HIGH-HAZARD CHEMICAL AND PETROCHEMICAL PLANTS

INTRODUCTION

This PRC Guideline presents guiding principles for loss prevention and control for high-hazard chemical and petrochemical plants. They are intended as a tool for evaluating the widely diverging protection levels provided at these facilities. The application of these concepts would help reduce the risk associated with chemical operations,

POSITION

Management Programs

Management program administrators should report to top management through the minimum number of steps. They should also institute adequate loss prevention inspection and audit programs to communicate program effectiveness to top management. This management feedback is a key feature of *OVERVIEW* (PRC.1.0.1). In developing a program, pay particular attention to the following important areas:

Hazardous Materials

Develop a program to determine the pertinent physical and chemical properties of all chemicals used in the process including reactants, intermediate products, by-products, and end-products. Choose test conditions that best represent all possible operating conditions.

Establish routine procedures for testing physical and chemical properties of all incoming raw materials, intermediates, and final products to confirm properties required for safe operating conditions.

Process Hazards Evaluation

Determine the safe operating and potential upset conditions of all new or existing chemical processes used by the plant. Include scaling factors (bench, pilot, semi-works, full scale, etc.) in establishing the safety parameters. Use industry recognized methodologies to determine and evaluate the potential causes and consequence that fires, explosions, and releases of hazardous chemicals might have on the facilities. Consider previous incidents, accidents and near-misses when conducting a PHA; assure that proper preventive and control measures have been identified and put in place.

Operator Training

Establish a structured training program for plant operators. Assure operators are fully trained for each operating mode initial start up, normal operation, normal start up, normal shut down, and emergency

shut downs. Educate all operators in the hazards involved and in functions of the safety control equipment. Forbid operators to run the process when any of this equipment is out of order. Forbid deviations from the written procedures. If PLCs are used in safety instrumented systems, then access to the programming should be strictly controlled.

Schedule re-education and training at least annually. Include testing to assure proper performance of all assigned duties with particular emphasis on emergency shutdowns.

Pre-Emergency Planning

The pre-emergency plan from PRC.1.0.1 may be used to develop a customized plan. This customized plan should include the following features:

- A fire and disaster alarm system.
- An emergency communications system, including radio where needed.
- Provide an adequately equipped emergency control centre remote from chemical operations hazards.
- An adequately trained, staffed, and equipped organization of employees for fire fighting and other emergency duties.
- Develop pre-emergency plans, and plans for recovery from natural disaster, plant failures, and other contingencies.
- A planned program of cooperation with neighboring plants and with public fire fighting and disaster control organizations.
- A program to analyze the interruption of business that may result from potential incidents and to develop plans for minimizing loss of production during rebuilding.
- Periodically conduct emergency exercises/simulations arranged to test the emergency response arrangements at all levels, including external resources such as civil brigades, mutual aid etc where these are part of the emergency response plan.

Preventive Maintenance and Inspection

Develop a full scheduled plant maintenance program for entire plant. Define clearly maintenance philosophy and procedures, including any definition of critical equipment. Adopt proactive maintenance philosophies (preventative and predictive) rather than breakdown philosophies.

Inspect and maintain process equipment, piping, instrumentation, electrical equipment, rotating equipment, and pressure relief devices according to a schedule established with proper consideration of design and service conditions. Include all appropriate types of modern nondestructive testing, IR. scanning, and vibration analysis, and lubrication oil analysis in the inspection techniques.

Collect and analyze maintenance data to facilitate improvement e.g. availability, mean time between failure, forced outage analysis, bad actor lists, backlogs, and equipment retirement forecasts. Assure maintenance personnel are very familiar with plant operation. Review the maintenance program annually.

Management of Change

Apply all management programs to any changes made to the facility's physical arrangements, change of process technology, variance of procedures, permanent changes, temporary changes, organizational changes. Pay particular attention to the following areas:

- Conduct a process hazards evaluation for all new processes and when making any modification to an existing process. Determine the need for new or different process safety equipment or control measures.
- Whenever equipment is changed from one service to another, or when process changes are made, examine the inspection and maintenance program and modify as necessary. Monitor daily operating changes.

