

## INHERENTLY SAFER SYSTEMS CHECKLIST

The intent of this checklist is to stimulate discussion and thinking about process improvements, and to encourage the concept of avoiding and reducing hazards, not just preventing/ mitigating consequences of hazard by adding protective equipment. “Out-of-the-box” thinking is strongly encouraged. The content of this checklist was extracted from CCPS “Inherently Safer Chemical Processes: A Life Cycle Approach”<sup>1</sup>, and “Process Minimization: Making Plants Safer”<sup>2</sup>.

The checklist questions are not always pertinent for an individual facility or for every phase of a project or an existing facility. The checklist should be tailored for your facility and for the stage the checklist is being applied for new processes, as follows:

- During the chemistry-forming (synthesis) phase for product/process research and development to focus on the chemistry and process
- During the facilities design scoping and development prior to completion of the design basis to focus on equipment and configuration
- During the basic design phase of the project

The checklist should also be tailored for existing process in your facility to be used during a Process Hazard Analysis, when appropriate for the Process Hazard Analysis Team. Some items may need to be reviewed by a team that is outside of the Process Hazard Analysis Team, because the personnel with the appropriate expertise or ability may not be a part of the Process Hazard Analysis Team. Issues, such as considering the transportation of hazardous materials, may require the ability to renegotiate contracts with shippers.

CCHS will review how the stationary source determined the appropriate checklist for that facility and for the stage of assessment, when the facility is audited or during an unannounced inspection.

Approaches to inherently safer systems may be categorized into the following strategies:

### I. Minimize

#### A. Inventory Reduction

1. Can hazardous raw materials inventory be reduced?
  - a) Consider just-in-time deliveries
  - b) Supplier management including strategic alliance
  - c) On-site generation of hazardous material from less hazardous raw materials
2. Can in-process storage and inventory be reduced?
  - a) Direct coupling of process elements
  - b) Eliminate or reduce size of in-process storage
  - c) Design process equipment involving hazardous material with the smallest feasible inventory
3. Can finished product inventory be reduced?
  - a) Improve production scheduling
  - b) Improve communication with transporters/material handlers

## B. Process Considerations

1. Can the use of alternate equipment with reduced hazardous material inventory requirement be done? Such as:
  - a) Wiped film stills in place of continuous still pots (distillation columns)
  - b) Centrifugal extractors in place of extraction columns
  - c) Flash dryers in place of tray dryers
  - d) Continuous reactors in place of batch
  - e) Plug flow reactors in place of continuous stirred tank reactors
  - f) Continuous in-line mixers in place of mixing vessels
  - g) Compact heat exchangers (higher heat transfer area per unit volume) in place of shell-and tube
  - h) Combine unit operations (such as reactive distillation in place of separate reactor with multi-column fractionation train; installing internal reboilers or heat exchangers) to reduce overall system volume
  - i) Alternate energy sources (such as lasers, UV light, microwaves, or ultrasound) to control reaction or direct heat to the unit operation
2. Has the length of hazardous material piping runs been minimized?
3. Has piping been designed for reducing the piping diameters?
4. Can pipeline inventory be reduced by using the hazardous material as a gas rather than a liquid (e.g., chlorine)?
5. Can process conditions be changed to reduce production of hazardous waste or by-products?

## II. Substitute

- A. Is it possible to completely eliminate hazardous raw materials, process intermediates, or by-products by using an alternative process or chemistry?
- B. Is it possible to completely eliminate in-process solvents and flammable heat transfer media by changing chemistry or processing conditions?
- C. Is it possible to substitute less hazardous raw materials?
  1. Noncombustible for flammable
  2. Less volatile
  3. Less reactive
  4. More stable
  5. Less toxic
  6. Low pressure steam rather than combustible heat transfer fluid
- D. Is it possible to substitute less hazardous final product solvents?

## III. Moderate

- A. Is it possible to limit the supply pressure of raw materials to less than the maximum allowable working pressure of the vessels they are delivered to?
- B. Is it possible to make reaction conditions (temperature, pressure) less severe by using a catalyst, or a better catalyst?
- C. Can the process be operated at less severe conditions? By considering:
  1. Improved thermodynamics or kinetics to reduce temperature or pressure

