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The Elimination and Control of Open System Chemical Operations

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Introduction

Open system chemical operations are in the best case undesirable and in the worst case unacceptable from an industrial hygiene, safety, environmental, and operating perspective. They cause and contribute to occupational illnesses, injuries, fatalities, fires and explosions, environmental releases, and operating constraints. This presentation examines the underlying reasons open systems continue to be used and an approach taken within one specialty chemical company to identify, eliminate and control open systems in its manufacturing operations.

Background

Open system handling of volatile materials and dust generating solids are recognized hazards due to potential inhalation exposures to gases, vapor, dust and mist (Renshaw 2013, NIOSH 2011). In addition to inhalation hazards, open systems pose dermal and ocular hazards from direct contact with corrosives, irritants and sensitizers. Systemic toxic effects from skin absorption of toxic materials are also foreseeable consequences of chemical handling in open systems.

Physical hazards from the handling of flammable, combustible, and reactive materials in open systems, and the environmental impact of spills and releases are no less consequential than the health hazards posed by these systems (Fairfax 2005). Fires and explosions from ignition sources such as static electricity as well as workplace and community incidents from releases of hazardous materials can be catastrophic (CSB 2007).

Operating constraints associated with open systems can be numerous and difficult to overcome. Opening vessel hatches can introduce product contamination. Inert atmospheres within closed vessels can be rapidly depleted by vessel opening, thereby negating the intended protection from fire and explosion. Confined space entry hazards can be eliminated and productivity improvements gained by converting vessel cleaning from open manual operations to closed, automated cleaning systems.

The need to eliminate or control open systems is compelling. And yet, open systems continue to exist in chemical manufacturing and other industries within and beyond the manufacturing sector. Industrial hygienists and safety professionals have not been fully effective in advocating for the elimination and control of open systems. We need to ask ourselves why our success in this area is limited, and what further we can do to eliminate and control this source of hazards.

Why Open Systems

There are two major reasons open system chemical operations continue to exist in industry. The first reason is that there is a demand for such systems. This demand is driven by many factors such as simplicity, versatility, feasibility and tradition. Chemical processing, especially batch processing operations, typically rely on the addition of small-volume ingredients to the process as part of the normal batch cycle. This processing requirement creates a demand and in all too many cases the use of open systems as the method of choice in introducing “small additives” to the process.

Another factor which has contributed to the persistence of open systems is the approach taken by industrial hygienists and safety professionals in applying exposure control strategies. We have traditionally been taught and apply control strategies which focus on post-release capture and control of contaminants through use of local exhaust ventilation or dilution of contaminants through use of general mechanical ventilation. There has been less emphasis on hazard elimination, substitution, and primary containment within the process equipment than on the use of ventilation. It was not until OSHA adopted general industry standards on 14 carcinogens in 1973-74, that closed systems were mandated and open systems prohibited (OSHA 1974). These standards remain in effect today, more than 40 years later. The industrial safety field has an even longer record of supporting closed system operations. The National Fire Protection Association specified closed system requirements for storage and handling of flammable and combustible liquids as early as 1963 and continues to do so in the latest edition of its Flammable and Combustible Liquids Code (NFPA 2012).

This brief summary of the history and practices associated with open systems has hopefully raised awareness of the inherent hazards in such operations. Elimination and control of these hazards through the use of higher order control strategies such as elimination, substitution, and containment by closed systems are accepted practices as evidenced by their adoption in government standards and industry codes of practice. The need exists across the industry sectors to search out and eliminate or control open systems by applying these recognized practices on a systematic basis. The following case study illustrates one company’s approach in assessing and addressing open systems in their chemical manufacturing operations.

