Management of Change for Laboratories and Pilot Plants

Neal Langerman*

Advanced Chemical Safety, Inc., 7563 Convoy Court, San Diego, California 92111, U.S.A.

Abstract:

In spite of the U.S. OSHA Laboratory and Hazard Communication Standards, incidents which result in injuries and property loss continue to occur in the research and teaching locations. Application of the Management of Change methods contained in the OSHA Process Safety Standard to laboratory and pilot plant operations has the potential to further reduce the risks associated with these locations. Application of Management of Change from the OSHA Process Safety Management standard to these locations is examined, and the benefits of the approach are discussed.

Introduction

Research as performed in laboratories and in pilot plants is subject to frequent changes in operating conditions. Reactant concentrations, temperature or pressure, solvent conditions, and more are changed as needed to achieve the research objectives. The safety implications of these changes are seldom considered.

Hazard recognition in laboratories and pilot plants is generally managed under either the U.S. OSHA "Laboratory Standard[1]" or "Hazard Communication Standard[2]". Both of these emphasize communication of hazard information via a Safety Data Sheet[3] (SDS) and a product label. The Laboratory Standard also places considerable hazard control responsibility on "technically qualified individuals" who work in chemical laboratories. These individuals are frequently students (undergraduate, graduate, or postgraduate) and usually have limited experience with either hazard recognition or risk assessment. Even with the guidance of these standards, incidents resulting in injuries and property damage continue to occur in these research settings.

The OSHA Process Safety Standard[4] is designed to provide the specific guidance needed to manage operational safety, particularly related to process change, without excessive operational interference. Much has been written on implementing PSM on the chemical plant scale.[5] PSM does not apply to pilot plants or laboratories as currently implemented. Some research locations do use process management approaches, particularly in pilot plants. The frequency of incidents strongly suggests that many research institutions do not have practices in place to manage risks associated with kilo-scale or pilot plant scale operations. Using experiences gained in a variety of laboratory and pilot plant settings, this article will examine the application of one element of PSM, "Management of Change" (MOC), to these settings.

Incident Examples

Investigation of pilot plant or laboratory-scale incidents reveals that the underlying causes are similar to those found in major chemical plant incidents. The following summaries are illustrative of such incidents.

Phosphorous Oxychloride Release. A new technician was operating a research pilot plant with a POCl feed from an outside external tank. A slow POCl leak developed within 2 m of the technician's workstation. The irritating, corrosive vapors and mists caused the technician to leave the area without hitting the EMERGENCY STOP or ALARM controls. The response was delayed which resulted in significant HCl corrosion to the unit and to electrical contacts. The technician received minor inhalation injuries. Investigation of the incident indicated that a gasket had failed (mechanical integrity and material compatibility) and that the technician had not received sufficient training and was not given adequate supervision, commensurate with his lack of experience.

The significant change in this incident was the introduction of a new operator who was not familiar with the details of the unit.

Cumene Hydroperoxide Detonation. A study of metal catalysis of the reaction of *tert*-butyl alcohol with phenol to form cumene hydroperoxide was being performed. Laboratory-scale and kilo-scale studies had been successfully completed, and an existing 400 L pilot plant reactor was prepared for running a scale-up experiment. A major detonation occurred which destroyed the pilot plant. The investigation revealed that the existing 400 L unit did not provide sufficient cooling or sufficient venting to handle the exothermic catalytic reaction. A new catalyst was used in the pilot plant that had not been used in the kilo-scale unit which generated much more heat than was noted with the kilo-scale process (Management of Change). The existing 400 L unit had developed internal corrosion which further reduced the heat transfer efficiency and exasperated the overall situation. The blow-out venting was improperly sized and could not handle the rapid pressure−temperature increase which resulted from the highly exothermic reaction. The pilot plant operator did not understand the implication of the rapid temperature increase and failed to take appropriate action to stop the reaction. This was the result of insufficient training and the lack of adequate supervision during the critical start-up phase of the pilot plant.

Several changes were significant in the lead-up to this incident. The reactor was being used for a chemical process

* To whom correspondence should be addressed. Telelphone: (858) 874-5577. E-mail: neal@chemical-safety.com.

(1) 49 CFR 1910.1450.
(2) 49 CFR 1910.1200.
(3) The usual U.S. usage is "Material Safety Data Sheet". Under Global Harmonization of Chemical Hazards, the usage is "Safety Data Sheet".
(4) 49 CFR 1910.119
(5) Hendershot, D. *J. Chem Health Safety* **2007**, *14* (3), 39–40, doi:10.1016/j.jchas.2007.03.010.

