This checklist may be used to stimulate the thinking of inherent safety review and process hazard analysis teams, and any other individuals or groups working on process improvements. It is intended to promote “blue-sky” or “out-of-the-box” thinking, and to generate ideas that might be usable in an existing facility or a “plant of the future” concept.

This checklist should not be used in a rote “yes/no” manner, nor is it necessary to answer every question. The idea is to consider what might be possible, and then determine what is feasible. The checklist should be reviewed periodically throughout the life cycle of the process. As technology changes, what was once impossible becomes possible, and what was once infeasible becomes feasible.

Users of this checklist may find it helpful to rephrase questions in order to prompt maximum creativity; for example “how might it be possible to . . .?” This approach can lead users to consider alternative means for reducing the hazard level inherent in the process.

The topics for this checklist have been taken from CCPS (1993b) and Bollinger et al. (1996). Every effort was made to ensure that this checklist is comprehensive; therefore, there may be some redundancy or overlap in questions among the different sections. It should be noted that some of the items in this checklist employ a very broad concept of inherent safety, as presented by Bollinger et al. (1996). As such, they may address inherent aspects of passive, engineered or even administrative controls, rather than the narrower inherent safety conception of reducing the underlying process hazards that must be contained and controlled to safely operate a facility.
1. Intensification/Minimization

1.1. Do the following strategies reduce inventories of hazardous raw materials, intermediates, and/or finished products?

- Improved production scheduling
- Just-in-time deliveries
- Direct coupling of process elements
- Onsite generation and consumption

1.2. Do the following actions minimize in-process inventory?

- Eliminating or reducing the size of in-process storage vessels
- Designing processing equipment handling hazardous materials for the smallest feasible inventory
- Locating process equipment to minimize the length of hazardous material piping runs
- Reducing piping diameters

1.3. Can other types of unit operations or equipment reduce material inventories? For example:

- Wiped film stills in place of continuous still pots
- Centrifugal extractors in place of extraction columns
- Flash dryers in place of tray dryers
- Continuous reactors in place of batch
- Plug flow reactors in place of continuous-flow stirred tank reactors
- Continuous in-line mixers in place of mixing vessels

1.4. Can thermodynamic or kinetic efficiencies of reactors be improved by design upgrades (e.g., improved mixing or heat transfer) to reduce hazardous material volume?

1.5. Can equipment sets be combined (e.g., replacing reactive distillation with a separate reactor and multi-column fractionation train; installing internal reboilers or heat exchangers) to reduce overall system volume?

1.6. Can pipeline inventories be reduced by feeding hazardous materials as a gas instead of a liquid (e.g., chlorine)?

1.7. Can process conditions be changed to avoid handling flammable liquids above their flash points?
1.8. Can process conditions be changed to reduce production of hazardous wastes or by-products?

2. Substitution/Elimination

2.1. Is it possible to eliminate hazardous raw materials, process intermediates, or by-products by using an alternative process or chemistry?

2.2. Is it possible to eliminate in-process solvents by changing chemistry or processing conditions?

2.3. Is it possible to substitute less hazardous raw materials? For example:
   - Noncombustible rather than flammable
   - Less volatile
   - Less reactive
   - More stable
   - Less toxic

2.4. Is it possible to use utilities with lower hazards (e.g., low-pressure steam instead of combustible heat transfer fluid)?

2.5. Is it possible to substitute less hazardous final product solvents?

2.6. For equipment containing materials that become unstable at elevated temperatures or freeze at low temperatures, is it possible to use heating and cooling media that limit the maximum and minimum temperature attainable?

3. Attenuation/Moderation

3.1. Is it possible to keep the supply pressure of raw materials lower than the design pressure of the vessels to which they are fed?

3.2. Is it possible to make reaction conditions (e.g., pressure or temperature) less severe by using a catalyst or by using a better catalyst?

