INDORAMA VENTURES

Module 4A Safeguard Concepts – Special LOPA Topics

Last Revised – October 2022

Special Topics in this Module

- Identifying Consequence D thru A Hazard Scenarios
- Quantifying the Initiating Events and Frequencies
- Taking Multiple BPCS Credits

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 9: Exothermic Reactions

Module 4A: Special LOPA Topics Agenda

Identifying Consequence D thru A Hazard Scenarios

Quantifying the Initiating Events and Frequencies

Taking Multiple BPCS Credits

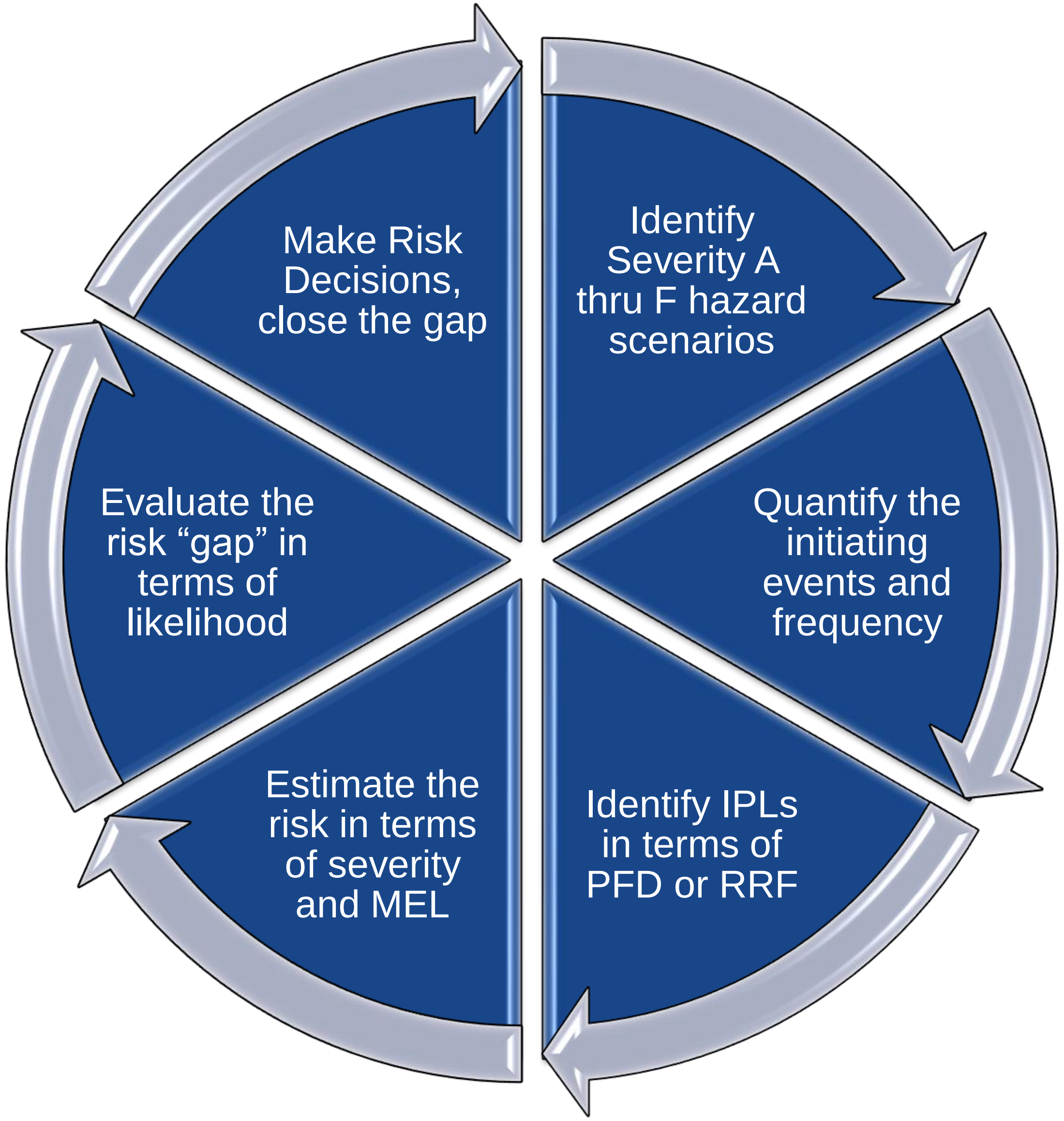
Module 4A: Training Objectives

Expanding Understanding and Familiarity with the following concepts:

- Identifying and documenting Consequence A thru F Hazard Scenarios
- Quantifying the Initiating Events and Frequencies
- Taking Multiple BPCS Credits

Identifying and Documenting Consequence A thru F Hazard Scenarios

LOPA Workflow



Consequence Evaluation in LOPA

LOPA Scenarios are mined from process PHAs

Worst Credible:

- A hazard event scenario (process related incident) where the quantity and condition, e.g. pressure, temperature, composition, of a hazardous chemical released takes into account the process conditions and passive mitigation measures:
  - Must be technically feasible
  - Must be physically feasible
  - Must not require two completely independent events (or initiating causes) to occur simultaneously

The consequence type with the maximum severity drives the Target Mitigated Event Likelihood (TMEL).

Consequences from the PHA should be validated by the LOPA team!

