**PME/CHE 531**

**Process Safety Management**

**Element #3 - Process Safety Review Procedures for Capital Projects**

Overview

Some examples of capital projects include: Construction of a new plant; capacity additions; manufacture of a new product; facility modifications;Why the need for some level of process safety review? New projects can introduce new equipment, new chemistries, state-of-the-art-controls, new operating procedures, increases in chemical inventories, new hazards.  Production could involve flammable, toxic, corrosive, explosive & other physical hazards.  Without verification, incidents could occur with injuries, loss of life & property and business interruptions, & impact on the community.  Also, heightened public awareness of chemical hazards and more stringent government regulations demand comprehensive and systematic reviews. The PSSR is critical to continued safe operations.

What do safety reviews address?  Equipment overpressure protection, materials of construction, fire protection systems, maintainability, compatibility, exotherms, adjacencies, etc. Are all process hazards known and adequately designed for mitigation?

Have equipment, piping and controls been checked for inadvertent hazards?

Example #1

Chlorine and acetone produce a violent exotherm.  In the original design of a reactor that mixed vaporized chlorine and acetone, there was no provision for preventing acetone from backing up into the vaporizer on the loss of Chlorine pressure.  As a result, when the chlorine feed was shutoff before the acetone, the acetone backed up into the vaporizer and filled it.  Upon restart of the Chlorine, the vaporizer melted and caused a Chlorine emission into the plant. A safety review of this could have identified this problem and put in additional engineering or administrative controls to prevent this problem.

Example #2

A liquid chlorine feed tank has steam on its jacket to maintain a pressure in order to feed it at a certain rate.  When there was a power failure, the inlet and outlet automatic valves failed closed, trapping liquid chlorine in the tank. Residual steam left in the jacket caused the pressure to increase and the safety valve blew.  How could this be prevented or mitigated?

Does the installed equipment conform to design as indicated on drawings and specifications, i.e., IQ (Installation Qualification)?

Have computer systems been validated?

Are the consequences of process deviations known and have they been acceptably mitigated?

Have the consequences of human failure been identified and planned for?

Project safety reviews need to be formalized, documented and communicated to various levels of management to tap collective knowledge and other perspectives.  They are most cost effective if done in the early stages of the project because they avoid costly modifications later.  Any change, regardless of size or cost, requires a safety review.

Five Phases of a Typical Major Capital Project

Phase I Conceptual Engineering  technical and economic feasibility, process chemistry, hazards, flow schematics, design basis for equipment, controls and safety.

Phase II  Basic Engineering mass and energy balances, process flow diagrams (PFD), piping and instrument diagrams (P&ID), equipment data sheets.

Phase III Detail Design  equipment calculations (pumps, heat exchangers, vessels), line sizing, isometric drawings, all specifications and drawings issued for construction.

Phase IV  Equipment Procurement and Construction  purchase of fabricated and bulk materials and installation on site.

Phase V Commissioning Prior to Startup  IQ/OQ (Installation Qualification/Operational Qualification).  Does everything work the way it was designed?  Is it all there?  Does it work together?  Is everything free of obstructions?

PQ (Process Qualification) usually performed by technical group with production personnel. Involves dummy runs with water and solvent.

Process safety considerations should begin during Phase I.  Watch out for fast-track projects where schedules are intentionally compressed.  Do not short-cut process safety reviews.

Example #3

In an effort to reduce costs, a vessel was tiled-lined instead of glass-lined.  The previous equipment used in the process was glass-lined.  Corrosion testing was done on the tile and it passed.  After running the equipment for a few months, there was a failure.  Apparently the grouting with which the tile was held together was not compatible with the process conditions.  Having the right people on the team for a safety review can bring out these issues, as well as, having a Pre-Startup Checklist as part of the safety review.

