Module 3 Indorama PS Risk Matrix – Hazard Assessment

Last Revised – June 2024

PS Bootcamp Modules

- ✓ Module 1: Introduction
- ✓ Module 2: Hazard Identification
- ✓ Module 3: Risk Matrix
- ❑ Module 4: Safeguard Concepts
- ❑ Module 5: Explosion/Fire Protection
- ❑ Module 6: Management of Change
- ❑ Module 7: Incident Investigation
- ❑ Module 8: Facility Siting

Module 3: PS Risk Matrix – Hazard Assessment Agenda

Review and Understand:

Hazard, Severity, Frequency and Risk

Overview of PS Risk Matrix

Additional Tools-References for Risk Ranking

Module 3: Training Objectives

Understand basics of performing a hazard Assessment

Familiarity with Indorama Risk Matrix new in 2022

Recognize when to use the Indorama Risk Matrix

Increase comfort on how to use the Risk Matrix for a hazard assessment or PHA

Provide some valuable tools/references

Hazard vs. Risk

What is a Hazard?

- Potential source of harm, e.g. (a) a material with toxic or flammable properties or (b) a process with physical or mechanical capability to cause harm, such as operation at high temperature or high speed.
- The term “hazard” is used qualitatively.

What is a Risk?

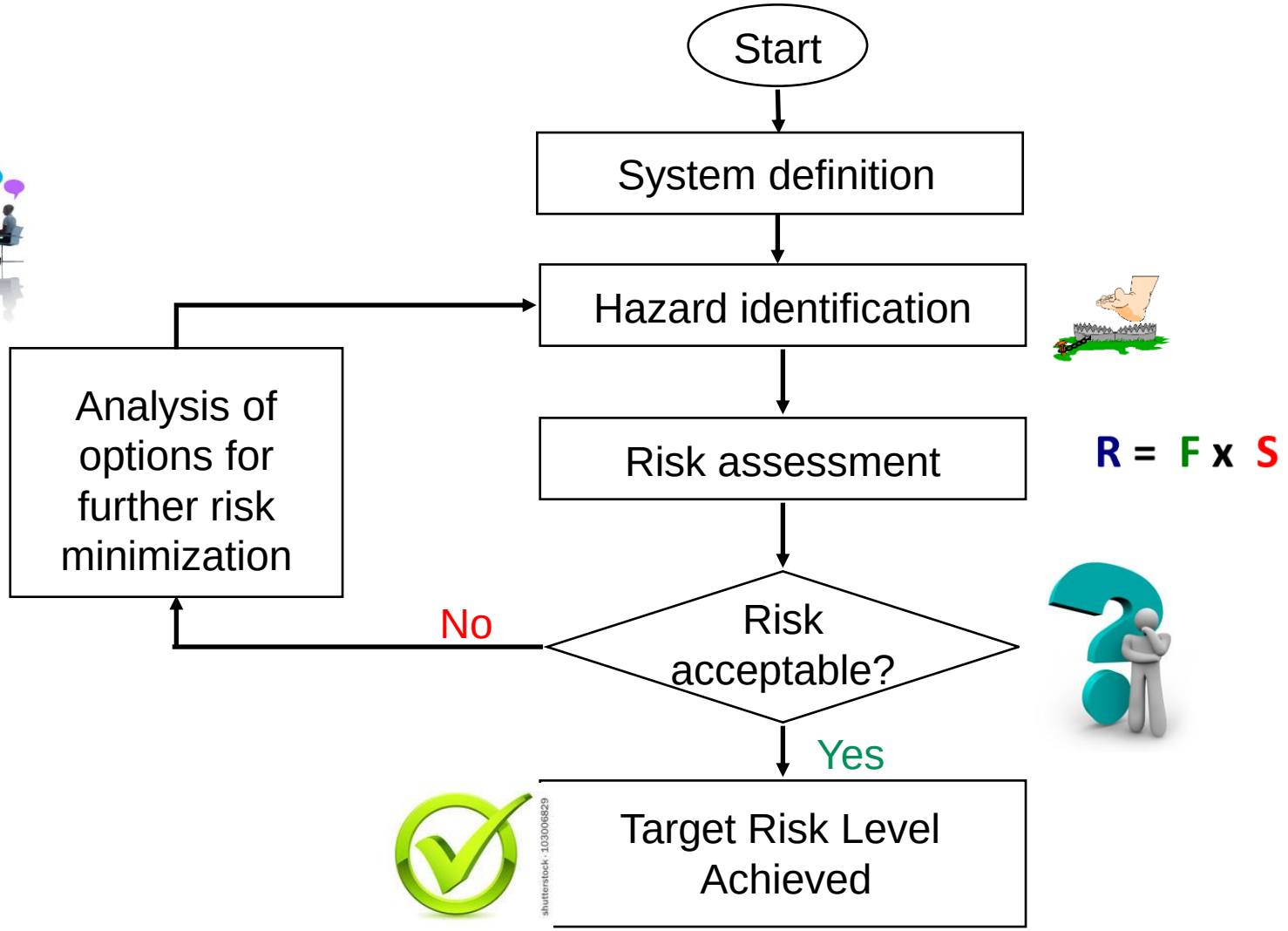
Frequency of Occurrence

Risk R = F x S

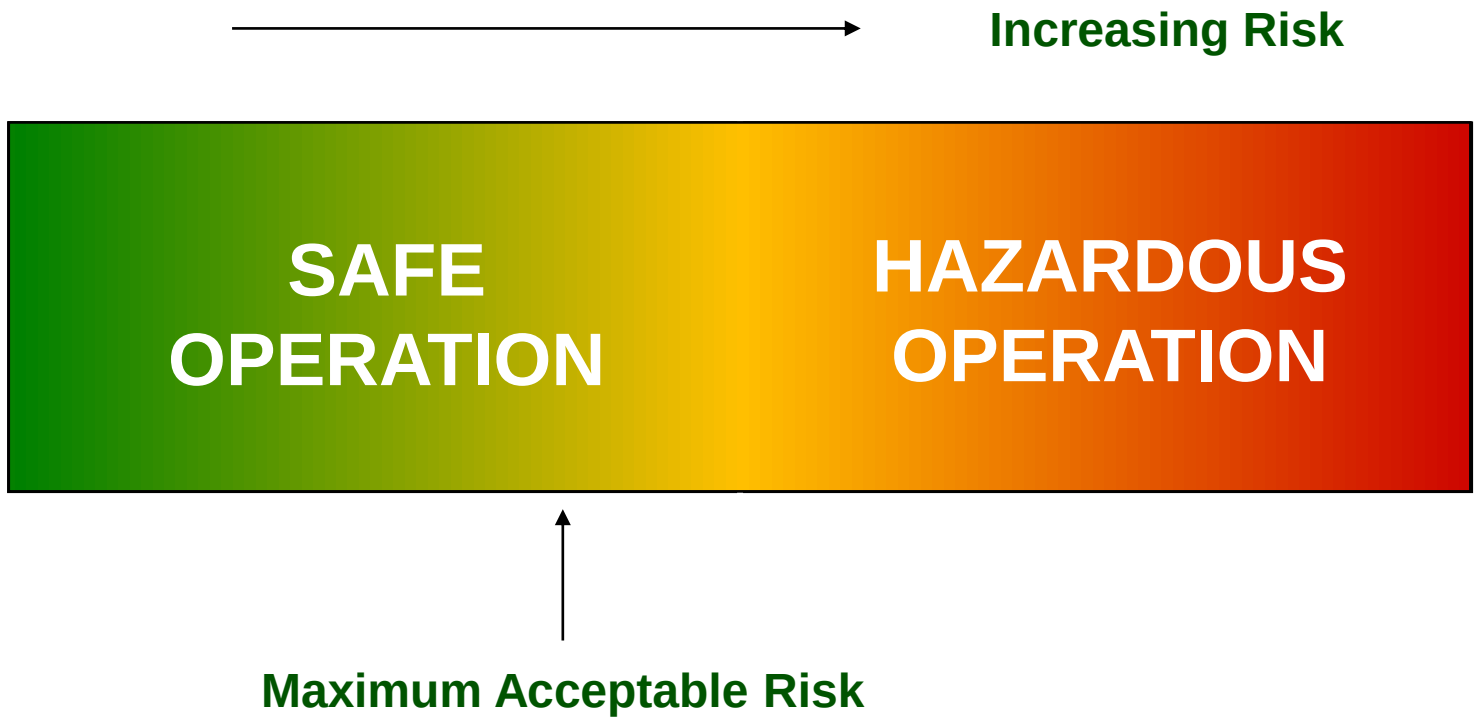
Severity of Consequences

The term “risk” can be used qualitatively or quantitatively.

Hazard Control



Concept of Acceptable or Tolerable Risk



Purpose of Creating Risk Matrix

Provide consistent guidance for assessing risk

Provide a common basis for discussing and managing risk across the business

Promote dialog on inherent safety

Define, based upon a determined risk level, the minimum requirements for countermeasures used in:

- Risk Prevention
- Risk Mitigation
- Risk Emergency Planning & Response

Foundation for Risk Based Process Safety

Indorama IVL Risk Matrix

IVL Risk Matrix