Consequence Descriptions

Consequence Descriptions should contain <u>FIVE</u> components:

Loss of containment mechanisms

- *Example: High temperature or pressure resulting in a leak at flange or fitting or vessel/pipeline rupture*

Nature of the release (Chemical name and properties)

- *Example: Release of propylene above its flash point*

Undesirable outcomes of hazard event scenarios due to loss of containment

- *Example: Flash, pool and jet fires; toxic exposure*

Effect on people onsite and offsite (Safety severity basis)

- *Example: Personnel exposure to radiant heat with severe injury*

Effect on the environment and community (Environmental severity basis)

- *Example: Atmospheric release above a reportable quantity with no offsite impacts*

Consequence Descriptions

Putting all 5 components together:

Potential for high temperature or pressure resulting in a leak at flange or fitting or vessel/pipeline rupture resulting in release of propylene above its flash point leading to flash, pool and jet fires; and toxic vapors.

Potential for personnel exposure to toxic fumes and radiant heat with severe lost time injury

Potential for atmospheric release or propylene above the reportable quantity of 10,000 lbs. with no offsite impacts.

Causes can be anywhere including outside of study boundaries.

Consequences should be documented in the node where they occur.

Safeguards are typically found in the same node as the consequence.

Screening Criteria from IVL-EHS-208

Table 1 - Consequence Definitions Severity Categories A-F

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

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

Consequence Assumptions and Considerations

When evaluating a consequence, the PHA/LOPA team should consider:

- Normal unit operations (trained staff, PPE, testing & inspection, signage, staffing levels, etc.)
- Release location and distance to ignition sources
- Possibility of evacuation due to propagation time, early warnings, and incident size
- Type and degree of equipment damage
- Local environmental sensitivity to toxic release
- Need for detailed modeling
- Active safeguards are <u>not</u> considered in the consequence development
- Modifiers are quantified outside of the consequence assessment

- **The team should distinguish between factors that affect SEVERITY and factors that affect LIKELIHOOD.**
- **Only those that effect SEVERITY should be considered when developing the consequence.**

Consequence Assumptions and Considerations

When evaluating environmental severity:

- An uncontrolled release of hazardous chemical that has the potential to exceed a regulatory reportable quantity (RQ) would be risk ranked as a <u>Category G</u> environmental severity if it is <u>**not**</u> also substantial enough to result in a plant evacuation and community shelter-in-place.

- An industrial neighbor such as Westlake at Lake Charles is not considered “community” when evaluating this criterion. Employees of companies that share the outer fence perimeter receive similar safety training, are informed and prepared, and in this case actually share an emergency response team.

Consequence Assessment Tools

The following tools can be used for consequence assessment:

Consequence definitions (IVL-EHS-406)

Risk Matrix (IVL-EHS-208)

Overpressure Tables based on ASME code

Facility siting consequence tools (IVL-EHS-407, modeling techniques and software)

Overpressure Table - 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

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 Table - Vessels

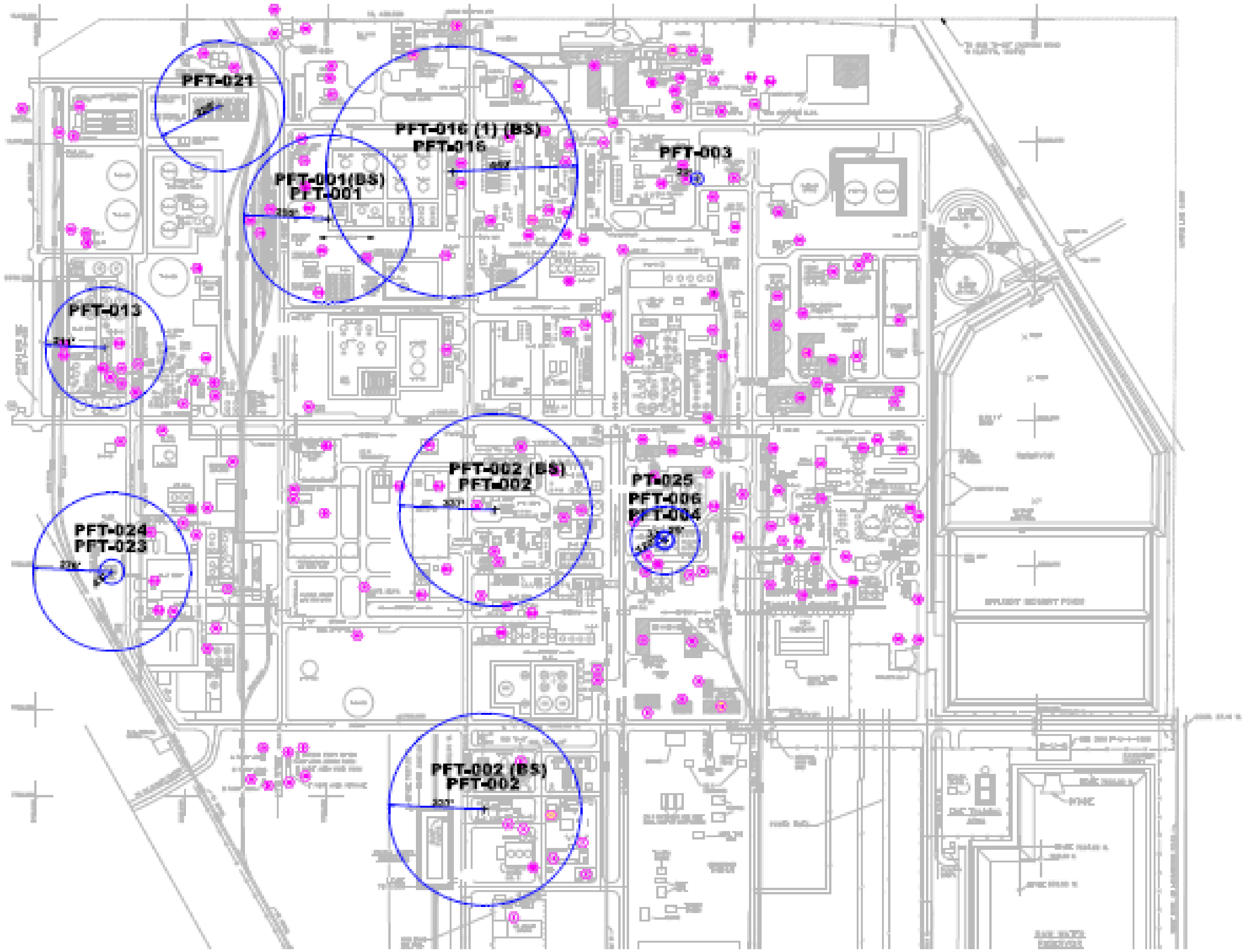
PRESSURE VESSELS:

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

Table 1: 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

Facility Siting and Modeling



Flash Fire Modeling Results – Distance to Lower Flammability Limit

EO Consequence Guidance

Model #	Scenario	Distances of Concern, ft										
		Flash Fire	Late Pool Fire				Jet Fire	VCE				
		LFL	5.9 kW/m2	12.5 kW/m2	25 kW/m2	37.5 kW/m2	Jet Flame Length	0.6/0.5 psi	1 psi	2 psi	3 psi	5 psi
PFT-001 (108, 1.5, F)	EO liquid leak, 3" line rupture on pipe rack over roadway, 35 psig saturated liquid, 20' elevation, horizontal	295	110	93	78	73	181	747	560	401	340	284
PFT-003 (108, 1.5, F)	EO liquid leak, hole size adjusted to limit flow to 36.5 lb./min (0.119"), 300 psig 108F, 10' elevation, horizontal	22	-	-	-	-	34	-	-	-	-	-
PFT-006 (108, 1.5, F)	EO liquid leak, hole size adjusted to limit flow to 70 gpm (0.292"), 1100 psig 108F, 30' elevation, horizontal	120	64	64	64	1	92	-	-	-	-	-
PFT-013 (108, 1.5, F)	EO liquid leak, quarter 4" feed line reactor gasket failure (0.7071"), 180 psig 108 F, 10' elevation, horizontal	211	79	69	60	60	143	-	-	-	-	-
PF-029 (108, 1.5, F) 100%	EO decomposition, deadheaded pump, IRI Graph, heat of decomposition 1,312 Btu/lb., TNT yield 100%, 15,000 lbs	-	-	-	-	-	-	1393	857	536	429	321
PF-029 (108, 1.5, F) 50%	EO decomposition, deadheaded pump, IRI Graph, heat of decomposition 1,312 Btu/lb., TNT yield 50%, 15,000 lbs	-	-	-	-	-	-	1106	680	425	340	255
PF-029 (108, 1.5, F) 25%	EO decomposition, deadheaded pump, IRI Graph, heat of decomposition 1,312 Btu/lb., TNT yield 25%, 15,000 lbs	-	-	-	-	-	-	877	540	337	270	202

Example data only. A dispersion modeling expert should be consulted to validate VCE credibility.

IOD-EHS-406 Radiant Heat Consequences

Table J-4
Radiant Levels Versus Observed Consequences

RADIANT HEAT LEVEL (kW/m^2)	OBSERVED CONSEQUENCE
1.6	Will cause no discomfort for long exposure
4	Sufficient to cause pain to personnel if unable to reach cover within 20 seconds
9.5	Pain threshold reached after 8 seconds; **second degree burns after 20 seconds**
12.5	Minimum required for piloted ignition of wood, melting of plastic tubing
25	Minimum required to ignite wood at indefinitely long exposures (non-piloted)
37.5	Sufficient to cause damage to process equipment

IOD-EHS-406 Explosion Consequences I

Table J-1
Peak Side-On Overpressure versus Consequences for Building Type [1, 2]

Building Type	Peak Side-on Overpressure Psi (bar)	Consequences	Vulnerability of Occupants (Probability of Serious Injury/Fatality)
Wooden frame trailer or shack **B1**	1 (0.069)	Isolated buildings overturn. Roof and wall collapse	0.1
	2 (0.14)	Complete collapse	0.4
	5 (0.34)	Building completely destroyed	1.0 [3]
Steel frame / metal siding pre-engineered buildings **B2**	1.25 (0.09)	Metal siding anchorage failure.	0.1
	1.5 (0.10)	Sheeting ripped off and internal walls damaged. Danger from falling objects	0.2
	2.5 (0.17)	Building frame stands, but cladding and internal walls are destroyed as frame distorts	0.4
	5 (0.34)	Building completely destroyed	1.0 [3]
Un-reinforced masonry bearing wall building **B3**	1 (0.069)	Partial collapse of walls that have no breakable windows	0.1
	1.25 (0.085)	Walls and roof partially collapse	0.2
	1.5 (0.10)	Complete collapse	0.6
	3 (0.21)	Building completely destroyed	1.0 [3]

IOD-EHS-406 Explosion Consequences II

Table J-2 Side-On Overpressure Versus Consequences for Building Components		
Building Component	**Overpressure psig (bar)**	**Component Response or Consequence**
Glass	0.2 (0.014)	Breaking of un-strengthened panes
Glass	0.5 to 1 (0.03 to 0.07)	Shattering with body penetrating velocities
Wooden frame	1 to 2 (0.07 to 0.14)	Structural failure
Steel cladding	1 to 2 (0.07 to 0.14)	Internal damage to walls, ceilings and furnishings
Concrete cladding	1 to 2 (0.07 to 0.14)	Shattering
Brick cladding	2 to 3 (0.14 to 0.21)	Blown-in
Unreinforced masonry	1 to 3 (0.07 to 0.21)	Wall collapse, possible shattering