Example #4

A low cost vendor was selecting to rubber-line piping in an anhydrous HCL process.  All the rubber-lined piping eventually failed, but it was a slow process, causing delays due

partial line collapsing.  There were also AHCL emissions due to pipe ruptures.  It is

important to qualify vendors to make sure they can produce quality work and not to select them merely on lowest cost.  Appropriate questions should be built into the safety review to address these issues.

Process safety management systems must consider the following components: appropriation request procedures, hazard reviews, siting, plot plans, process design and review procedures and project management procedures and controls.

Appropriation Request Procedures

At the very beginning of a project the core scope items should be outlined.  Core scope items can be established in checklists, such as , safety and environmental checklists. These types of checklists should have such questions as:

What are the hazards of the chemicals?  What are the process hazards?  What are the quantities of chemicals?  Where and how will they be stored?  What are the worst-case scenarios, including loss potentials?  How will the risks be controlled?  What are the personnel or community exposure potentials?

The costs associated with identified process safety issues should be included in the initial phase estimate.  These costs will be firmed up in the detailed engineering phase.  The process safety management system should be integrated with the planning process and the funding authorization system.  The appropriation request should not only include the cost of capital, but also, the operating cost of the resources (people, utilities, materials)needed to effectively manage the risks.  After appropriate people have assessed the process safety management designed into the project and signed off on it, the request can proceed to management for approval.  Depending on the potential risk and impact should determine to what level of management it goes to for approval.  Management cannot accept the project for approval consideration until the process safety checklist has been completed.

Watch out for fast track projects.  While fast track labeling can expedite reviews, it should not prevent the process safety review from being completed.  Sometimes needed information is not available.  The estimate moves forward with gaps.  Have all concerned parties acknowledge by signing off that the project cannot be closed until these gaps are filled.  Examples of gaps:  corrosion data not completed, critical PMs not written, process safety lab testing not completed, emission calculations not completed (exposure potential), HAZOPs not completed, etc.

Siting

The main consideration is the risk of human exposure to toxic and flammable chemicals.

Consider the consequences of credible worst case scenarios.  Examples: fires, explosions, safety valve release, blown rupture disc or gasket on a reactor, line failure, spill during a transfer.  Consider the risk of transporting hazardous chemicals to the site.  Alternative sites should be considered. Accountability should be established for siting and a checklist for consideration.  Items to be considered include:

Is there a buffer zone?  What surrounds the site? (homes, schools, hospitals) Can an effective evacuation plan be implemented?  How can we communicate with the neighbors? Is there good transportation available to the site for materials?  Is there adequate fire protection water?  Is there emergency response support at the site or from the surrounding community?  Are there outside sources of risk that can threaten the site? (people, activists, other chemical plants)  Are there weather extremes?  What about the topography/geology of the area?

Siting selection may be made where potential offsite impacts cannot be avoided.  In this case the risks can be mitigated.  Examples of mitigation:  Inventory reductions (cylinders vs tank cars),  backwards integration (make hazardous chemical), protective devices (blowout panels, encasements, scrubbers) and process controls (alarms, interlocks, emergency shutdown switches), educate the community, run drills. Consequences and probability analyses can be done of all credible release events by applying quantitative risk analysis techniques.  In the final selection, the decision-maker should be provided a written assessment of the process safety evaluation.

Plot Plan

The siting of the project on the site requires the evaluation of what will be surrounding it and the distances separating it from other equipment, structures and people.  Some companies have extensive internal engineering standards that govern these situations.

There are other guidelines or codes (OSHA, NFPA) that can be used and aides found in other CCPS publications.  Examples of plot plan considerations: location of storage tanks, separation and placement of storage tanks, electrical safety for flammables, safe distances from onsite and offsite populated areas, stack or vent discharges, accessibility for maintenance and emergency equipment, removal of equipment, deliveries. There may be special legal requirements depending on the chemicals involved.  For example, benzene, which is a known carcinogen, much be discharged at least 50 ft. above where anyone is working and lofted at a velocity of 3500 fpm (NJPDES).