- Verify that new construction materials and all maintenance parts and supplies conform to the original (or modified) design specifications.
- Apply the program for handling new construction, including the control of outside contractors.
- Update operations procedure manuals after each process unit modification which results in a change in operating procedure.
- Review and follow through expeditiously on all inspection recommendations from insurance, code enforcement, and regulatory agencies.

Other Management Programs

Incorporate these features into the comprehensive management program for loss prevention and control:

- Formal work permit system (i.e. cutting, welding and other hot work, confined space, hot tapping, etc).
- A program of supervision of impairments of fire protection equipment using AXA XL Risk Consulting's "RSVP" program.
- Smoking regulations.
- Plant security and surveillance.
- Pre-startup safety review program.
- Business Continuity Plan

Duplication of Facilities

Duplicate with installed spares equipment that is highly susceptible to loss or very important for continued operations. If this is not possible, keep readily available spare parts and maintain them ready for use. Physically separate or compartmentalize duplicated equipment.

For smaller scale or batch type plants, install processes important to production in the form of multiple small-scale units rather than a single unit. Design a single unit to facilitate prompt repair using readily obtainable or pre-purchased parts. Where neither is feasible, store the product of the process in question in sufficient quantity to permit normal sales until repair or replacement is complete.

For large-scale chemical and petrochemical plants, provide multiple process trains. Also maintain spare parts for equipment known from industry experience to be critical. Develop and maintain a critical spare parts database.

Plant Layout and Separation

Space separation is the most effective loss control method. Design separation into a plant during the early planning stages of a project. Consider separation of main processing areas, separation of sections within a processing area, and separation of equipment within the various sections. Separate storage tank areas from process areas. Give special consideration to pressure storage vessels to minimize exposure to all other plant areas.

Consider the following factors in determining the need for or the degree of separation:

- High hazard operations.
- High property or business interruption values.
- Exposure to possible explosion overpressures.
- Access for effective fire fighting and good maintenance.
- Adequate space for future expansion.

See PRC.2.5.2 for details.

Design Considerations

During the early stages of chemical process design, explore the application of inherent safety concepts to reduce the risk potential, and the requirement for using multiple layers of protection.

Consider options such as substitution of highly reactive chemical, reduction of hold-up of hazardous materials, using cooling water instead of combustible heat-transfer fluids, operating at low pressure and temperature to avoid creating conditions for a runaway reaction.

During the design process, keep the following in mind:

- In process design, minimize the flammable and combustible material hold-up per vessel. Improved equipment may require less of these materials, and consequently the amount that may be spilled by equipment failure or operator error will be less.
- Design all processes with inherent safety by the use of instrumentation and by enforcing adherence to written operating procedures, and with ultimate safety by providing adequate pressure relieving devices. Interlock processes to shut down automatically and safely in event of operator error or equipment failure. Provide intermediate alarms to allow operators time to take corrective action.
- Design, install, and maintain all safety instrumented systems according to ISA 84 or IEC 61512. The preferred mechanism for the most critical systems is hardwired interlocks (non-PLC).
- Provide redundant instrumentation for all critical controls. In redundant loops, include **both** separate signal transmitters and signal receivers. In most cases, install a comparator to notify operators when control and redundant signals differ significantly.
- To limit the amount of materials released by equipment failure, include the following in shut-down measures: block valves; venting to flare stacks or to incinerators; liquid dumping to blowdown systems; and purging or flooding of equipment with a nonhazardous fluid. Actuate these shutdown measures with combustible vapor detectors where appropriate. Design block valves to be fire safe and fail to the safe position.
- When designing safety features, assume a minimum of two consecutive errors, one of which may be misinformation because of a faulty instrument or a misunderstanding of instructions.
- Design and specify equipment considering all possible operating conditions, both normal and abnormal. Give particular attention to suitability of the equipment to handle the process materials and to withstand external environmental influences.