Case Study

A global specialty chemical company ushered in the new millennium with a major acquisition which nearly doubled the size of the workforce. The number of manufacturing sites increased by fifty percent within the business group whose product lines included adhesives, coatings, monomers and plastics additives. Within a year of the acquisition the group experienced three serious incidents in three months time in the newly acquired facilities. All three incidents involved open systems. Following the incidents, management undertook a group-wide, multi-year initiative which consisted of the following three stages:

1. Surveying all plants for open systems
2. Prioritizing the open systems based on hazard, and
3. Developing and implementing a closed system control strategy

Plant Surveys

In the first stage of the initiative each plant in the manufacturing network was asked through a self-administered survey to identify and describe their open system operations. Open systems were defined according to the following criteria:

- Any vessel, tank or container in which a toxic, flammable, or combustible material is handled with the manhole or hatch cover open at some point during the normal processing cycle.
- Normal processing including: loading, feeding, processing, sampling, and unloading.
- Maintenance operations, where opening of equipment is normally covered by a safety permit procedure, are not included.

Survey questions covered key information concerned with processing equipment, materials handled, operating temperatures, and the extent to which safeguards such as local exhaust ventilation, personal protective equipment, pressure rated equipment, inertion and emergency relief were in use. Survey results were returned to the group environmental, health, and safety office for review and compilation in an open systems data base.

Prioritizing Open Systems

The second stage of the initiative called for the rating of each reported system on the basis of hazard. This was accomplished by assigning a numerical "hazard factor" to each open system. The factor included penalty points based on the inherent flammability, toxicity, reactivity and volatility of the materials handled, penalty points for processing conditions such as temperature, and penalty points for operating practices such as hatch cover position which increased the hazard (Figure 1). Credits (deductions from the hazard factor rating) were assigned for conditions which reduced the hazard such as local exhaust ventilation. This hazard rating system helped focus attention on the operations of greatest concern and aided in comparing operations across sites, technologies and materials.

- Hazard Penalty Points
  - Toxicity + Fire + Reactivity Ratings
  - Vapor Pressure
  - Processing Temperature
  - Hatch Cover Condition
  - Solids Charging
- Hazard Credits
  - Local Exhaust Ventilation
  - Vessel Inertion
  - Emergency Relief System & Safe Discharge
- Hazard Factor (HF) = Penalty Points - Credits

Figure 1. Hazard Factor Formula.

In addition to calculating a hazard factor for each of the open systems, additional attention was given to two special hazard concerns, 1) operations which involved materials known to be highly toxic, and 2) operations which involved the direct addition of solids into flammable atmospheres.

Highly toxic effects were taken into account by compiling a list of materials which included confirmed human carcinogens, sensitizers, and chemical cyanosis inducing materials which were recognized for their acute or chronic toxicity. The second special hazard concern, operations involving the addition of solids into flammable atmospheres, was taken into account by qualitatively assessing the physical properties of the materials handled, and conditions of handling in each open system.

Agreement on this prioritization process and target dates to address the systems (Figure 2) provided focus and management support at the site and regional business unit level. It defined the size of the job ahead and ensured the systems of greatest concern were addressed first.

Priority	Criteria	Target
1	HF ≥ 16.5	3 Months
2	HF < 16.5 to 14 + Listed Toxics + Solids into Flammables	1 Year
3	HF < 14	Site/Regional Determination

Figure 2. Open Systems Priority Groupings.

Developing and Implementing a Control Strategy

The third stage of the initiative involved the development of a control strategy and implementation plan to address the hazards of each open system. The strategy was based on classical industrial hygiene, fire protection, and prevention through design (PtD) principles. It was developed with input from the company's corporate engineering staff, manufacturing managers, industrial hygiene and safety professionals, and drew from company and industry practice. The control strategy included these six principles:

1. Vessels, tanks and containers must be operated with manways and hatches closed during normal chemical processing cycles.
2. Chemical processing in open topped vessels is not permitted.
3. Open system transfer of listed toxic materials to or from vessels, tanks or containers is not permitted. Such transfers must be conducted in closed or enclosed-ventilated systems.
4. Open system transfer of non-flammable materials other than listed toxics, to or from vessels, tanks or containers, is permitted provided that:
    a. Worker exposure is assessed and controlled in accordance with corporate standards, and
    b. Appropriate personal protective equipment is provided and worn