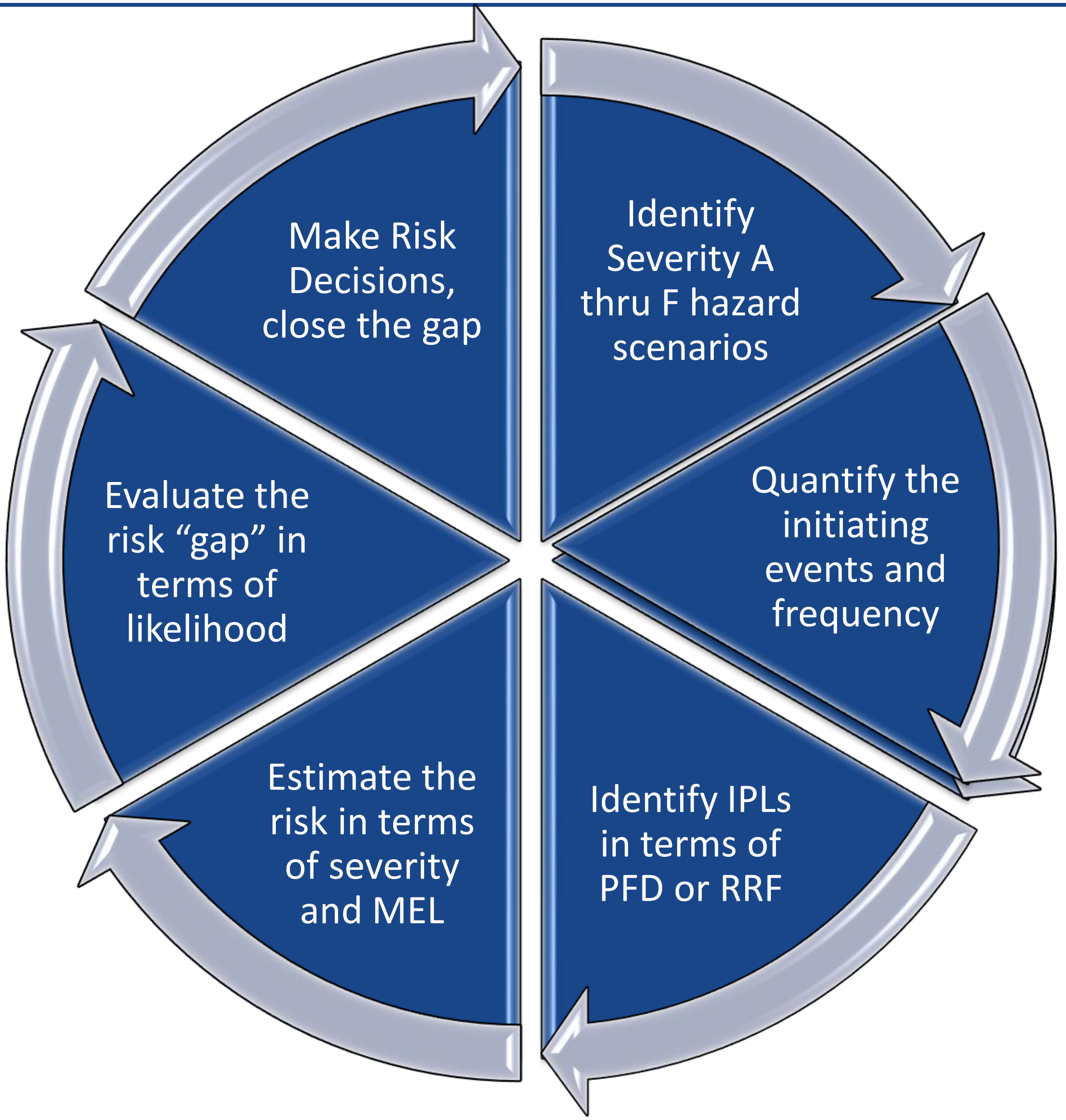
IOD-EHS-406 Toxic Consequences

Table J-5 Toxic Concentrations Versus Potential Off-Site Consequence	
Toxic Concentration (ERPG)	**Potential Off-Site Consequence**
ERPG-1	Severity Category 2 injury / illness
ERPG-2	Severity Category 3 injury / illness
ERPG-3	Severity Category 4 or 5 injury / illness

Questions/Comments

Quantifying the Initiating Events and Frequencies

LOPA Workflow



Identifying Initiating Event Frequency

Failure rates must be selected with the following considerations:

Consistent with the basic design of the facility

- Take all variables into account (environmental conditions, service concerns, etc.)

Consistent with Indorama's defined methods for evaluating initiating event frequencies

- Historical data
- IVL-EHS-406 Table C-4

When using failure data other than Table C-4, data should be well documented and used from the same location in the data range (e.g., upper bound, lower bound or midpoint), as this will provide a consistent degree of conservatism for the entire process

The data should be representative of the industry or operation that is under study.

Identifying Initiating Event Frequency

Historical data is preferred when available.

When historical data is not available, or the team does not believe that historical data is defendable, tabulated values are available in Table C-4 of IVL-EHS-406 for the following types of Initiating Events:

