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Agency

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Occupational Safety and
Health Administration

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Chemical Safety Alert: Safer Technology and Alternatives

Introduction

The Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA) (EPA/OSHA) issue this Chemical Safety Alert as part of an ongoing federal effort to improve chemical risk management, advance safety and protect human health and the environment.[1] Recent catastrophic chemical facility incidents in the United States prompted the President to issue Executive Order (EO) 13650 - *Improving Chemical Facility Safety and Security* on August 1, 2013. Feedback from industry, workers, community members and environmental organizations emphasized the benefits of implementing safer technologies, including those, where possible, that are inherently safer, as part of an integrated approach to reducing risks associated with hazardous chemicals.

This Alert is one of several actions discussed in the May 2014 Report to the President - Executive Order 13650 - *Actions to Improve Chemical Facility Safety and Security,* on promoting the use of safer technologies. In the Report to the President, EPA/OSHA committed to issuing this Alert. EPA/OSHA also committed to developing voluntary guidance for facility owners and operators that will offer a more thorough examination of alternative measures and safety techniques and how these might be applied to existing processes to further reduce chemical and process risks. This Alert is intended to introduce safer technology concepts and general approaches and establish the risk management framework for the planned guidance document. The guidance will offer more practical details and examples. Also, as mentioned in the Report to the President, EPA and OSHA will not specify technology, design, or process selection for chemical facility owners or operators.

This Alert explains the concepts and principles and gives brief examples of the integration of safer technologies into facility risk management activities. Sources of information on process hazard analysis and inherently safer approaches to process safety are provided.

[1] The statements in this document are intended as guidance only. This document does not substitute for EPA and OSHA statutes or regulations, nor is it a regulation itself. It cannot and does not impose legally binding requirements on the agencies, states, or the regulated community, and the measures it describes may not apply to a given situation based upon the specific circumstances involved. This guidance does not represent final agency action and may change in the future.

What Does "Safer Technology and Alternatives" Mean?

Safer technology and alternatives means the integration of a variety of risk reduction or risk management strategies that work toward making a facility and its chemical processes as safe as possible. Usually these strategies are applied to a chemical process throughout its life cycle: from initial process and facility design, through initial startup, to on-going operations. Development usually starts with a systematic hazard identification using *process hazards analysis* (PHA) tools like "What If" or "HAZOP" (see 2008 CCPS). These tools work to identify and assess chemical and process hazards. Follow-on activities develop, refine, and implement a hierarchy of hazard controls and safeguards (see below) to reduce risks.

The first choice for managing chemical hazards and risks is the use of Inherently Safer Technology (IST) or Inherently Safer Design (ISD). IST and ISD are recognized approaches embraced by chemical process designers that are most effectively and powerfully applied at the process design stage. But they are increasingly applied by process operators to existing chemical processes.

Hazard Identification and Process Hazard Analysis (PHA)

- First and foremost, you should thoroughly know and understand ***ALL*** of the hazards of the chemicals present at your site (e.g., toxicity, flammability, vapor pressure, reactivity).
- Next, you should thoroughly know and understand ***ALL*** of the hazards associated with how you process or handle those chemicals (e.g., what happens when the power goes off, what happens when a tank overfills).

Armed with this information, you can now figure out the best ways to manage these hazards to prevent chemical incidents!

What is the "Hierarchy of Controls"?

The various chemical and process hazards present in a chemical facility are managed using a range of controls and safeguards. For example, properly designed and maintained vessels, pipes, valves, and temperature and pressure instruments are needed to safely store a toxic gas liquefied by pressure. The kinds of controls for managing chemical and process hazards range from "inherent" to various layers of "add-on" protections. Process safety experts generally prefer using the following "Hierarchy of Controls" to manage chemical and process hazards:

1. Inherent: The first preference is to avoid hazards by using non- or less-hazardous substances or materials (e.g., water may be inherently safer than an alcohol used as a solvent in a particular process), minimizing the quantity of hazardous substances, or simplifying or moderating process conditions to eliminate or reduce the likelihood or severity of incidents. Although this approach is best applied at the process design stage, there may be opportunities as described below for existing chemical operations;

