee participation, process safety information (PSI), process hazard analysis (PHA), operating procedures, training, contracts, pre-startup safety review (PSSR), mechanical integrity (MI), hot work permit (HWP), management of change (MOC), incident investigation, emergency planning and response, compliance audits, and trade secrets.

The Hazardous Work Place Review and Inspection Rules [2], a rule of PSM in

Taiwan, was promulgated according to Article 26 of the Labor Inspection Law [3] in 1994. It was required in Article 26 of the Labor Inspection Law: Without the approval of labor inspectorate or having passed the inspection(s), the business entity shall not allow workers to work in the following workplaces: … Most plants, with the workplaces belong to the hazardous work places, in Taiwan just want to pass the inspection, and do not have the intention to implement the PSM, exactly, before. In 2010, three serious fire and explosion accidents occurred in the factory sites of the Formosa Plastics Group of Taiwan. The Formosa Plastics Group accepted the suggestions of the invited expert, Dr. Mannan, professor of Texas A&M University, to carry out the PSM. Recently, the positive result of the implementation of PSM was observed by the government of Taiwan. The Occupational Safety and Health Administration, Ministry of Labor (formerly known as Council of Labor Affairs), of Taiwan required the work places, in which basic petrochemical raw materials are produced through cracking reactions and manufacture, process or use dangerous or harmful materials in quantities at or above the threshold level to implement the 14 elements of PSM, as suggested in 29 CFR 1910.119.

Description of the accident

Impurities of crystal was found in the chemical, o,o-dimethyl phosphoramidothioate (DMPAT), which is the raw material of manufacturing the agricultural chemical, acephate. It was decided to filter the impurities in the later January, and there were 40 tanks of DMPAT need to be filtered. Filtering impurities for DMPAT has never been done before. Since there is no filtering equipment, the DMPAT was pumped to a reactor, and heated to 40°C. The heat source was 80°C hot water, which was heated by steam from boiler. The impurities were filtered through a filter cloth by gravity.

Fire and a series of explosions occurred between five and six o'clock. One man was moved to other place by the shockwave during the explosion [4]. The wall of the workshop building was deformed and bulged (Fig. 1). The reactor was disappeared in the accident scene (Fig. 2). The control room was destroyed, and all the operation data was destroyed during the explosion.

Figure 1. The explosion scene (I)

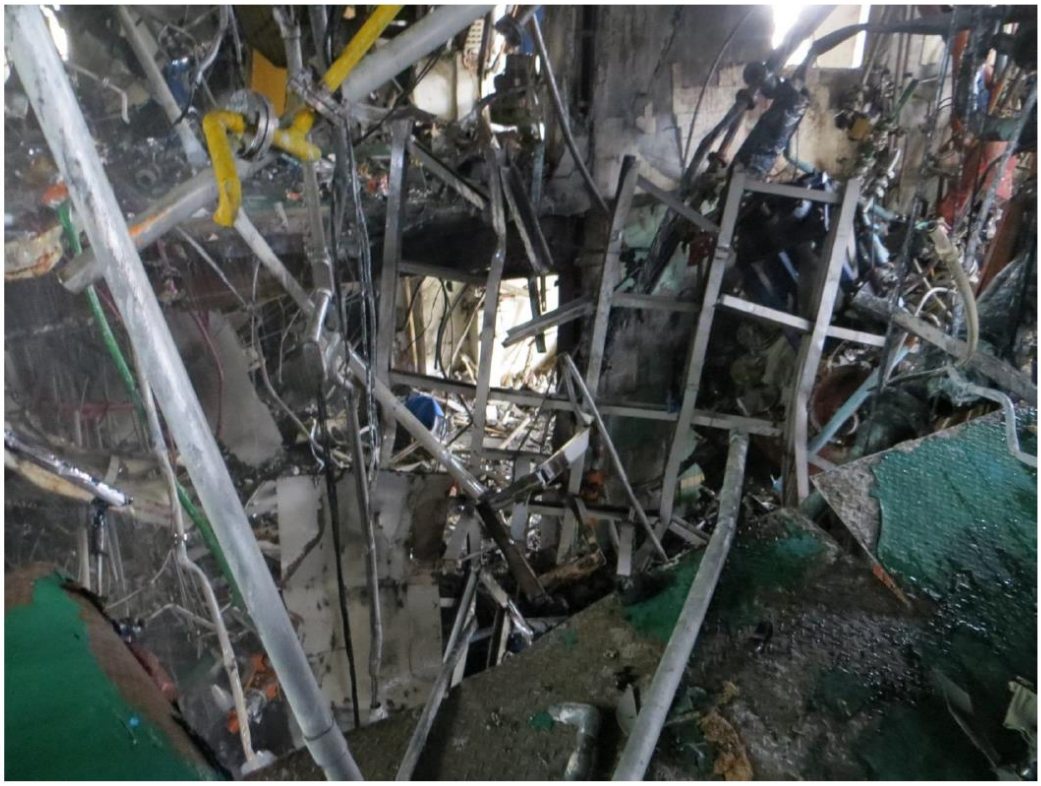

Figure 2. The explosion scene (II)

Lessons learned

Process safety information (PSI)

Most Safety Data Sheet (SDS) described that DMPAT is stable under normal temperatures and pressures. However, the TGA thermogram indicated that mass loss began at 93.5°C (Fig. 3), and the mass loss is greater than 20% for DMPAT being heated at 80°C for 5 hours (Fig. 4). The chemical stability description in SDS will mislead that DMPAT is stable, and make the workers not cautioning against temperature control. The process condition frequently far from the normal temperature and normal pressure, and the chemical hazards provided by SDS may be not adequate for the process condition.