Design standards can control the level of risk that is acceptable in a consistent manner.  Safe layout requires the review of people familiar with the site, the process and the hazards.  The design process should allow for this input.  Examples of people who should be involved: Fire protection engineer, electrical, HVAC, process engineer, safety engineer, utilities, material management, technical support.

Hazard Reviews

Hazard reviews identify any potential hazard introduced in a capital project and what measures that can be taken to control them. Hazard reviews should be conducted at various stages of a capital project.  Depending on the stage of the project determines the type of review (See Appendices 5A & 5B, pp. 51 - 55).  Corporate policies should dictate these reviews be done.  The intention of hazard reviews at the earliest stages is to rule out proposals that may have unacceptable risks and thereby not waste time and  money on these.  Many companies use HAZOP (Hazards and Operability Studies) software.  These are very detailed and structured and the  questions pre-selected.  They lead to easy action plan development with responsibility and timing.  Both equipment/piping configurations and procedures can be HAZOPed.  The hazards review team should be multi-disciplined and have a team leader:  manufacturing, process engineering, research, safety, maintenance, environmental, process experts, etc. There should be documentation of the hazards review process, including: the hazards identified, recommendations to control or eliminate hazards, action plans developed with follow-up mechanisms, tracking unanswered questions, basis for decisions.  All outstanding items should be resolved prior to startup.  This is particularly important for procedural recommendations that need to be built into the SOPs.  Verification of these are part of the validation protocols. The documentation becomes part of the project acceptance checklist.

Process Design and Review Procedures

Quality control of adequate designs must be checked by design specialists and other design team members.  Vendor drawings should be cross-checked against equipment specifications.  There should be process safety design and pre-startup safety reviews.  Process safety design reviews include: equipment design conditions vs process conditions, fail-safe analysis, alarm set points and interlocks, reactivity, emergency backups, such as, utilities or scrubbers, critical instruments, fire protection, compatibility, line and pump sizing, etc.  Pre-startup safety review should include: hazard recommendations status, safety critical equipment, IQ/OQ completed, SOPs written, training, computer validation, emergency response procedures, etc.  The earlier the reviews, the cheaper to fix any problems.  Safety reviews should still be done when the design was done by a vendor.  You should also require the vendor to provide their own documented safety review.

Example #5:

Bridgebreakers Metal vibrating grids were inserted in the bottom discharge cone of a hopper that collected particles of product from a dust collector. These metal grids would vibrate periodically in order to break-up product bridging along the bottom cone.  After a time, the metal fatigued and snapped.  A spark was produced and there was a dust explosion causing damage to the hopper internals.  A safety review should have

anticipated this.  The corrective action was to install an explosive suppression system that

actually senses the spark and discharges a halon (fire suppression gas) system to prevent the explosion.  In addition to this the explosion vent on the side of the hopper was enlarged.

Example #6

Site water contamination problem: A filtrate system discharges a solution containing filter cake at 120 psig.  This line would be periodically flushed with city water to keep the line from plugging.  One time the line was flushed with water and the hose connection left connected.  The filtrate line plugged and backed up into the site city water line causing a sitewide emergency.  The city water line was only at 75 psig and had this incident not been caught quickly, the contamination would have spread offsite.  As a result of this, engineering standards were developed that prohibited any direct connection from city water lines to process water lines.  The design standard was to have city water added to any process system via a physical break tank or by way of a funnel.  Another option was to install 2 backflow preventors in the line in series.

Project Management Procedures and Controls

Project management procedures and controls are an essential part of process safety management.  The key role at this time is to check that plans are carried out as intended. It is a quality assurance phase. Is equipment fabricated correctly and of the right material? Is it installed properly? Does it operate properly?  Does maintenance have the information (Bill of Materials - BOMs, specs, PMs) needed to properly maintain the equipment.  Sometimes inspectors are sent to fabricators to ensure proper assembly and operation at their site.  All these costs should be part of the core scope of a project.  Many times vendors are pre-qualified by companies to ensure they conform to your company standards and procedures.