2. Passive: Protective hardware or structures added on to a process that provide a risk reduction benefit with no action required by personnel and no motive power or energy source required (e.g., secondary containment such as dikes and sumps; blast barriers and shrapnel shields; pressure vessel vent rupture disks; tank vent flame arrestors);

3. Active: Safety features or engineering controls added on to a process that require active operation of equipment to prevent or mitigate safety hazards (e.g., process control devices such as flow control valves and pressure sensors, temperature, pressure and flow alarms, control interlocks (e.g. a vessel high level alarm triggers a flow valve to close), emergency shutdown systems, vent and relief valve scrubbers, vapor suppression systems, de-inventory systems that require pumps); and

4. Procedural: Administrative systems that mandate maintaining safe process conditions, operating procedures defining safe operating modes and the steps to be followed to maintain those modes, training, emergency response procedures, emergency warning and evacuation procedures.

What are Inherently Safer Approaches?

As noted above, it is preferable to avoid hazards in the first place. “What you don’t have, can’t leak.” (Trevor Kletz, University of Loughborough, UK). Here, in order of desirability, are four inherently safer approaches designed to avoid or reduce chemical and process hazards and brief examples that illustrate how they can be implemented:

Inherently Safer Approach	Examples
1. Substitution Use non- or less-hazardous materials, chemistry, and processes. This approach can potentially eliminate the underlying hazard.	***Replace a hazardous material with a less hazardous one*:** ▪ Replace gaseous chlorine with hypochlorite ▪ Replace anhydrous gases stored under pressure (e.g., hydrogen fluoride and hydrogen chloride) with acid solutions (e.g., hydrofluoric acid and hydrochloric acid) that have a lower vapor pressure ▪ Replace a flammable solvent with a water-based system ***Processes that reduce or eliminate a hazard*:** ▪ Eliminate bulk oleum and sulfur trioxide storage by using sulfur burning equipment onsite ▪ Convert anhydrous ammonia refrigeration system to a system that uses a less toxic refrigerant (e.g., glycol and ammonia) or an ammonia solution
2. Minimization Use smaller quantities of hazardous materials; reduce the size of equipment operating under hazardous conditions such as high temperature or pressure.	***Reduce hazardous material inventory in process:*** ▪ Use pipe or loop reactors vs. batch vessels ▪ Use continuously stirred, flow-through systems vs. batch reactor vessels ▪ Adjust reactant ingredient quantities to minimize runaway reaction magnitude. ***Reduce quantity of hazardous substances stored as feed or product inventory:*** ▪ Implement “produce to consume” processes (e.g., eliminate storage of chlorine gas by generating chlorine and consuming it as it is produced) ▪ Generate feedstock on-site at the consumer location ▪ Implement “just-in-time” deliveries of feed or product (e.g., use of 100-150 pound cylinders instead of 1-ton containers to supply a process)

3. Moderation Reduce hazards by dilution, refrigeration, or process alternatives that operate at less-hazardous conditions.	***Operation at conditions that reduce the potential for and magnitude of vapor release in the event a leak occurs:*** ▪ Reduce temperature or pressure at which a process operates ▪ Use a semi-batch reactor rather than a batch reactor to reduce peak temperature/pressure in a runaway reaction scenario ▪ Store gas as a refrigerated liquid in a low pressure vessel instead of at ambient temperature in a pressure vessel
4. Simplification Eliminate unnecessary process or chemistry complexity to reduce the likelihood of controls and safeguards failing to operate properly on demand.	▪ Standardize equipment and/or control systems to simplify operator training and operations to reduce the potential for human errors ▪ Reduce the number of process vessels or other components handling hazardous materials ▪ Reduce the number of interconnections to reactors to minimize inadvertent flow paths ▪ Use fully welded construction to eliminate/minimize the potential for flange leaks ▪ Locate pipelines to minimize collision impact ▪ Minimize the length of hazardous material piping runs; eliminate "dead legs" ▪ Eliminate situations where rapid operator intervention is required to prevent accidents or spills

What Should You Do First?