	Frequency Category							
	$>10^{-7}$ to 10^{-6}/yr	$>10^{-6}$ to 10^{-5}/yr	$>10^{-5}$ to 10^{-4}/yr	$>10^{-4}$ to 10^{-3}/yr	$>10^{-3}$ to 10^{-2}/yr	$>10^{-2}$ to 10^{-1}/yr	$>10^{-1}$ to 1/yr	>1/yr
Severity Category	1	2	3	4	5	6	7	8
A	EHS-2	EHS-3	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4
B	EHS-2	EHS-3	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4
C	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4
D	EHS-1	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4
E	EHS-1	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4
F	EHS-1	EHS-1	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4
G	EHS-1	EHS-1	EHS-1	EHS-2	EHS-2	EHS-2	EHS-3	EHS-3
H	EHS-1	EHS-1	EHS-1	EHS-1	EHS-1	EHS-2	EHS-2	EHS-3

EHS-4 Very High Risk Range (Unacceptable Region – Immediate risk reduction required)
EHS-3 High Risk Range (Intolerable Region – Schedule risk reductions for implementation)
EHS-2 Medium Risk Range (Tolerable Region – Acceptable if further risk reduction is impracticable)
EHS-1 Low Risk Range (Broadly Acceptable Region – No further risk reduction necessary)

IVL Risk Matrix for Process Safety Activities

	Frequency Category								
	≤ 10^{-6}	> 10^{-6} to 10^{-5}	> 10^{-5} to 10^{-4}	> 10^{-4} to 10^{-3}	> 10^{-3} to 10^{-2}	> 10^{-2} to 10^{-1}	> 10^{-1} to 1	> 1	
Severity Category	1	2	3	4	5	6	7	8	
A	EHS-2	EHS-3	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	Facility Siting Scope
B	EHS-2	EHS-3	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	
C	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	
D	EHS-1	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	LOPA Scope
E	EHS-1	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	
F	EHS-1	EHS-1	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	
G	EHS-1	EHS-1	EHS-1	EHS-2	EHS-2	EHS-2	EHS-3	EHS-3	HazOp Scope
H	EHS-1	EHS-1	EHS-1	EHS-1	EHS-1	EHS-2	EHS-2	EHS-3	

