CE 400 / CE 500

Process Safety Management

Lecture 28 Layer of Protection Analysis Part I

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Quantitative Risk Analysis

1. Define the potential event sequences and potential incidents
2. Evaluate Incident Consequences
   - Dispersion Modeling
   - Fire and Explosion Modeling
3. Estimate Frequency using event trees and fault trees
4. Estimate the incident impacts on people, environment, and property
5. Estimate Risk
   - Hazard Analysis Risk Categories

- A full blown quantitative analysis is relatively complex and may not be warranted

Semi-Quantitative Risk Analysis – LOPA

Layer of Protection Analysis

- Simplified by using Consequence Categories
  - In my experience, some level of consequence calculation is usually still considered
- Frequencies are estimated
  - Values and Categories are chosen to be conservative
  - LOPA results should always be MORE conservative than full scale QRA
- In addition to the initial frequency consideration for the event, one takes into consideration other safeguards and probabilities
  - Layers of Protection

Layer of Protection Analysis

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HAZOP Study	LOPA	Quantitative Risk Analysis (QRA)
Examines an entire process for what can go wrong	**Studies only one incident scenario**	Generally examines an entire process for what can go wrong, or all events leading up to a specific Top event
Qualitative/category estimates of cause frequency, loss event impacts & safeguards effectiveness	Order-of-magnitude estimates of cause frequency, loss event impacts & safeguards effectiveness	Fully quantitative estimates of all risk parameters
Team-based	Rule-based	Expert-based

Layer of Protection Analysis

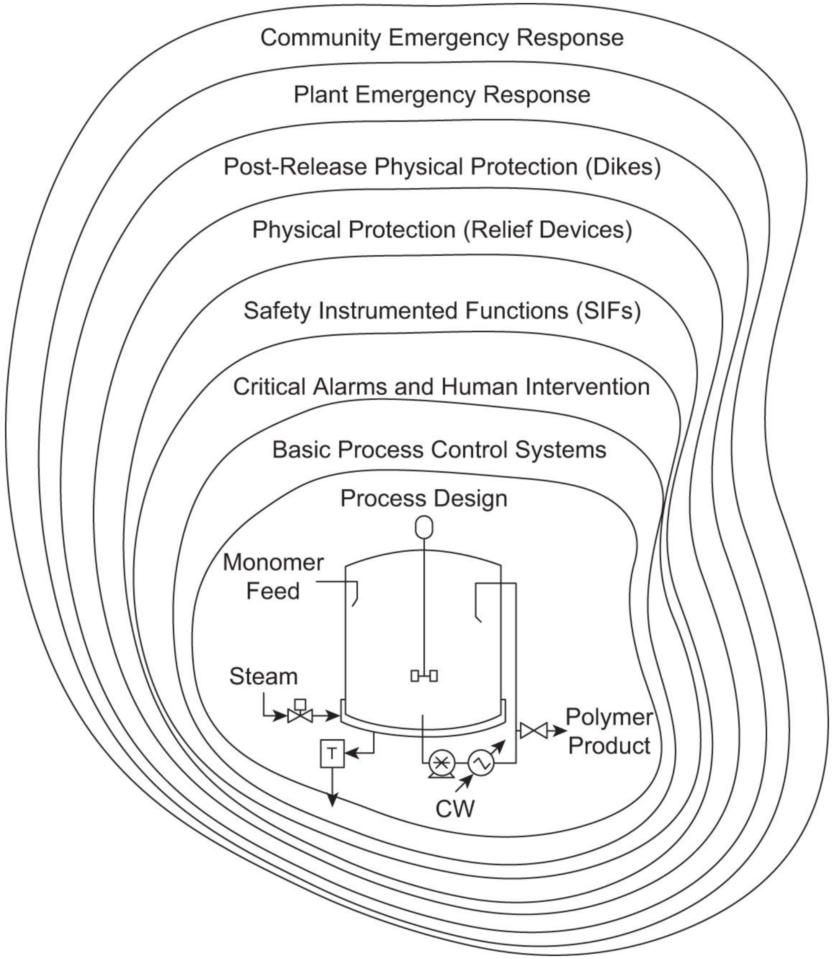

FIGURE 12-16 Layers of protection, with examples, to lower the frequency of a specific incident scenario. Not all of these are likely to be independent. (Source: Center for Chemical Process Safety. Layer of Protection Analysis: Simplified Process Risk Assessment, ed. D. A. Crowl. (New York, NY: American Institute of Chemical Engineers, 2001).)