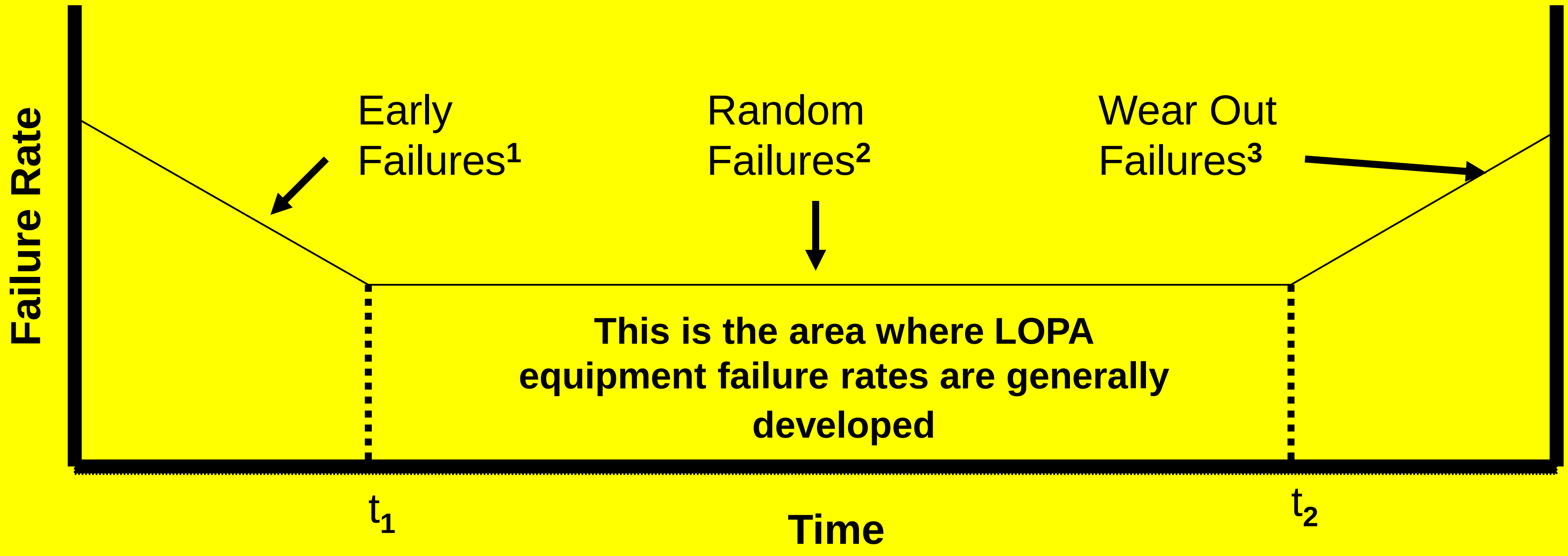
- *Standard Operating Procedures (SOP)*
- *Basic Process Control System (BPCS)*
- *Safety Instrument System (SIS)*
- *Local Control Systems or Shutdowns (LOCAL)*
- *Miscellaneous Items (OTHER)*

Be sure that:

- The team understands the underlying assumptions of the failure rates
- These assumptions are consistent with the process under study
- The frequency is not greater than that of the most experienced person on the team

Identifying Initiating Event Frequency

UNDERLYING ASSUMPTIONS FOR LOPA EQUIPMENT FAILURE RATE (λ)



Identifying Initiating Event Frequency

IVL-EHS-406 has defined frequencies based on types of initiating causes. Use this information to populate the frequency cells in the LOPA worksheets.

Causes	Cause Type	Frequency
1. CONTROL LOOP FAILURE - (FV-255) FAILS CLOSED OR (FT-255) MALFUNCTIONS HIGH.	BPCS INSTRUMENT LOOP FAILURE - CLEAN SERVICE	1.0E-01

Human Factor Initiating Events

Human Factor Initiating Events are categorized using the following:

Team experience

Normal manual actions by a single operator

Normal routine manual actions by an operator with online diagnostics or independent review

Frequently performed events

There is a HAZARD associated with performing each task.
A Harmful Event begins with a Human Error while performing the task

Human Factor Initiating Events

For initiating events defined per Table C-4 as:

Normal manual actions by a single operator

Normal routine manual actions by an operator with online diagnostics or independent review

Human error rate, f, is estimated from the human error probability and how often the task is performed.

f = probability of human error * (# of opportunities / year)

Where the probability of human error is defined as:

Trained single operator with procedures: 0.01

Trained single operator with procedures and feedback from online diagnostics or independent person: 0.001

Human Factor Initiating Events

For initiating events defined per Table C-4 as:

Frequently Performed Events (more than once per week)

Human error rate, f, can be assigned a frequency of 0.1 per year if supported by site data.

$$f = 0.1 / yr.$$

These should be skill-based events performed more than once per week. The team should consider if historical data reflects use of protective safety measures to ensure they are not “double counted”.

Human Factor Initiating Events

Example:

Consider a valve that is manipulated by the field operator once every 5 years during a turnaround.

What is the initiating event frequency?

Normal routine action with independent supervisory review:

$f_{\text{Initiating Cause}}$ = probability of failure * (# of opportunities / yr.)

$f_{\text{Initiating Cause}}$ = (0.01) * (1 opportunity / 5 years)

= 2 * 10^{-3}/yr. or 0.002/yr.

Human Factor Initiating Events

Example: [Reference Table C4]

A PO unloading station is used to unload 2 trucks of PO per day. The site does not have a history of incidents at this unloading station or at any other truck unloading stations.

What is the frequency that the truck driver may drive away while the truck is still connected?

Frequently performed task with no site history of incidents:

f = 0.1 / yr.

Potential Questions:

Is this realistic?

Is this conservative?

Is this representative of actual event history at the site?

If the answer is no, estimate using historical data or human error probabilities.

Piping & Pressure Vessel Failure – Initiating Events

Piping Failure and Pressure Vessel Failure Initiating Events due to general corrosion are typically handled by the RBMI program.

If piping failure is considered as an initiating event in the LOPA, the length of the pipe must be addressed.

The frequency of failure is expressed per 100m of pipe:

$f_{residual\_failure}$ = pipe length / 100m * 1e-05

f_{leak} = pipe length / 100m * 1e-03

Example:

What is the frequency at which 80m of piping would experience full breach?

$f_{residual\_failure}$ = pipe length / 100m * 1e-05 = 80/100 * 1e-05 = 8e-06

Enabling Events or Conditions

Enabling Events or Conditions are events or conditions that make it possible for an incident sequence to proceed to a consequence of concern.