IVL Risk Matrix for Process Safety Activities

Severity Category	Credible Consequence of the Harmful Event		
	On-Site Injuries and Illnesses (One or More of the Consequences Below)	**Off-Site Injuries and Illnesses (One or More of the Consequences Below)**	**Environmental and Other Effects (One or More of the Consequences Below)**
A	Potential for: • 100 or more fatalities	Potential for: • 50 or more fatalities	Release of hazardous material with potential for: • Off-site release with catastrophic off-site damage and long term clean-up (restored in 1 to 5 years) Other Potential Impacts: • More severe release than the level below
B	Potential for: • 50 to 99 fatalities	Potential for: • 10 to 49 fatalities	Release of hazardous material with potential for: • Off-site release with significant clean-up (restored in 1 year) Other Potential Impacts: • More severe release than the level below • Catastrophic contamination of water/land • Catastrophic loss of wildlife and wildlife habitat • Extensive community evacuation • Threat of loss of license to operate
C	Potential for: • 10 to 49 fatalities	Potential for: • 3 to 9 fatalities	Release of hazardous material with potential for: • Off-site release with extensive clean-up (restored in months) Other Potential Impacts: • More severe release than the level below • Severe damage to rivers/sea, flora/fauna or land resulting in recovery time (months) • Severe loss of wildlife and wildlife habitat • Public outrage • Government intervention
D	Potential for: • 3 to 9 fatalities	Potential for: • 1 to 2 Fatalities • Multiple permanent partial disability injuries	Release of hazardous material with potential for: • Off-site release with prolonged clean-up (restored in weeks) Other Potential Impacts: • Major contamination of water/land • Temporary damage to rivers/sea, flora/fauna or land resulting in recovery time (weeks) • Major loss of wildlife and wildlife habitat • Harmful effect on source of drinking water • Community evacuation • Catastrophic impact to property or assets • Damage to relationships with key stakeholders

Table 1 - Consequence Definitions – Severity Categories A-D

IVL Risk Matrix for Process Safety Activities

Severity Category	Credible Consequence of the Harmful Event		
	On-Site Injuries and Illnesses (One or More of the Consequences Below)	**Off-Site Injuries and Illnesses (One or More of the Consequences Below)**	**Environmental and Other Effects (One or More of the Consequences Below)**
E	Potential for: • 1 to 2 Fatalities • Multiple permanent partial disability injuries	Potential for: • Permanent partial disability injury • Multiple hospitalizations (over night stay)	Release of hazardous material with potential for: • Off-site release with quick clean-up (restored in days) Other Potential Impacts: • Short term damage to rivers/sea, flora/fauna or land resulting in short recovery time (days) • Minor loss of wildlife and wildlife habitat • Contamination of water/land • Plant Evacuation • Community Shelter-in-Place • Severe impact to site property or assets
F	Potential for: • Permanent partial disability injury • Multiple recordable injuries	Potential for: • Single hospitalization (overnight stay) • Multiple first aid injuries	Release of hazardous material with potential for: • On-site release beyond secondary containment and requiring clean-up and possible response by the site ERT Other Potential Impacts: • Plant Shelter-in-Place • Moderate impact to site property or assets • Regulatory compliance issue which leads to a regulatory consequence, such as a Notice of Violation or Compliance Order • Limited Community Impact
G	Potential for: • Recordable injury • Multiple first-aid injuries	Potential for: • First-aid / Minor injury	Release of hazardous material with potential for: • On-site release within existing secondary containment possibly including small ERT response. Other Potential Impacts: • Permit deviation • Exceedance of permit/emission limits that does not lead to a regulatory consequence • Minor impact to the community with isolated complaints. • Minor impact to site property or assets
H	Potential for: • First-aid / Minor injury	Potential for: • No impact	Release of hazardous material with potential for: • Minor on-site release requiring no follow-up and no ERT response. Other Potential Impacts: • Minor release below permit/emission limits • Minor impact to site property or assets

Table 1 - Consequence Definitions – Severity Categories E-H

Frequency Definitions - Table 2

Frequency Category	Scenario Harmful Event Defined Frequency Range	Description
1	$>10^{-7}$ /yr to 10^{-6} /yr	
2	$>10^{-6}$ /yr to 10^{-5} /yr	Scenario very unlikely to happen within the life of this asset.
3	$>10^{-5}$ /yr to 10^{-4} /yr	
4	$>10^{-4}$ /yr to 10^{-3} /yr	Scenario unlikely to happen within the life of this asset.
5	$>10^{-3}$ /yr to 10^{-2} /yr	Scenario may happen within the life of this asset. It may have happened in the life of directly similar facilities internal or external to the company.
6	$>10^{-2}$ /yr to 10^{-1} /yr	Scenario likely to happen within the life of this asset. Current personnel may have knowledge, but no experience of its occurrence.
7	$>10^{-1}$ /yr to 1 /yr	Scenario has a high likelihood of happening in a year. For an operating plant, the event has probably happened in the last five years.
8	>1 /yr	Scenario can happen several times per year

Qualitative Risk Ranking Example

	Frequency Category								
	$\leq 10^{-6}$	$> 10^{-6}$ to 10^{-5}	$> 10^{-5}$ to 10^{-4}	$> 10^{-4}$ to 10^{-3}	$> 10^{-3}$ to 10^{-2}	$> 10^{-2}$ to 10^{-1}	$> 10^{-1}$ to 1	> 1	
Severity Category	1	2	3	4	5	6	7	8	
A	EHS-2	EHS-3	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	Facility Siting Scope
B	EHS-2	EHS-3	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	
C	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	
D	EHS-1	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	LOPA Scope
E	EHS-1	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	
F	EHS-1	EHS-1	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	
G	EHS-1	EHS-1	EHS-1	EHS-2	EHS-2	EHS-2	EHS-3	EHS-3	HazOp Scope
H	EHS-1	EHS-1	EHS-1	EHS-1	EHS-1	EHS-2	EHS-2	EHS-3	

Example: A fatality scenario is assigned a Severity Category of E that is "unlikely to happen in the lifetime of the plant" in a Frequency Range of 1 x 10^{-3} and 1 x 10^{-4}. The relative Risk Level is EHS-3, High Risk.