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which had never been run in the system. A new catalyst was being used that had not been subject to small-scale testing. The operator, while familiar with the unit, was not familiar with the possible scenarios the new chemistry and new catalyst could cause.

Reflux Apparatus Failure. A reaction was being conducted in a tetrahydrofuran (THF) solvent at reflux using sodium–potassium catalyst. 1,3-Butadiene was bubbled into the system. The system was open to the atmosphere at the top of the condenser and was inside a laboratory fume hood. The 2 L flask was filled with 1 L of THF. During the reaction, the overhead stirring motor seized at the flask neck. The glass flask broke while the technician was trying to relieve the mechanical failure. This released the hot THF and NaK which immediately ignited upon contact with air. The resulting fire destroyed part of one laboratory and caused water and smoke damage throughout the building. Several weeks of lost time was incurred while the incident was investigated and the laboratory was rebuilt.

The investigation indicated that a mechanical failure at the bearing of the stirrer shaft was the root cause. Among the many contributing causes were the lack of procedures for out-of-normal conditions, failure to recognize that the THF–NaK mixture would immediately ignite upon contact with air, failure to cool the device prior to attempting to fix the seizure, lack of training, lack of adequate supervision, and lack of any written procedures. The investigation report stated that this specific mechanical failure was well-known and the possibility of such an occurrence should be addressed in the operating procedures. It was not addressed.

This incident is an example of a classic response to an "out-of-normal" situation in that the operator decided to take some action without determining if this was the correct action. While not specifically a "change" as used in PSM, this action resulted in a system change that led directly to a mechanical failure.

Review of these incidents and many more clearly shows that the underlying causes should be addressed by applying the guiding principles of PSM to laboratories and pilot plants.

Applying MOC to Laboratories and Pilot Plants

Research laboratories and pilot plants are, by definition, undergoing continuous change. The changes are usually evolutionary and small, for example, a modest increase in temperature or concentration. In the chemical process industry, units are designed to operate within narrow ranges of temperature and pressure with very specific chemistry. In research, changes in temperature, solvents, and actual chemistry are routine. During a reaction kinetics study, for example, the determination of the activation energy requires measuring the reaction rate of the temperature range of interest. A reaction mechanism study may require running the reaction with a series of leaving-group functions. These changes may seem routine, but each has the potential to result in an unintended runaway reaction. Implementation of a research program does require oversight to reduce the risks inherent in the activity. All-too-often the changes are made strictly in terms of the scientific demands without any safety consideration. Applying Management of Change concepts to the research environment can help reduce the risks associated with that environment.

Change is an inherent characteristic of the research environment. Significant changes, such as a complete change in the process chemistry or a complete change in the catalyst used in a process (see the cumene hydroperoxide example), occur much less frequently. At the pilot plant and full production plant level, failures resulting from inadequate management of change are well documented.[6] This is much more problematic in research because of the frequency of small changes to processes. Given the nature of research, procedures need to be implemented which allow the routine changes but identify and properly control significant process changes.

For each process identified within a pilot plant, a set of parameters need to be developed for acceptable routine changes. For example, in an organic synthesis pilot pant, allowing temperatures up to 130 °C with incremental changes not to exceed 10 °C might be reasonable. Similarly, providing a list of acceptable solvents or catalysts which can be used with no additional review is reasonable.

When a significant change must be made in a process, the proposed change should be documented and should address at a minimum the following:

- The technical basis for the proposed change
- Impact of change on safety and health
- Modifications to operating procedures
- Necessary time period for the change
- Authorizations for proposed change

For example, a pilot plant research student decides to change from a palladium-based catalyst to a nickel-catalyst system. The new catalyst is not on the preapproved list, so the student develops a proposal to make the change, using the outline above and submits it to the PI for review and approval. This assures that new health hazards are recognized and properly addressed.

Conclusions

The OSHA Laboratory Standard and Hazard Communication Standard have helped reduce injuries and illnesses. Incidents, including skin and eye injuries, overexposure injuries, and fires still occur with high frequency. Frequent changes in operating conditions are inherent in a research setting. While many changes are benign from a safety perspective, some are not. There seems to be no structured method for the research personnel to distinguish between these extremes. Use of a *Management of Change* with established limits of changes will control the hazards associated with research changes and will thereby allow risks to be reduced. Using *Management of Change* to manage change does not impose a significant bottleneck on the research process, but it will help raise the level of supervision of research changes.

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