The initiating event frequency is multiplied by the probability of the enabling events or conditions to obtain the frequency of the total initiating cause.

$$\mathrm{f}_{\text{Initiating Cause}} = \mathrm{f}_{\text{Initiating Event}} * \prod P_{\text{Enabling Condition}}$$

Enabling Events or Conditions

Example:

Consider a hose connected to a batch reactor. The hose has an in-service base failure rate of $1*10^{-2}$/yr. but is only used for a particular batch which takes 2 hours and is run 40 times per year.

What is the failure rate?

$$f_{\text{Initiating Cause}} = (1 * 10^{-2}) * 40 * 2 * \frac{1}{8760}$$

$$f_{\text{Initiating Cause}} = 0.0001/yr \text{ or } (1 * 10^{-4})/yr$$

LOPA Scenarios and Components

NOTE!

Many companies do not use Enabling Events to modify their frequencies for LOPA studies due to the complexity and the potential for underestimating the Initiating Event Frequency. This adjustment can significantly underestimate the RISK that a specific operation poses to the Site.

Only teams/persons who are <u>very experienced</u> with LOPA studies should consider these adjustments to Initiating Event Frequencies.

Conditional Modifiers

Conditional Modifiers are factors that represent the probability that a release scenario propagates to a consequence of concern.

Conditional modifiers are represented as a probability. The overall probability of the conditional modifiers is determined by the product of all conditional modifiers.

$$P_{Total\_CM} = \prod P_{CM}$$

Example

Flammable material is released due to a storage tank overfill in a remote tank farm. One field operator is in the area 2 hours per day during rounds. An analysis is performed that determines probability of ignition at 0.1.

What is the contribution from occupancy?
What is the overall contribution from conditional modifiers?

$$P_{Occ} = 2 \text{ hr.} / 24 \text{ hr./day}$$
$$= 0.0833$$
$$= 0.1 \text{ (Rounded to nearest factor of 10 per EHS-208)}$$

$$P_{CM} = P_{Occ} * P_{Ig}$$
$$= 0.1 * 0.1$$
$$= 0.01$$

Breakout Examples

Go to the Breakout Examples section of your workbook.

Use the P&IDs provided and the comments in the LOPA worksheets as a basis. Brainstorm initiating causes and identify Enabling Events or Conditions and Conditional Modifiers. Use Table C-4 from the appendices for reference.

Complete the following sections:

- **Initiating Causes**
- **IPL/CMS/EE/CM (for EE and CM only)**

Our vision: To be a world-class sustainable chemical company making great products for society.

Breakout Example - Solutions

Example 1 (Storage Tank Overfill)

Cause A:

- **Description:** Control Loop Malfunction - LCV-101 fails closed
- **Freq (/yr.):** 0.1
- **Justification:** BPCS instrument loop failure - clean service

EE 1:

- **Description:** Time at Risk
- **Prob (0 to 1):** 0.25
- **Justification:** Based on feed process running 3 months per year.
- **IPL/CMS/EE/CM:** EE

What if the BPCS was in dirty service?

Breakout Example - Solutions

Example 2 (Pump Deadhead)

Cause A:

- **Description:** Control Loop Malfunction - FCV-101 fails closed
- **Freq (/yr.):** 0.1
- **Justification:** BPCS instrument loop failure - clean service

Cause B:

- **Description:** Human Factor - Manual block valve at P-2 discharge closed
- **Freq (/yr.):** 0.005
- **Justification:** SOP - normal actions, trained operator, with procedures available. (frequency of event per year *1/100)
  Routine pump maintenance is typically performed every 2 years.
  0.5 * 1/100 = 0.005

Can these cause frequencies be improved? If so, how?

Breakout Example - Solutions

Example 3 (Reactor Explosion)

Cause A:

- **Description:** Control Loop Malfunction - TCV-301 fails closed
- **Freq (/yr.):** 0.1
- **Justification:** BPCS instrument loop failure - clean service

Cause B:

- **Description:** Human Factor - Manual block valve at TCV-301 closed
- **Freq (/yr.):** 0.002
- **Justification:** SOP - normal actions, trained operator, with procedures available. (frequency of event per year *1/100)
  Valve closed once every 5 years for vessel cleanout
  0.2 * 1/100 = 0.002

Continued on next slide…

Breakout Example - Solutions

Example 3 (Reactor Explosion)

Cause C:

- **Description:** Loss of cooling water supply
- **Freq (/yr.):** 0.1
- **Justification:** Other - loss of process supply

EE 1:

- **Description:** Time at Risk
- **Prob (0 to 1):** 0.5
- **Justification:** Based on batch process of concern only operated 6 months per year.
- **IPL/CMS/EE/CM:** EE

Summary of Key Points

Discussed methods for identifying initiating event frequencies

Discussed special considerations for evaluating human factor and piping failure initiating events

Discussed how to apply enabling events or conditions

Discussed how to apply conditional modifiers

Questions/Comments

Taking Multiple BPCS Credits

Multiple IPLs from a Single BPCS

IPL <u>independence</u> means independence from:

- Initiating event (including any enabling events)
- Any other device, system or action already credited as an IPL in the same scenario

Approach A (CCPS Purple Book, Page 83, 174 - 176)

- Allows only one IPL in a BPCS
- Requires that IPL to be independent of the initiating event
- Assumes if one BPCS loop fails, then all of the loops within the same logic solver fail
- Most conservative approach.

Approach B (CCPS Purple Book, Page 86, 174 - 177)

- Allows more than one IPL to be in a single BPCS
- Requires the IPL to be independent of the initiating event
- Assumes if a BPCS loop fails, it is more probable the failed component is either the sensor or final control element, and the BPCS logic solver remains functional.
- The result of using this method is an improved PFD number (1×10^{-2} instead of 1×10^{-1}).