5. Open system transfer of flammable liquids into vessels must be eliminated or controlled by:
    a. Charging large quantities through hard piped systems
    b. Ensuring that each inlet stream minimizes the potential for buildup of static electrical discharge, and/or providing an inert atmosphere above the liquid level in the vessel
    c. Charging small quantities through an addition vessel or funnel
6. Open system transfer of solids into vessels, tanks or containers with flammable atmospheres must be eliminated or controlled in accordance with the following hierarchy of controls:
    a. Process change (elimination or substitution)
    b. Preferred method (engineering controls)
    c. Alternate method (administrative controls and personal protective equipment)

Examples are provided which illustrate the application of each control strategy principle.

Control Strategy #1: Vessels, tanks and containers must be operated with manways and hatches closed during normal chemical processing cycles.
Slides illustrate the conforming practice of an additives tank with the hatch closed and the non-conforming practice of a mix tank with the hatch cover left open.

Control Strategy #2: Chemical processing in open topped vessels is not permitted.
Slide provides a schematic diagram of a non-conforming open topped tank and indication that its use is not acceptable.

Control Strategy #3: Open system transfer of listed toxic materials to or from vessels, tanks or containers is not permitted. Such transfers must be conducted in closed or enclosed-ventilated systems.
Slides include a schematic diagram of closed system transfer of a listed toxic material by pumping from a drum to a receiving vessel, and a further refinement by remote-controlled transfer from an intermediate bulk container via hard piping to a processing vessel. An enclosed, ventilated drum unloading station is also shown as an acceptable alternative.

Control Strategy #4: Open system transfer of non-flammable materials other than listed toxics, to or from vessels, tanks or containers, is permitted provided that:
- *Worker exposure is assessed and controlled in accordance with corporate standards, and*
- *Appropriate personal protective equipment is provided and worn.*

Slide illustrates the acceptable practice of manual weigh-up and transfer of non-flammable and non-listed toxic raw materials with suitable personal protective equipment in use.

Control Strategy #5: Open system transfer of flammable liquids into vessels must be eliminated or controlled by:
- *Charging large quantities through hard piped systems*
- *Ensuring that each inlet stream minimizes the potential for buildup of static electrical charge, and/or providing an inert atmosphere above the liquid level in each vessel*
- *Charging small quantities through an addition vessel or funnel*

Slides illustrate different methods of controlling for static electrical buildup and discharge with free falling flammable liquids as they enter a vessel, and an innovative method of feeding small quantities of flammables by a closed system into a vessel.

Control Strategy #6: *Open system transfer of solids into vessels, tanks or containers with flammable atmospheres must be eliminated or controlled in accordance with the following hierarchy of controls:*

- Process change – elimination or substitution
- Preferred method – engineering controls
- Alternate method – administrative controls and personal protective equipment

Slide lists process change options such as substitution of a liquid form of a raw material in place of a solid form. Slide also provides a schematic diagram of a solid raw material charging station involving transfer by vacuum of the solid from the shipping container into a separator and transfer of the solid from the separator into the processing vessel. Additional slides show other mechanical solids charging alternatives as well as a list of administrative precautions and personal protective equipment requirements when the alternate method is chosen.

Summary

Open system chemical operations are sources of hazard which cause or contribute to occupational illnesses, injuries, fatalities, environmental releases and operating constraints. Open systems continue to exist across many industry sectors, and the need to eliminate or control these systems is compelling. Industrial hygienists and safety professionals can increase their effectiveness in addressing open systems by focusing greater attention on the higher order control strategies of elimination, substitution and closed system containment. A three-stage initiative of surveying, prioritizing, and implementing a closed system control strategy is described as one successful approach in assessing and addressing open system operations. Incorporating such an approach into an organization's manufacturing and occupational health and safety standards is an effective means of eliminating and controlling open systems at the design and redesign stage on an ongoing basis.

References

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