LOPA Approach

- Start with a specific scenario
  - A specific initial failure leads to a specific undesired outcome
- Choose a Risk Goal to obtain
  - Example – Obtain a Risk Level of III
- Have a set of Rules to Follow
  - Each company must generate their own process, but there are generally accepted guidelines
- Document the Process
  - Each company must generate their own format, but there are generally accepted guidelines

Scenario Identification

- This is **NOT** part of the LOPA process
- It typically comes out of the hazards analysis section of a Process Hazards Analysis
  - Could come from an incident investigation or Management of Change procedure, among others
- Example: FMEA considers the failure of a differential pressure level measurement
  - Follow that incident path to its conclusion
  - What are the consequences of that failure?
    - Unmitigated (ignoring all of the safeguards)
    - With the safeguards provided
- If the unmitigated consequences are low you can move on
- If the unmitigated consequences are high you may want to use LOPA
  - If one of the safeguards is an interlock you will need to do LOPA to determine the required Safety Integrity Level of the interlock

Essential LOPA Scenario Elements

- Every LOPA scenario has the following essentials:
  1. Initiating event
     - Control Valve fails open
     - Operator skips a critical startup step
  2. Loss event
     - Toxic Plume
     - Vapor Cloud Explosion
     - Environmental release to a lake
- Most LOPA scenarios also include:
  3. Success or Failure of Safeguards
  4. The loss event impacts
     - Does it involve Medical Treatment? Fatalities?

Cause / Consequence Pairs

- A LOPA scenario has a unique initiating event/loss event pair
- Each LOPA only examines <u>one</u> scenario
- If there are more than one way to have a given loss event that would require multiple LOPA cases

Screening of Scenarios

- How do you choose which scenarios on which to perform a LOPA?
- Screen using basis of Loss Event
  - e.g. All scenarios with major release potential
- Screen using basis of Impact
  - e.g. All scenarios with major injury/fatality or off-site impact
- Screen using basis of Risk
  - e.g. All scenarios with a Risk Level of I and II

Risk Goals

- Objective: Each evaluated scenario meets level of risk tolerable to the organization or required by authorities

- Most Common **LOPA** Approach:
  - Compare scenario risk with tolerable risk level
    - In other words, get the Risk Level to III or IV

LOPA Objective

- After a scenario has been identified the goal is to determine the actual Risk (order of magnitude resolution) with all of the safeguards that are in place
- Determine if additional safeguards are needed
- Determine the reliability that the new safeguard will require

- The first thing to do is determine the frequency of the initiating event

Layer of Protection Analysis

Generic Initiating Event Frequencies for Use in LOPA(from CCPS 2014)*	
0.1 / yr	BPCS control loop failure
0.1 / yr	Pressure regulator failure
1 / yr to **10** / yr	Screw conveyor failure
0.1 / yr	Screw conveyor overheating of materials
0.1 / yr	Pump, compressor, fan or blower failure *(not including due to loss of power)*
0.1 / yr	Localized (single-circuit) loss of power
0.1 / yr	Failure of a single check valve used as a control device; clean service
0.01 / yr	Failure of double check valves in series used as control device; clean service
1 / yr	Pump seal leak
0.1 / yr	Complete primary pump seal failure

Layer of Protection Analysis

Generic Initiating Event Frequencies for Use in LOPA* (continued)	
0.1 / yr	Hose leak
0.01 / yr	Hose rupture
0.01 / yr	Premature opening of spring-loaded relief valve
10^{-5} / yr	Atmospheric tank: catastrophic failure
10^{-4} / yr	Atmospheric tank: continuous 10 mm diameter leak
10^{-5} / yr	Pressure vessel; catastrophic failure
10^{-6} / yr per m	Aboveground piping: full breach failure (pipe size ≤ 150 mm [6"])
10^{-5} / yr per m	Aboveground piping: leak (pipe size ≤ 150 mm)
10^{-7} / yr per m	Aboveground piping: full breach failure (pipe size > 150 mm)
10^{-6} / yr per m	Aboveground piping: leak (pipe size > 150 mm)

Control Loop Failures

- The overall failure rate of a control loop includes the failure of any of the components involved in that loop
  - Sensors/transmitters
  - Air supply
  - Distributed Control System
  - Valves
- Other factors
  - Improper setpoints
  - Mis-calibaration
  - Operating in manual mode
- Typical BPCS (Basic Process Control System) failure rate is 10^{-1} per year

Procedure-Based Operations

- For procedure-based operations where the intitiating even is an operational error:
- Initiating Event Frequency = Frequency of Performing Operation x Probability of error per operation
- In other words: “How often do you do it” times “how likely are you to make an error each time you do it”
- Probability of error per operation
  - Range from literature - $10^{-1}$to 10^{-3}per opportunity
  - This will, of course, depend upon:
    - Training
    - Complexity of the Operation