2. Changes in reaction phase (e.g., liquid/liquid, gas/liquid, or gas/gas)
3. Changes in the order in which raw materials are added
- D. Is it possible to dilute hazardous raw materials to reduce the hazard potential? By using:
  1. Aqueous ammonia instead of anhydrous
  2. Aqueous HCl instead of anhydrous
  3. Sulfuric acid instead of oleum
  4. Dilute nitric acid instead of concentrated fuming nitric acid
  5. Wet benzoyl peroxide instead of dry
- E. Is it possible to design operating conditions such that materials that become unstable at elevated temperatures or freeze at low temperatures heating and cooling medium will not be operating in those ranges?
- F. Can process conditions be changed to avoid handling flammable liquids above their flash points?
- G. Is equipment designed to totally contain the materials that might be present inside at ambient temperature or the maximum attainable process temperature (i.e., higher maximum allowable working temperature to accommodate loss of cooling, simplify reliance of external systems such as refrigeration systems to control temperature such that vapor pressure is less than equipment design pressure)?
- H. For processes handling flammable materials, is it possible to design the layout to minimize the number and size of confined areas and to limit the potential for serious overpressure in the event of a loss of containment and subsequent ignition?
- I. Can process units be located to eliminate or minimize:
  1. Adverse effects from adjacent hazardous installations
  2. Off-site impacts
  3. On-site impacts on employees and other plant facilities
- J. Can process units be designed to limit the magnitude of process deviations:
  1. Select pump with maximum capacity for rate of addition lower than safe rate of addition for the process
  2. Maximum feed rate may be limited by pipe size to be within safe limits for gravity fed systems
- K. Can hazardous material liquid spill be prevented from entering drainage system/sewer?
- L. For flammable materials, can spills be directed away from the storage vessel to reduce the risk of a boiling liquid expanding vapor explosion (BLEVE) in the event of a fire?
- M. Passive safety design is preferred. Can passive design be implemented? For example, to prevent or reduce fire damage, an active method is automatic water spray actuated by flame or heat detector; a procedural method by having an operator turn on the water spray, or passive method by using fire insulation.

#### IV. Simplify

- A. Can equipment be designed such that it is difficult or impossible to create a potential hazardous situation due to an operating or maintenance error? Such as:
  1. Easy operation of valves designed to prevent inadvertent errors

2. Simplified control displays
  3. Design temperature-limited heat transfer equipment
  4. Use corrosion resistant materials for the process
  5. Operate at lower pressure to limit release
  6. Operate at higher temperature to eliminate cryogenic effects such as embrittlement failures
  7. Operate at lower temperature to prevent run away reactions or material failure
  8. Use passive rather than active controls
  9. Use buried or shielded tanks
  10. Use fail-safe controls if utilities are lost
  11. Limit the complexity and degree of instrumentation redundancy
  12. Use refrigerated storage vs. pressurized storage
  13. Spread electrical feed over independent or emergency sources
  14. Reduce wall area to minimize corrosion/fire exposure
  15. Minimize connections, paths and number of flanges in hazardous processes
  16. Use fewer bends in piping
  17. Use expansion loops in piping rather than bellows
  18. Design into the process, equipment isolation mechanism for maintenance
  19. Limit manual operations such as filter cleaning, manual sampling, hose handling for loading/unloading operations, etc.
  20. Design vessels for full vacuum eliminating risk of vessel collapse
  21. Design both shell and tube side of heat exchangers to contain the maximum attainable pressure, eliminating the need for pressure relief
  22. Can the equipment be designed to make incorrect assembly impossible
  23. Use equipment that clearly identifies status:
    - a) Check valves with easy to identify direction of flow
    - b) Gate valves with rising spindles to clearly indicate open or close position
    - c) Spectacle (or figure 8) blinds instead of slip plates
  24. Design the equipment with sufficient strength to contain the maximum pressure generated, even if “worst credible event” occurs?
- B. Can passive leak-limiting technology be used to limit potential loss of containment? Some examples include the following:
1. Blowout resistant gaskets
  2. Increasing wall strength
  3. Using fewer seams and joints
  4. Providing extra corrosion/erosion allowance
  5. Reducing vibration
  6. Minimizing the use of open-ended, quick-opening valves
  7. Eliminating open-ended, quick-opening valves in hazardous service
  8. Improving valve seating reliability
  9. Eliminating unnecessary expansion joints, hoses, and rupture disks
  10. Eliminating unnecessary sight glasses/glass rotameters

- V. Transport of Hazardous Materials
  - A. Can the plant be located to minimize need for transportation of hazardous materials?
  - B. Can materials be transported:
    - 1. In a less hazardous form
    - 2. In a safer transport method
    - 3. In a safer route

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<sup>1</sup>Center for Chemical Process Safety, "Inherently Safer Chemical Processes: A Life Cycle Approach," CCPS, AIChE, New York, 1996

<sup>2</sup> Hendershot, Dennis C., "Process Minimization: Making Plants Safer," Chemical Engineering Progress, pp.35-40 (January 2000).