Risk Level Action Required – Table 3a (1)

EHS-4 – Very High Risk

- These findings shall be reported to the Site Head and it is essential that immediate measures be taken to mitigate this risk to the EHS-3 risk level or discontinue operations (or activity) until the hazard can be addressed.)

EHS-3- High Risk

- Unacceptable; need to identify and implement measures to achieve at least an EHS-2 within a timely manner not to exceed 9 months for admin/procedural controls or not to exceed 66 months for major expense or capital.
- When further studies are required, they shall be completed, and resolution identified in a timely manner not to exceed 12 months

EHS-2- Medium Risk

- Shall determine whether further risk reduction is practicable. Implementing further risk reduction measures for these scenarios will be done at the discretion of the Site Head or delegate. Continue good practice. (2)

(1) These actions are for an Existing Operating Plant. See Table 3 IVL EHS-208 actions for Design Proposals for New Plants or Modifications to Existing Plants.

(2) To ensure that risk is maintained at or below the current level.

EHS-1 – Low Risk

- Broadly acceptable and indicative of a well-managed operation; use current good practices (2)

Risk Level Review and Endorsement Guidance from IVL-EHS-208

Table 3b
Risk Level Reviews and Endorsements Guidance

(see Attachment C for further guidance)

Risk Level	Risk Review Guidelines	Applicable Severity Levels: Frequency
EHS – 4 Very High-Risk Range	Risk Reviews for A thru H Severity scenarios operating in the EHS-4 risk range are only necessary at the time the EHS-4 risk range is determined and immediately mitigated to reach the EHS-3 or lower risk range. No follow-up Risk Reviews are recommended since there is an expectation of no EHS-4 scenarios previously discovered to be currently in operation.	Not Applicable
EHS – 3 High Risk Range	Risk Reviews for A thru F Severity scenarios operating in the EHS-3 risk range are recommended to be conducted Annually. Risk Reviews for G thru H Severity scenarios operating in the EHS-3 risk range are recommended to be conducted at least once prior to or during the next PHA Revalidation.	A thru F: Recommended Annually G thru H: Recommended per Revalidation Process and Schedule
EHS – 2 Medium Risk Range	Risk Reviews for A thru H Severity scenarios operating in the EHS-2 risk range are recommended to be conducted at least once prior to or during the next PHA Revalidation.	A thru H: Recommended per Revalidation Process and Schedule
EHS – 1 Low Risk Range	Risk Reviews for D thru H Severity scenarios operating in the EHS-1 risk range are recommended to be conducted at least once prior to or during the next PHA Revalidation.	D thru H: Recommended per Revalidation Process and Schedule

Risk Ranking at the Boundaries

	Frequency Category								
	$\leq 10^{-6}$	$> 10^{-6}$ to 10^{-5}	$> 10^{-5}$ to 10^{-4}	$> 10^{-4}$ to 10^{-3}	$> 10^{-3}$ to 10^{-2}	$> 10^{-2}$ to 10^{-1}	$> 10^{-1}$ to 1	> 1	
Severity Category	1	2	3	4	5	6	7	8	
A	EHS-2	EHS-3	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	Facility Siting Scope
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C	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	
D	EHS-1	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	LOPA Scope
E	EHS-1	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	
F	EHS-1	EHS-1	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	
G	EHS-1	EHS-1	EHS-1	EHS-2	EHS-2	EHS-2	EHS-3	EHS-3	HazOp Scope
H	EHS-1	EHS-1	EHS-1	EHS-1	EHS-1	EHS-2	EHS-2	EHS-3	

A fatality scenario that may occur once every 10000 years is on the border of an EHS-3 and EHS-2. This scenario is given an EHS-2 risk level, light green, Medium Risk.

A fatality scenario that may occur once every 10 years is on the border of an EHS-4 and EHS-3. This scenario is given an EHS-4 risk level, red, Very High Risk.

Target Frequency Table – Table 4 (Quantitative Risk Assessments)

Severity Category	Tolerable Target Frequency (per year) EHS-3 / EHS-2 Boarder	Broadly Acceptable Target Frequency (per year) EHS-2 / EHS-1 Boarder
A	1×10^{-6}	$>1 \times 10^{-7}$
B	1×10^{-6}	$>1 \times 10^{-7}$
C	1×10^{-5}	1×10^{-7}
D	1×10^{-5}	1×10^{-6}
E	1×10^{-4}	1×10^{-6}
F	1×10^{-3}	1×10^{-5}
G	1×10^{-1}	1×10^{-4}
H	1	1×10^{-2}

Quantitative Risk Ranking Example

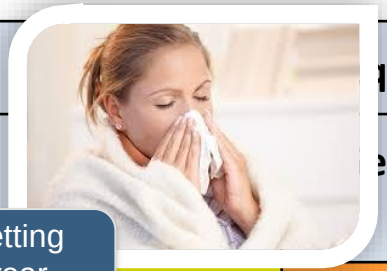
	Frequency Category								
	$\leq 10^{-6}$	$> 10^{-6}$ to 10^{-5}	$> 10^{-5}$ to 10^{-4}	$> 10^{-4}$ to 10^{-3}	$> 10^{-3}$ to 10^{-2}	$> 10^{-2}$ to 10^{-1}	$> 10^{-1}$ to 1	> 1	
Severity Category	1	2	3	4	5	6	7	8	
A	EHS-2	EHS-3	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	Facility Siting Scope
B	EHS-2	EHS-3	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	
C	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	
D	EHS-1	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	LOPA Scope
E	EHS-1	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	
F	EHS-1	EHS-1	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	
G	EHS-1	EHS-1	EHS-1	EHS-2	EHS-2	EHS-2	EHS-3	EHS-3	HazOp Scope
H	EHS-1	EHS-1	EHS-1	EHS-1	EHS-1	EHS-2	EHS-2	EHS-3	

Example: A fatality scenario is assigned a Severity Category of E that is "unlikely to happen in the lifetime of the plant" in a Frequency Range of 1×10^{-3} and 1×10^{-4}. The relative Risk Level is EHS-3, High Risk.