GREAT CARE MUST BE EXERCISED WHEN USING APPROACH B.

Multiple IPLs from a single BPCS

Indorama allows up to two BPCS credits (Approach B)

BPCS credits include the initiating event, BPCS IPLs and alarm IPLs implemented through the BPCS

Minimum requirements are in Figure C-3 of IOD-EHS-406

Figure C-3 Requirements

The following general rules qualify multiple functions on a single BPCS logic solver as multiple IPLs:

The sensor for a BPCS function credited as an IPL must be independent from any other sensor that is part of the Initiating Event or Enabling Events or Conditions of the scenario.

The final control element for a BPCS function credited as an IPL must be independent of the final element that is part of the Initiating Event or Enabling Events or Conditions of the scenario.

The sensor for a BPCS function credited as an IPL must be independent from any other sensor used in an IPL in the scenario.

The final control element for a BPCS function credited as an IPL must be independent from any other final element used in an IPL in the scenario.

IVL-EHS-406
Figure C-3 Requirements

Per IEC 61511, if RRF > 10 is claimed for the BPCS, then it shall be designed to the requirements of IEC 61511.

This is substantiated by the idea that the logic solver has a higher degree of integrity than 0.1. The degree of integrity and history of the logic solver must be validated.

Multiple credits may be available from a single BPCS control system.

No more than TWO credits are permitted from the BPCS.

Use of multiple BPCS credits should be made with adequate analysis and documentation.

No credit can be taken for multiple loops if the sensors or final elements are common.

Operator alarms initiated in the BPCS count as a BPCS credit.

Initiating events in the BPCS count as a BPCS credit.

Exercise caution when applying multiple BPCS credits!

IVL-EHS-406
Figure C-3 Requirements

Data must be available and analyzed to support the basic assumption:

PFDavg (Logic Solver) << PFDavg (Components)

This data should include:

- Historical performance data for the BPCS logic solver, input/output cards, sensors, final control elements, human response, etc.
- Data from the manufacturer of the system.
- Inspection, maintenance and test data over a significant period.
- Instrument diagrams, P&ID, loop diagrams, standards, specifications, etc., describing the actual installation.
- Information on the security of access to the BPCS for programming changes, alarm bypassing, etc.

Multiple BPCS IPL Requirements

The recommended guidelines for crediting multiple BPCS loops as IPLs for the same scenario are as follows:

Automatic Mode

- Must be designed to be non-settable / “stand-alone”.
- Must be proven-in-use as highly available and reliable.

MOC

- Managed under formal MOC.

Adequate Access and Security Procedure

- Required to provide assurance the potential for human error in programming, modifying or operating the BPCS is reduced to an acceptable level.

Failure of the Programmable Device

- Must have written procedure to address blank screens, workstation ‘freezes’ or other signs that the programmable device has stopped working correctly.

Multiple BPCS IPL Requirements

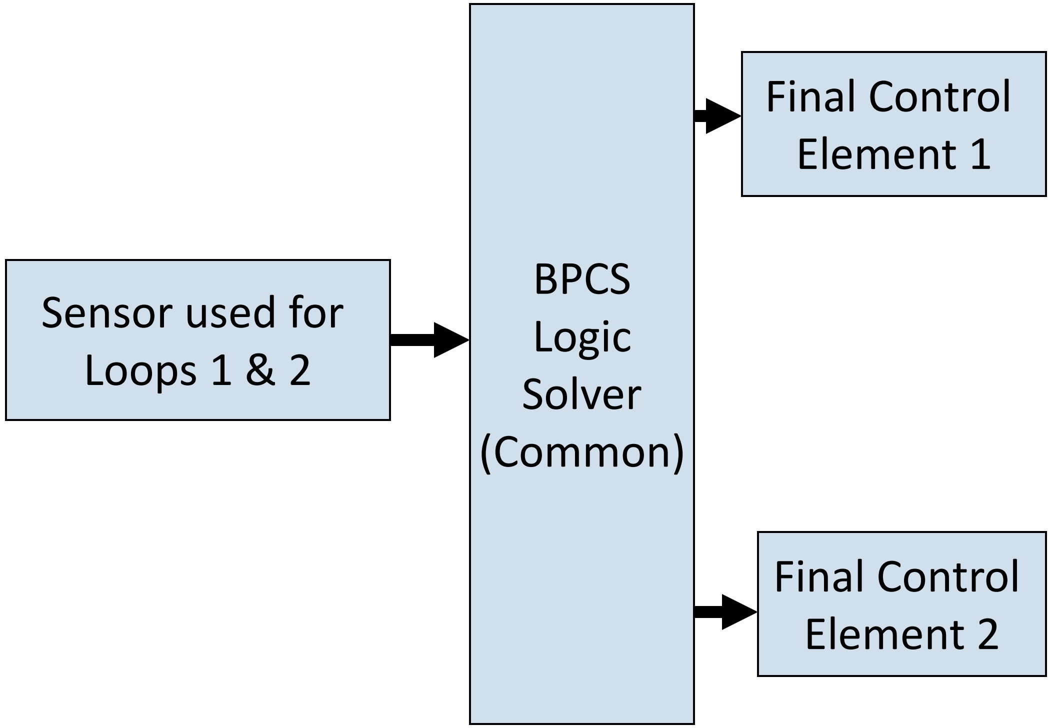
The recommended guidelines for crediting multiple BPCS loops as IPLs for the same scenario are as follows:

- **Backup Power**
  - Must have sufficient capacity for emergency actions.
  - Emergency actions are specified in a written procedure.
  - Backup power is maintained per a written procedure.

- **Verification**
  - Basis must be verified during design.