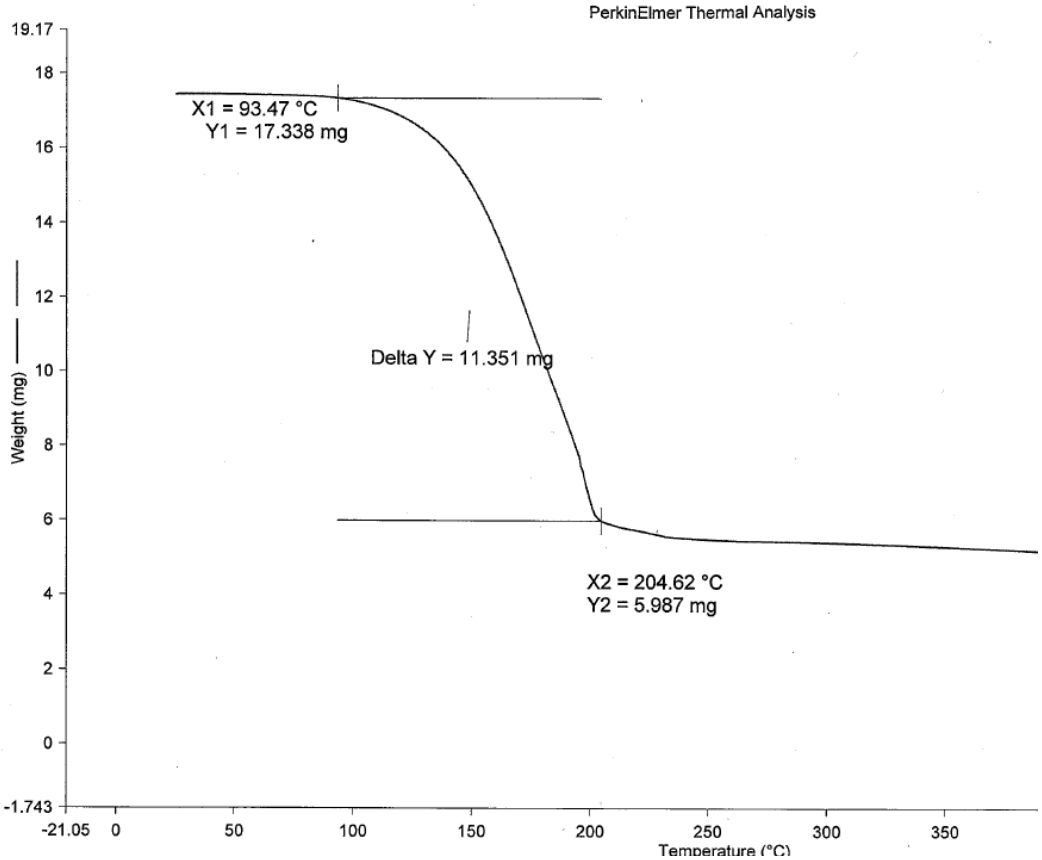

Figure 3. Thermogravimetric data for DMPAT

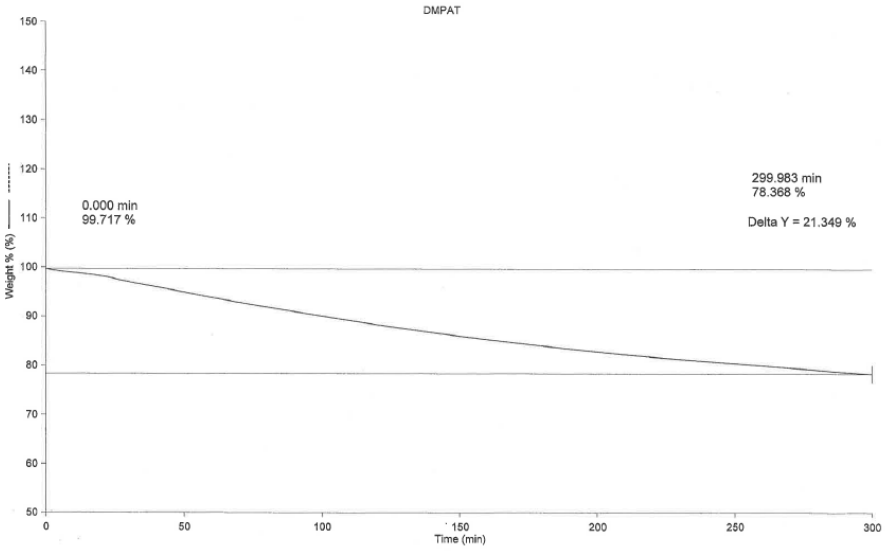

Figure 4. Isothermal thermogravimetric data for DMPAT heated at 80°C for 5 hours

The information pertaining to the hazards of the highly hazardous chemicals in the process, one of the process safety information, required by OSHA of USA consists of seven information or data. Since the information provided by SDS meets this requirement and SDS is the only required information in the Hazardous Work Place Review and Inspection Rules of Taiwan, SDS is always the only information of the chemical hazards in Taiwan. SDS provide the broad information of chemical hazards, nonetheless, it does not provide detailed information for chemical hazards. The detailed information necessary for processes are different for different process, based on the characteristics of process. Take the accident process concerned in this manuscript, the thermal hazard data of DMPAT is the critical data. However, such a data is not provided by the SDS. This data not only can be applied in temperature control in the operation, but also can be applied in incident investigation after the accident. Only SDS is possible not to provide enough chemical hazard information for workplace. The employee should identify the detailed safety information necessary for the processes based on the characteristics of processes, and develop the necessary detailed safety information.

Management of change (MOC)

The manager on duty indicated that the reactor was used as a buffer tank for operation of filtering because of no filtering equipment. The reactor being used as a buffer tank is a change; the impact of change should be evaluated. Since there is no significant hazard in the filtering process, the evaluation was not performed. The purpose of MOC is to prevent hazards resulted from change. In this case, hazard in the process of filtering, itself, is not the key point; the assessment should focus on the hazards attributed to applying the existing reactor to the filtering process as a buffer tank. Maybe there is no significant hazard in the filtering process, itself, in this case. However, the failure of the heating system may make the temperature of DMPAT to be greater than its onset temperature, and the failure of stirrer may produce hot spot in DMPAT. Both failures could result in thermal explosion of DMPAT decomposition.

The real operation is to pump the DMPAT to the reactor, and remain the

temperature at 40°C by the 80°C hot water through the jacket of the reactor. The hot source of jacket, hot water, was heated by steam generated from a boiler. Any cause makes the hot water to be greater than 80°C may result in high temperature of DMPAT.

Process hazard analysis (PHA)