Putting Risk into Perspective

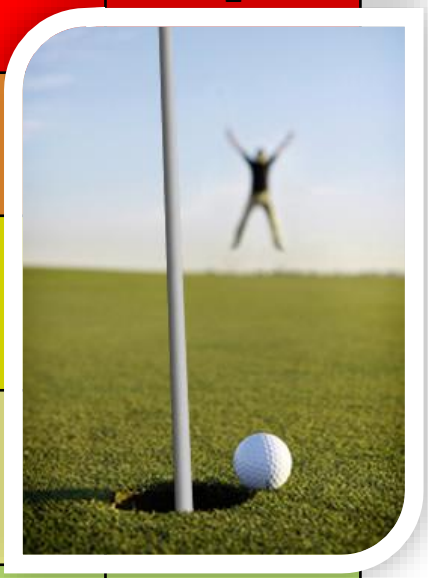
FREQUENCY (Likelihood)	Ranking	Negligible		erious III	Critical II	Catastrophic I
	A (1/10)	Discretion	3		1	1
	B (1/100)	Required	4		2	
	C (1/1000)	Required	eam's scretion 5	4	3	
	D (1/10,000)	Required	Required	Team's Discretion	4	
	E (1/100,000)	Required	Requ		Team's Discretion 5	Team's Discretion 5

Chance of getting the flu this year 1 in 10



Chance of having identity stolen 1 in 200

Chance of a hole in one in golf 1 in 5,000



Chance of a finding a four-leaf clover 1 in 10,000

Chance of getting struck by lightning 1 in 80,000

Hazard Assessment

Hazard Assessment

- **What is it?**
  - A Consistent Methodology
  - A Standardized set of Tools
- **When do I use it?**
  - To Evaluate EHS (Business) Risk
  - To Compare Risk between Alternatives
  - To Quantify Risk
  - To Determine Criticality and Reliability Required of Safeguards
  - To Allocate limited Resources
  - To Achieve Consensus in Decision Making

Application Examples:

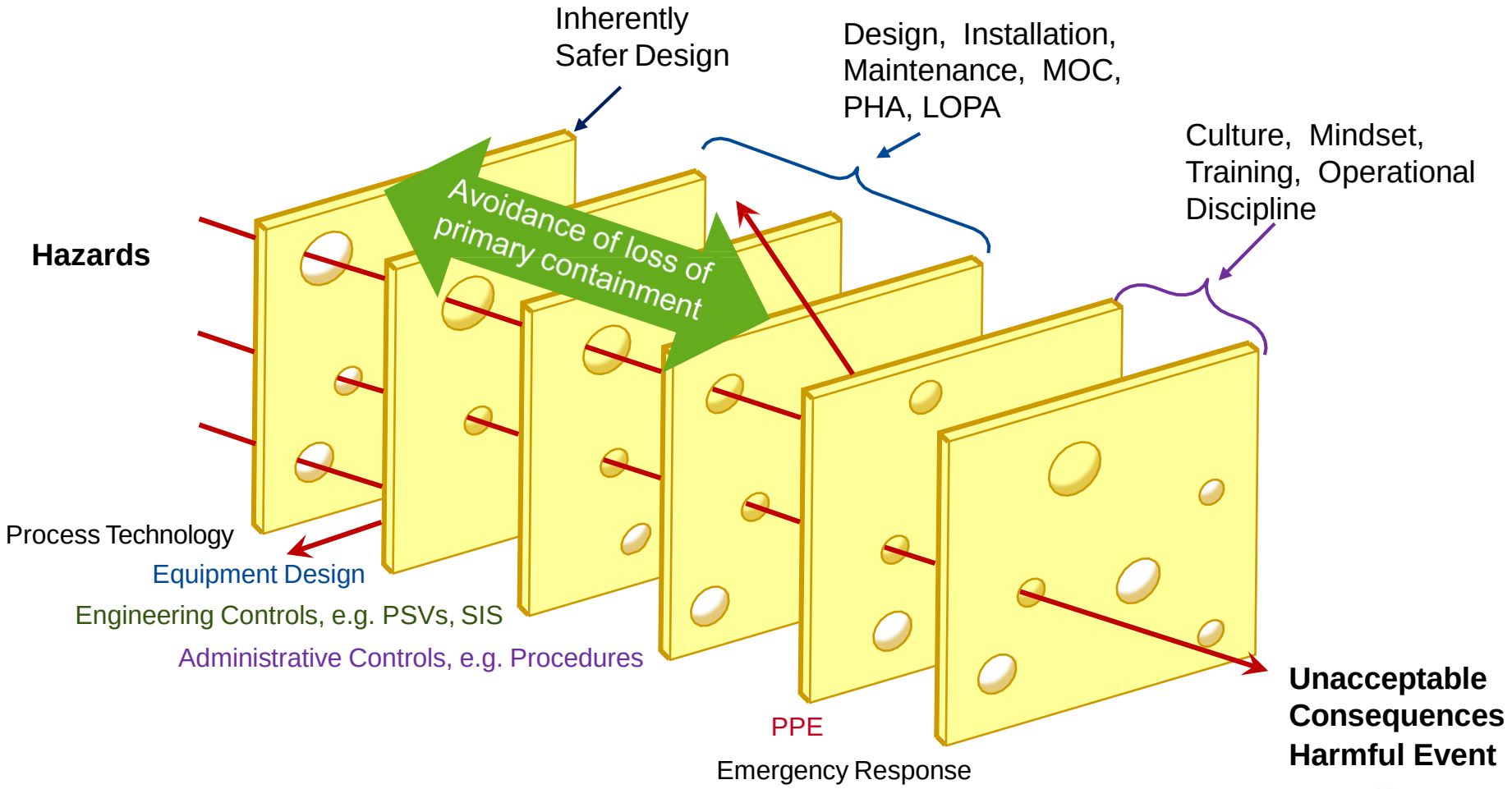
Identify ‘Unacceptable Risks’