1. *Know Your Chemicals*
   Your first step should be to thoroughly know and understand ***<u>ALL</u>*** of the physical and chemical properties of the substances present on your site. Is the chemical volatile? Is it toxic? Will it generate a dense gas cloud if it gets released? What happens if it is accidentally mixed with water or something else handled at the site? Is if flammable? What happens if there's a fire?

2. *Know Your Processes*
   Next, thoroughly know and understand ***<u>ALL</u>*** of the hazards of the ways in which the substances at your site are handled and/or processed, including those that just temporarily sit in a warehouse. What happens if the power goes off? What happens if a storage tank overfills? What happens if the temperature rises in the reactor? What happens if the compressor generates too much pressure? What if there's a fire? What happens if a forklift punctures the container?

There are many tools to help you gather and understand chemical and process hazards such as "What If?" and "HAZOP." These tools help you step through the many ways things can go wrong and to understand the potential consequences when something does go wrong (see CCPS 2008).

Armed with this information, now you can figure out ways to manage and control these hazards and to reduce risks as low as possible.

What are Some Approaches to Safety / Risk Management?

Here is a flow chart you can use to take steps to find ways to address the chemical and process hazards you identified above. Please note: there is no "silver bullet" or "one size-fits-all" solution. You may not be able to eliminate all chemical and process hazards. In some cases, there may not be practical inherently safer alternatives, and in other situations, an inherently safer approach will only reduce part of the potential risk associated with the use of a hazardous material or process. You may find you need to use multiple "layers of protection" (see below) at various points to make your site safer.

At each point in this flow chart, you should examine whether any of the alternative opportunities you might choose is achievable, practical and cost effective and that it doesn't inadvertently transfer risks elsewhere that could either be unmanaged or less desirable. For example, reducing chemical inventory too low could trigger the need for more frequent supplier shipments at odd hours, increasing the potential for a release during transfer operations.

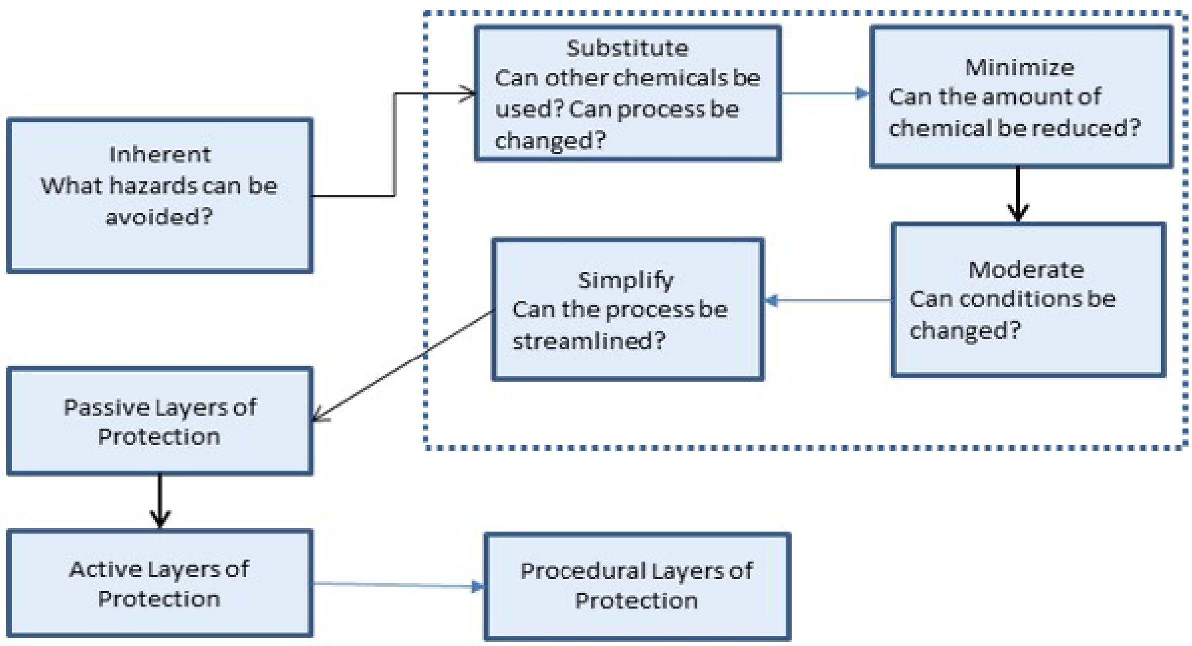

Figure 1

What are "Layers of Protection"?