In Taiwan, place which manufacture agricultural chemicals using specific raw materials was required to implement PSM. However, filtering the impurities of DMPAT is not a regular process, but an unexpected process, and such a process is not the area of being required to implement PSM. Thus, the PHA was not performed for the filtering process using reactor as a buffer tank. In addition, MOC was not performed for this change of using reactor as a buffer tank of filtering process, this change was not evaluated. If this change was evaluated by a proper methodology, such as HAZOP, not only the potential hazards of DMPAT in the heating process can be identified, but also how to prevent such hazards can be highlighted. Maybe this tragedy would not be happened.

Operating procedures

The plant manager indicated that filtering the impurities of DMPAT is the first time operation, the standard operating procedures was not set out. Because of first operation, the necessary operation time of each step is unknown. If the MOC was performed, a new operating procedure to filter the impurities of DMPAT by a temporary set of equipment including reactor would be developed. To ensure the safety of operation according to the new developed operating procedure, the operating procedure should be reviewed by a proper methodology, such as Job safety Analysis (JSA). The potential hazard in the operation can be identified and highlighted in the safety review, and the useful recommendations and suggestions can be proposed.

Pre-startup safety review (PSSR)

New facilities and modified facilities, when modification is significant enough to change the PSI, are required to perform pre-startup safety review by the USA OSHA [1]. The reactor was used as a buffer tank in the filtering process, the piping and instrument diagram (P&ID) of PSI should be changed, thus, a pre-startup safety review is necessary before the operation of filtering, based on the requirement of OSHA. However, the pre-startup safety review was not performed. If PSSR has been performed, the lack of standard operating procedures for filtering can be identified, and development of such operating procedures will be required to prevent the thermal explosion resulted from inadequate operation. More important, the PHA for the change not being conducted in MOC can be identified, the assessment of this change will be required, the thermal explosion resulted from high temperature deviation can be identified, the temperature control will be highlighted, and this tragedy might not be happened.

Conclusions

The purpose of implementing process safety management is to prevent or reduce the catastrophic release of highly hazardous chemicals [1]. However, not only the release of highly hazardous chemicals can result in major hazards of processes. Explosions attributed to runaway reactions, the accident discussed in this manuscript, and oxidation reactions with improper fuel/air ratio are examples of major hazards of processes but not being associated with the release of highly hazardous chemicals. Since the major hazards of processes are not limited to release of highly hazardous chemicals, it is suggested to perform PSM for the processes, with potential major hazards of processes, rather than just the processes, with release of highly hazardous chemicals.

References

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