Determine Best Methods of Risk Reduction (Process Safety)

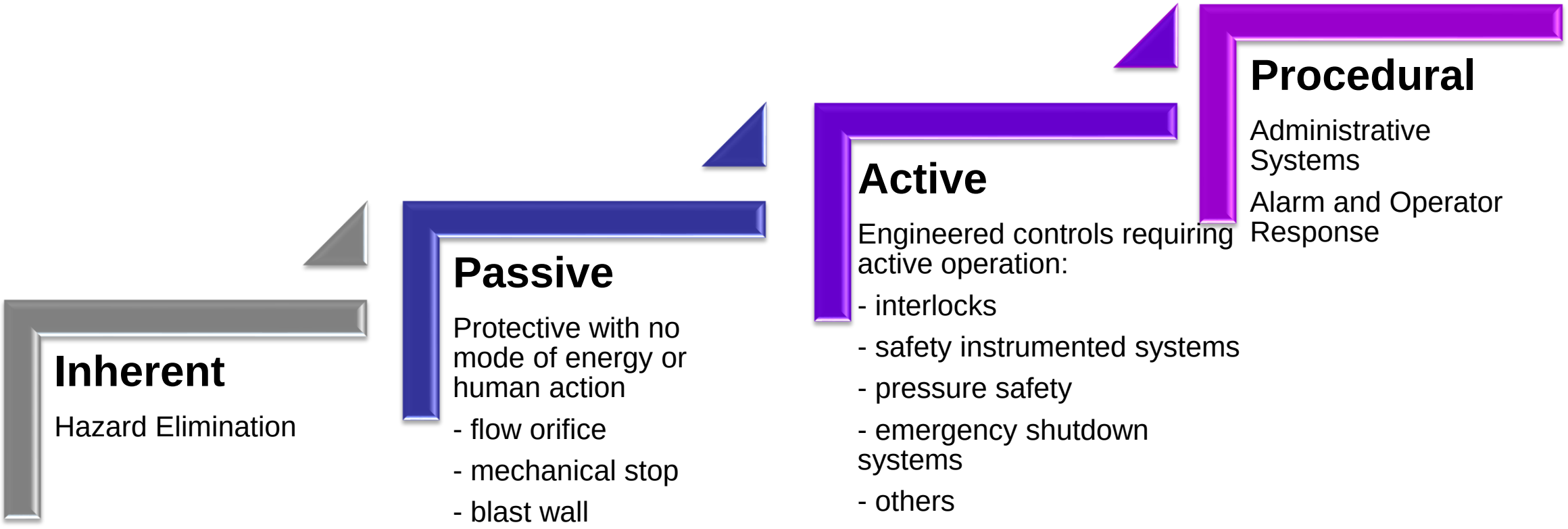
Risk Based Allocation of Capital and Expense Funding

Identify the Hazard and the “Layers” or “Safeguards” to Prevent the Harmful Event

Adapted “Swiss Cheese Model” to highlight the layers of protection



Hierarchy of Controls



Event Tree – Hazard Assessment

CHLORINE RAILCAR RELEASE

Initiating Event – CAUSE

(BPCS - Flow Totalizer (FTQ) interlock failure to trip loading system – High Level/Pressure, Lifting of Pressure Safety Valve on Railcar)

Success

IPL 1
PLC1

Result 1 (Minor release, no significant issues)

Success

IPL 2
Hardwired Interlock SIS

Result 2 (Intermediate release, minor issues)

Failure

Success

CMS 1
PLC2

Result 3 (Loss of contents from railcar with knockdown of vapors)

Failure

Failure

Undesired Harmful Event
Consequence, Chlorine Vapor Cloud
Onsite fatality and offsite injuries

Documenting the Consequence in a Hazard Assessment

Flow Totalizer (FTQ-XXX) malfunctions low or feed block valve (XV-XXX) malfunctions open resulting in potential to overfill and overpressure the railcar to the deadhead pressure of P-100 (75 psig) and venting of chlorine through (PSV-XXX) set at 65 psig.

Documenting the Consequence in a Hazard Assessment – ANSWER SLIDE

Flow Totalizer (FTQ-XXX) malfunctions low or feed block valve (XV-XXX) malfunctions open resulting in potential to overfill and overpressure the railcar to the deadhead pressure of P-100 (75 psig) and venting of chlorine through (PSV-XXX) set at 65 psig.

Potential for toxic vapor cloud at concentrations exceeding an ERPG-3 with onsite injuries or single fatality (loading operator) due to inhalation.

Potential for toxic vapors offsite at ERPG-2 with potential for public exposure to individuals in vehicles with multiple injuries and hospitalizations.

Potential for environmental impacts with release of chlorine above the RQ of 10 pounds and acid water runoff from deluge to POTW with environmental impact of fish/wildlife.

Risk Ranking

Flow Totalizer (FTQ) Trip Failure resulting in overfill of the railcar and overpressure to deadhead pressure of P-100 (XX psig) and venting of chlorine through the railcar Pressure Safety Valve set at XX psig.

Potential for toxic vapor cloud at concentrations exceeding an ERPG-3 with onsite injuries or single fatality (loading operator) due to inhalation.

Potential for toxic vapors offsite at ERPG-2 with potential for public exposure to individuals in vehicles with multiple major injuries and hospitalizations.