Construction

Use only noncombustible materials when constructing equipment, buildings, or other structures. For interior finish, ceilings, and insulation, use listed construction materials having a flame spread rating less than 25 and fuel contributed and smoke developed rating less than 50, when tested in accordance with ASTM E84.

Fireproof all major load-bearing structural steel supports for outdoor process structures, process equipment, important exposed pipe racks, and buildings with materials tested and listed by Underwriters Laboratories utilizing UL 1709 test procedures. Provide 2½ h rated fireproofing for equipment or structures handling or exposed by liquefied flammable gases, flammable or combustible liquids, or by flammable gases. If these structural members are protected by properly designed deluge sprinkler systems, or they are located in areas of less severe exposure (as defined in the referenced published material), fireproofing with a 1½ h rating by UL 1709 is acceptable.

Provide fireproofing for important grouped power, control, and instrumentation cables, tubing, or conduit, and fire-sensitive thermal insulation on important equipment. To allow sufficient time for shutdown of the process unit, the fireproofing for this application requires only a 30-min protection rating. See PRC.2.5.1 for details.

Where flammable gases or liquids are handled, select open-sided process structures rather than closed buildings because of inherently good ventilation and explosion relief. Where closed buildings must be used, provide ventilation. Supplement normal ventilation rates with emergency ventilation actuated manually and by diffusion-head-type combustible gas detectors.

Where an explosion hazard exists and closed buildings must be used, provide explosion venting facilities. Design the nonrelieving walls and roof (depending upon where relief is provided) for explosion resistance. See NFPA 68 for details.

Where an explosion hazard exists, do not use load-bearing walls. Design control rooms and other important facilities to withstand explosion overpressure, taking into consideration the possibility of open-air vapor cloud or confined vapor-air explosion exposure. Carefully consider proper clearance from possible fire exposures and proper classification of hazardous locations for electrical installations.

Drainage

Provide drainage facilities to carry spilled flammables away from buildings, structures, storage tanks, pipe racks, and process equipment. Design drainage facilities to effectively and rapidly carry spills, fire protection water, and rain water simultaneously to a safe location without exposing adjacent plant facilities. This may require hydrants, monitors, fixed foam, or dry chemical protection, diversionary curbs, trenches, collection sumps, skimmers, and holding ponds or basins. Design general area grading with the anticipation that normal drainage facilities may overflow. See PRC.2.5.3 for details.

Water Supplies

Provide adequate water volumes and water distribution systems to supply the maximum simultaneous demand for hose and monitor nozzle streams and water spray systems for a minimum period of 4 h. Meet the foregoing criteria with the largest single water supply out of service. Include the size and congestion of the plant in determining the maximum simultaneous demand. Keep fire protection water storage independent of plant process water storage. Consider cooling tower basins and process water pumps only as alternate emergency supplies.

Use only diesel engine driven fire pumps.

Use buried pipe in a looped distribution system, sized and equipped with sectional control valves so that with one section of the distribution system out of service, the maximum simultaneous demand can be provided in any of the high-valued areas. Place individual control valves as far from process units as possible so they will be accessible for use if portions of the underground or aboveground systems are damaged by explosions. If control and sectional valves must be placed in areas exposed to explosions, protect them with barricades. See PRC.14.1.1.1 for details.

Fixed Water Based Systems

Install automatic deluge sprinkler systems per NFPA 15 and PRC.12.2.1.2 in process structures on an area basis and, where warranted, water spray pumps (unless seal-less), reactors, run-down tanks, columns, or other vessels and equipment where flammable materials are handled. Apply automatic water spray to structural steel, turbines, compressors, process pumps, grouped piping, instrumentation leads and tubing, and electrical cables where exposed by process areas handling flammable materials.

Apply automatic water spray systems on pressure storage tanks (spheres, spheroids and horizontal pressure storage tanks, etc.) containing flammable materials, and to atmospheric storage tanks containing flammable materials where spacing between tanks or between tanks and other facilities does not meet PRC.2.5.2.