3.3. Can the process be operated at less severe conditions using any other route? For example:
• Improved thermodynamic or kinetic efficiencies of reactors by design upgrades (e.g., improved mixing or heat transfer) to reduce operating temperatures and/or pressures
• Changes to the order in which raw materials are added
• Changes in phase of the reaction (e.g., liquid/liquid, gas/liquid, or gas/gas)

3.4. Is it possible to dilute hazardous raw materials to reduce the hazard potential? For example, by using the following:
• Aqueous ammonia instead of anhydrous
• Aqueous HCl instead of anhydrous
• Sulfuric acid instead of oleum
• Dilute nitric acid instead of concentrated fuming nitric acid
• Wet benzoyl peroxide instead of dry

4. Limitation of Effects

4.1. Is it possible to design and construct vessels and piping to be strong enough to withstand the largest overpressure that could be generated within the process, even if the “worst credible event” occurs (eliminating the need for complex, high-pressure interlock systems and/or extensive emergency relief systems)?

4.2. Is all 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, simplifying reliance on the proper functioning of external systems, such as refrigeration systems, to control temperature such that vapor pressure is less than equipment design pressure)?

4.3. Can passive leak-limiting technology (e.g., blowout resistant gaskets and excess flow valves) be utilized to limit potential for loss of containment?

4.4. Can process units be located to reduce or eliminate adverse effects from other adjacent hazardous installations?

4.5. Can process units be located to eliminate or minimize the following?
  • Off-site impacts
  • On-site impacts on employees and other plant facilities
4.6. For processes handling flammable materials, is it possible to design the facility layout to minimize the number and size of confined areas and to limit the potential for serious overpressures in the event of a loss of containment and subsequent ignition?

4.7. Can the plant be located to minimize the need for transportation of hazardous materials?

4.8. Can materials be transported in the following ways?
   - In a less hazardous form
   - Via a safer transport method
   - Via a safer route

5. Simplification/Error Tolerance

5.1. Is it possible to separate a single, procedurally complex, multipurpose vessel into several simpler processing steps and processing vessels, thereby reducing the potential for hazardous interactions when the complexity of the number of raw materials, utilities, and auxiliary equipment is reduced for specific vessels?

5.2. Can equipment be designed so that it is difficult to create a potentially hazardous situation due to an operating or maintenance error? For example:
   - Simplifying displays
   - Designing temperature-limited heat transfer equipment
   - Lowering corrosion potential by use of resistant materials of construction
   - Lowering operating pressure to limit release rates
   - Using higher processing temperatures (to eliminate cryogenic effects such as embrittlement failures)
   - Using passive vs. active controls (e.g., stronger piping and vessels)
   - Using buried or shielded tanks
   - Using fail-safe controls if utilities are lost
   - Limiting the degree of instrumentation redundancy required
   - Using refrigerated storage vs. pressurized storage
   - Spreading electrical feed over independent or emergency sources
   - Reducing wall area to minimize corrosion/fire exposure
   - Reducing the number of connections and paths
   - Minimizing the number of flanges in hazardous processes
   - Valving/piping/hose designed to prevent connection error
• Using fewer bends in piping
• Increasing wall strength
• Using fewer seams and joints
• Providing extra corrosion/erosion allowance
• Reducing vibration
• Using double-walled pipes, tanks, and other containers
• Minimizing the use of open-ended valves
• Eliminating open-ended, quick-opening valves in hazardous service
• Improving valve seating reliability
• Eliminating unnecessary expansion joints, hoses, and rupture disks
• Eliminating unnecessary sight glasses/glass rotameters

5.3. Can procedures be designed so that it is difficult to create a potentially hazardous situation due to an operating or maintenance error? For example:
• Simplifying procedures
• Reducing excessive reliance on human action to control the process

5.4. Can equipment be eliminated or arranged to simplify material handling?
• Using gravity instead of pumps to transfer liquids
• Siting to minimize hazardous transport or transfer
• Reducing congestion (i.e., easier to access and maintain)
• Reducing knock-on effects from adjacent facilities
• Removing hazardous components early in the process rather than spreading them throughout the process
• Shortening flow paths

5.5. Can reactors be modified to eliminate auxiliary equipment (e.g., by creating a self-regulatory mechanism by using natural convection rather than forced convection for emergency cooling)?

5.6. Can distributed control system (DCS) modules be simplified or reconfigured such that failure of one module does not disable a large number of critical control loops?

This checklist courtesy of Art Burk, E. I. du Pont de Nemours & Co., Inc.