Potential for environmental impacts with release of chlorine above the RQ of 10 pounds and acid water runoff from deluge to POTW with environmental impact of fish/wildlife.

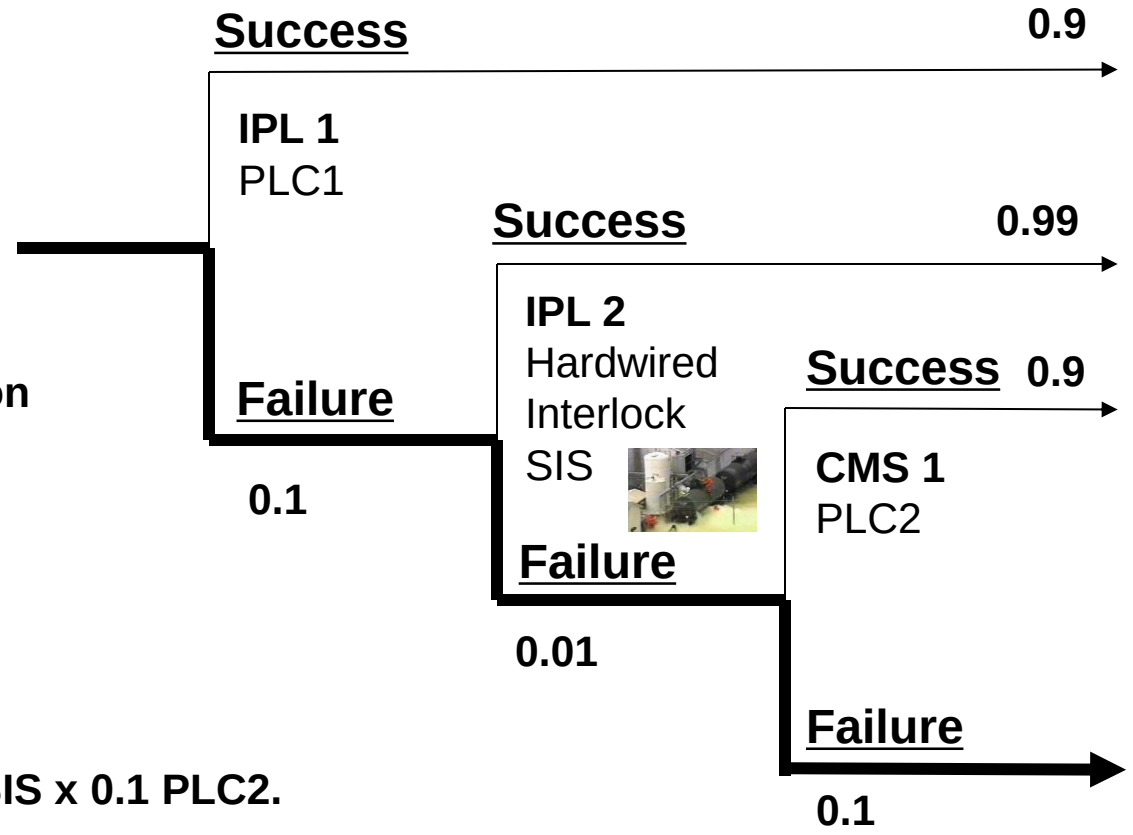
Event Tree – Hazard Assessment

CHLORINE RAILCAR RELEASE

Initiating Event – CAUSE

(BPCS - Flow Totalizer (FTQ) interlock failure to trip loading system – High Level/Pressure, Lifting of Pressure Safety Valve on Railcar)

0.1/yr.. or 1/10 yrs.



0.1/yr.. BPCS x 0.1 PLC1 x 0.01 SIS x 0.1 PLC2.
1/10000 yr.. or 1 x 10 (-5)/yr..

Undesired Harmful Event
Consequence, Chlorine Vapor Cloud
Onsite fatality and offsite injuries

Determination of Risk Level

	Frequency Category								
	$\leq 10^{-6}$	$> 10^{-6}$ to 10^{-5}	$> 10^{-5}$ to 10^{-4}	$> 10^{-4}$ to 10^{-3}	$> 10^{-3}$ to 10^{-2}	$> 10^{-2}$ to 10^{-1}	$> 10^{-1}$ to 1	> 1	
Severity Category	1	2	3	4	5	6	7	8	
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C	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	EHS-4	EHS-4	
D	EHS-1	EHS-2		EHS-	-3		EHS-4	EHS-4	LOPA Scope
E	EHS-1	EHS-2					EHS-4	EHS-4	
F	EHS-1	EHS-1	EHS-2	EHS-2	EHS-3	EHS-3	EHS-3	EHS-4	
G	EHS-1	EHS-1	EHS-1	EHS-2	EHS-2	EHS-2	EHS-3	EHS-3	HazOp Scope
H	EHS-1	EHS-1	EHS-1	EHS-1	EHS-1	EHS-2	EHS-2	EHS-3	

CMS1
PLC1 0.1

IPL2
SIS = 0.01

IPL1
PLC1 0.1

Inherent Risk of BPCS Flow Totalizer Interlock Failure
0.1/yr.. Initiating Cause Frequency

Case Study: Ethylene Oxide Railcar Overfill

- **EO tank car overfilled venting 15,000 lbs. of liquid EO through the PRV**
- **Human inattentiveness, inadequate and bypassed safety systems**
- **No employee injuries only environmental reportable**
- **Did not find a source of ignition**
- **Potential Severity “5” event**

✓ **Key Finding**

Importance of complete and thorough process hazard analysis on loading and unloading operations for high hazard chemicals

References to Assist with Risk Ranking

Hazard Assessment References

PNO Flammable Pump Seal Hazard Assessment and Safety Functions Technical Guidance Note

PNO Boiler Study Comparison for F8, O&O, and F5

Overpressure Consequence Tables

EO Guidance Manual 3rd Edition

CCPS Probability of Ignition Tool

US EPA RMP*Comp or ALOHA Free Consequence Modeling Software

Other AIChE CCPS Published Reference Documents

HSE Published Reference Documents

Site Facility Siting Consequence Modeling Results

Overpressure Consequences - Piping

PIPING:

Reference Code B31.3 (Allowable Stress = Min of 2/3 SMYS or 1/3 Tensile Strength, TS)

Flange rating at temperature/pressure generally limit MAOP unless there is a weaker point in the line (e.g. sight glasses – service).