Provide automatic closed-head sprinkler or automatic water spray protection in buildings containing flammable materials in storage or those housing processes handling flammable materials. Refer to NFPA 30 and PRC.8.1.0 for protection criteria.

Use foam, foam-water or aqueous film forming foam closed head or deluge sprinkler or water spray systems where flammable or combustible liquids are handled. This is especially important where drainage is inadequate.

Provide very large atmospheric storage vessels, tanks exposed by other tanks or process equipment with water spray systems to protect the exposed segments of the tank shell. Arrange this protection as a sectionalized water curtain per NFPA 13.

Provide automatic sprinkler or water spray protection for large important combustible cooling towers. In lieu of sprinkler protection, the use of UL Listed and / or FM Approved cooling towers is considered acceptable.

Where exposed to potential damage by explosion, locate automatic water spray valves 50 ft – 75 ft (15 m – 23 m) away and barricade them. Run feed mains underground wherever possible. Anchor aboveground feed or bulk mains to fireproofed structural members and, where possible, locate behind the structural members or walls to shield the piping from shrapnel from explosions. Construct all aboveground automatic water spray system piping 2½ in. (65 mm) and larger with welded, flanged piping. See NFPA 15.

Design automatic waterspray systems to be actuated by **all** of the following means:

- Temperature sensors or dry pilot.
- Diffusion-head-type combustible gas detectors where a flammable vapor or gas hazard may occur.
- Remote-manual-control stations.

See NFPA 13, PRC.12.1.1.0 and PRC.12.2.1.2 for details.

Monitors, Hydrants, and Hose Protection

Locate fixed monitor nozzles around the perimeter of process blocks. Locate nozzles with consideration given to accessibility and desired coverage. All area of the process blocks should be reached by at least two monitor nozzle streams, so, if necessary, install additional monitor nozzles in the interior of process blocks. Substitute foam induction type or elevated monitors where needed. See PRC.14.5.0.1 for details.

Locate hydrants throughout the plant. Provide an adequate amount of hose, nozzles, and other equipment located on motorized apparatus or in hose houses throughout the plant.

Provide portable monitor nozzles.

Foam Protection

Provide fixed or semi-fixed foam equipment, including an adequate supply of foam concentrates to protect all areas where flammable or combustible liquids are stored. Provide adequate application equipment and foam concentrates to extinguish a fire involving the largest storage tank. For small facilities, supply foam equipment and supplies from responding fire departments and/or mutual aid organizations. Make back-up foam supplies available within a 1 h delivery time.

Provide foam injection connections to allow injection of foam concentrate into waterspray systems protecting process areas that handle flammable liquids.

Motorized Apparatus

Use motorized foam/water pumper apparatus to provide foam production and storage capability in facilities. Supplement fire trucks with dry chemical apparatus where needed. Provide sufficient trained manpower to operate the apparatus. Supply additional manpower from responding fire departments and/or mutual aid organizations. Test pumper apparatus in accordance with NFPA 1901, NFPA 1911 and PRC.12.5.1.

DISCUSSION

This section does not contain detailed protection design criteria. Guidance in developing specifics may be found in the following publications:

- American Institute of Chemical Engineers: Center for Chemical Process Safety, Various publications.
- American Institute of Chemical Engineers: “Loss Prevention,” Various volumes.
- American Institute of Chemical Engineers: “Safety in Air and Ammonia Plants,” Various volumes.
- American National Standards Institute: Standards (such as ANSI ASME B31.3-2012, “Process Piping”).
- American Petroleum Institute: Various publications.
- American Society of Mechanical Engineers: Standards (such as “Boiler and Pressure Vessels Code”).
- European Federation of Chemical Engineering: “Loss Prevention and Safety Promotion in the Process Industries,” Various Symposia.
- AXA XL Risk Consulting: “PRC Guidelines,” Various sections.
- National Fire Codes.
- Vervalin, Charles H., “Fire Protection Manual for Hydrocarbon Processing Plants,” Volumes 1 and 2, Gulf Publishing Co.
- ISA 84/IEC 61512.
- OSHA 1910.119 PSM.