The hierarchy of controls concept helps classify safeguards by their reliability, with inherently safer approaches generally being highly reliable while administrative safeguards tend to be less reliable in preventing harm. However, controlling risk almost always requires using multiple approaches. The concept of layers of protection acknowledges that individual safeguards are not totally reliable or effective, and thus multiple safeguards ("layers") may be needed to minimize the chances of an initial fault propagating to a full blown incident with potential for harm. This is often illustrated using the "Swiss Cheese" model for incidents (see Figure 2). In this model, each safeguard layer has the potential to fail, with highly reliable safeguards (e.g., "inherent" ones) having relatively few "holes", and less reliable safeguards (e.g., "procedural") having more. While no single layer can adequately control the hazard, having a sufficient number of adequately reliable safeguards can greatly reduce the chance of all of the "holes" lining up so that an incident actually occurs.

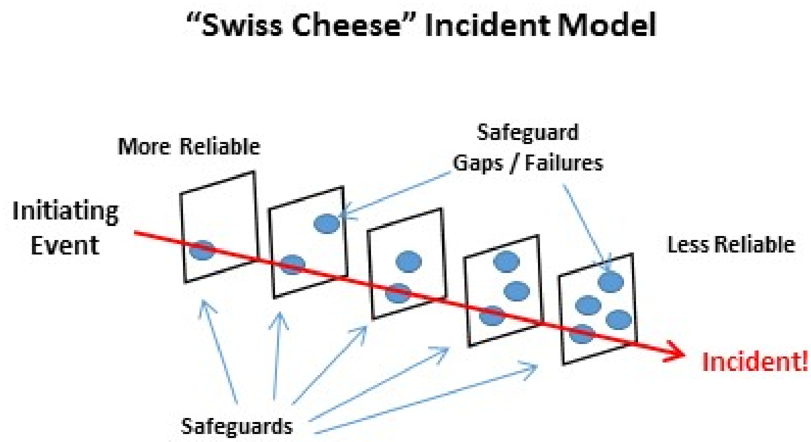

Figure 2

Facilities typically utilize as many layers as necessary to adequately control their process hazards, with preference given to more reliable safeguards. Thus an atmospheric storage tank containing a highly hazardous chemical might contain the minimum amount of material needed for the process to operate reliably (inherent - minimization), have secondary containment provisions (passive), use multiple level alarms and controls to detect and react to potential overfills (active), and utilize operating and maintenance procedures to reduce the likelihood of an overfill or leak occurring and to ensure that safeguards operate properly when called upon. By ensuring that an adequate number of reliable safeguards are in place and functional, the facility can confidently manage the risks associated with the storage tank.

What's Next?

As noted above, this Alert is designed to introduce approaches and concepts associated with safer technology and alternatives; future guidance will offer more practical details and examples. In the meantime, you can certainly start to learn more about process hazards analysis (see 2008 CCPS), the hierarchy of controls and layers of protection. The second edition of the Center for Chemical Process Safety (see 2009 CCPS) guideline document *Inherently Safer Chemical Processes - A Life Cycle*

Approach (CCPS 2009) is one of the most detailed references, with numerous examples and case studies related to inherently safer applications. More recent publications continue to contribute new ideas, tools, and examples in the inherently safer arena (See Appendix A).

Ultimately, it is up to you to understand your facility's risks and what you need to do to protect your workers, the public, the environment and your capital assets. As described in the CCPS "Business Case for Process Safety" (see http://www.aiche.org/ccps/about/business-case) diligence by owners and operators to adopt good process safety management practices and to do things the right way, every day, enjoy the positive benefits of better operations and continuous improvement.

Finally, the various agencies involved in chemical safety and security are working with industry to collect, develop and publicize best practices, including approaches for consideration of inherently safer alternatives to existing controls and safeguards (see https://www.osha.gov/chemicalexecutiveorder/LLIS/index.html).

Appendix A - References

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