NOTE: Facilitators should review piping specifications sheets for actual flange ratings.

Table 1: Piping - B31.3 (A53B A106B – Carbon Steel)

Percent (%) MAOP Over pressure	Most Likely Consequence
1.0 - 1.45 x the design pressure	None
1.45 - 1.75 x design pressure	Gasket leakage possible
1.75 - 2.4 x design pressure	Gasket leakage, non-resealing
2.4 -3.0 x design pressure	Line rupture possible

Example use of table: Piping is typically hydrostatically tested at 1.5 x MAOP (flange rating); e.g. 300 class flanges are rated for approx. 740 psig. Therefore, leakage is not anticipated to occur until pressure exceeds 740 psig x 1.5 = 1110 psig. For purposes of a general reference, the table lists 1.45 to 1.75 X MAOP.

Table 2: Piping - B31.3 (A312 TP304 – 304 Stainless Steel)

Percent (%) MAOP Over pressure	Most Likely Consequence
1.0 - 1.25 x design pressure	None
1.25 - 1.5 x design pressure	Gasket leakage possible
1.5 - 3.5 x design pressure	Gasket leakage, non-resealing
3.5 - 5.5 x design pressure	Line rupture possible

Overpressure Consequences – ASME Pressure Vessels

PRESSURE VESSELS:

Reference Code ASME Section VIII Div. 1 and Div. 2

Table 3: Vessels - ASME Section VIII Div. 1 and Div. 2

Percent (%) MAWP Over pressure	Most Likely Consequence
1.0 - 1.3 x the design pressure	None. Typically within PSV accumulation allowance for Fire case
1.3 - 1.5 x design pressure	Potential for gasket leakage, likely no permanent damage to vessel.
1.5 - 2.0 x design pressure	Gasket Leakage is likely. There is potential of permanent vessel deformation and potential for cracking or leakage.
2.0 - 2.5 x design pressure	Gasket Leakage is very likely and very likely to result in permanent vessel deformation, cracking and leakage.
2.5 - 3.0 x design pressure	Gasket Leakage and vessel deformation leading to significant leakage
> 3.0 x design pressure	Potential for bursting of the vessel

Hazard Assessment References

AIChE Center of Chemical Process Safety (CCPS) Published Documents

- *Layer of Protection Analysis*
- *Guidelines for Initiating Events and Independent Protection Layers in Layer of Protection Analysis*
- *Guidelines for Engineering Design for Process Safety*
- *Guidelines for Determining the Probability of Ignition of a Released Flammable Mass and* Probability of Ignition Tool
- *Guidelines for Enabling Conditions and Conditional Modifiers in Layer of Protection Analysis*

Hazard Assessment References

UK Health Safety Executive (HSE) Published Documents

- Guidance on Human Factor Safety Critical Task Analysis
- Human Factors Toolkit
- Reducing Error and Influencing Behavior
- Assessment of the Dangerous Toxic Load (DTL) for Specified Level of Toxicity (SLOT) and Significant Likelihood of Death (SLOD)
- HSE Severe Weather Checklist and Guidance
- HSE Operating Procedure Guidance

www.hse.gov.uk

Indorama EO Guidance

Ethylene Oxide Manual 3rd Edition

Indorama EO PHA Guidance

EO Pump Standard

EO Purge Pocket Design

EO Unloading Poster – Job Aide

Site Facility Siting Study

PSI for PHA

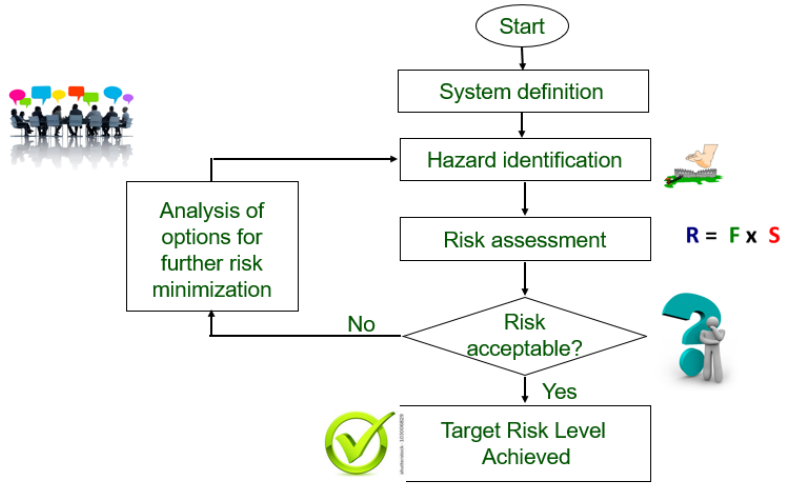
Do we want to create something specific to CPET for this and the next 4 slides?

Summary

IVL EHS-208 defines the formalized process to assess and rank levels of risk related to process safety and to prioritize risk-reduction actions.

The general steps in performing a Hazard Assessment and Hazard Control are:

- Identify scenarios of interest including modifiers and safeguards
- Risk rank using the risk matrix
- Recommend risk-reduction measures for EHS-3 / EHS-4
- Consider if further risk reduction is practicable for EHS-2
- Continue practices to keep EHS-1 / EHS-2 at that risk level.



Questions/Comments