Multiple IPLs from a single BPCS - Examples

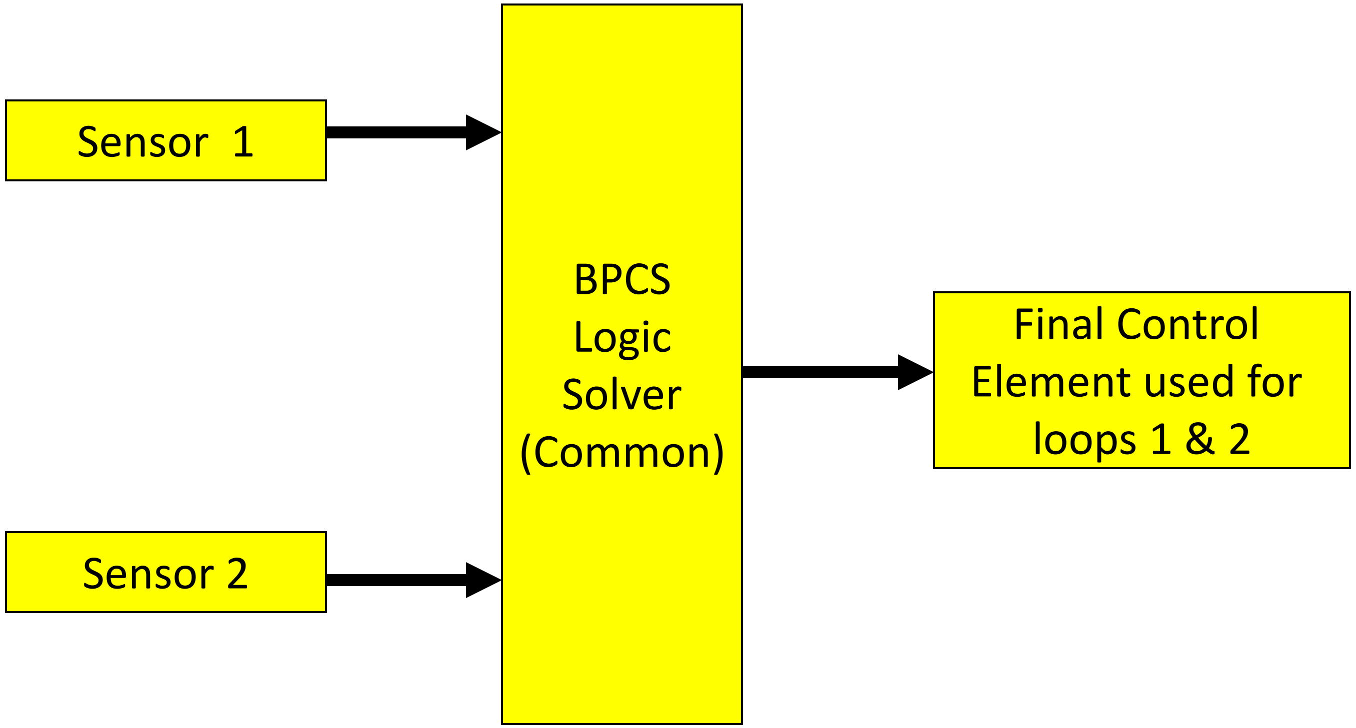
How many levels of BPCS credit can this system achieve?



Our vision: To be a world-class sustainable chemical company making great products for society.

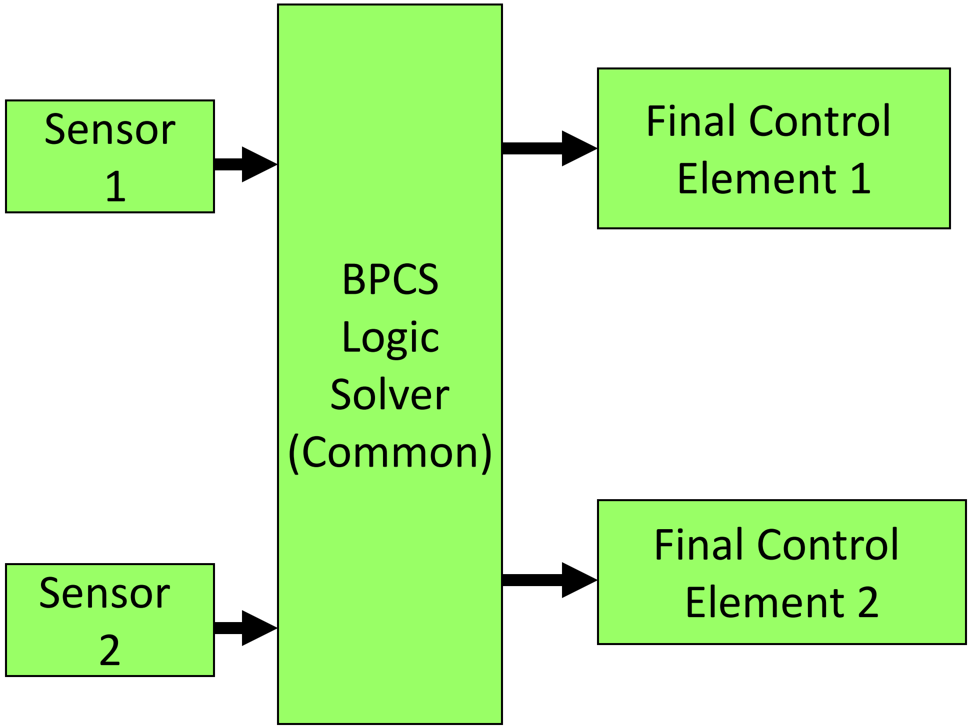
Multiple IPLs from a single BPCS - Examples

How many levels of BPCS credit can this system achieve?



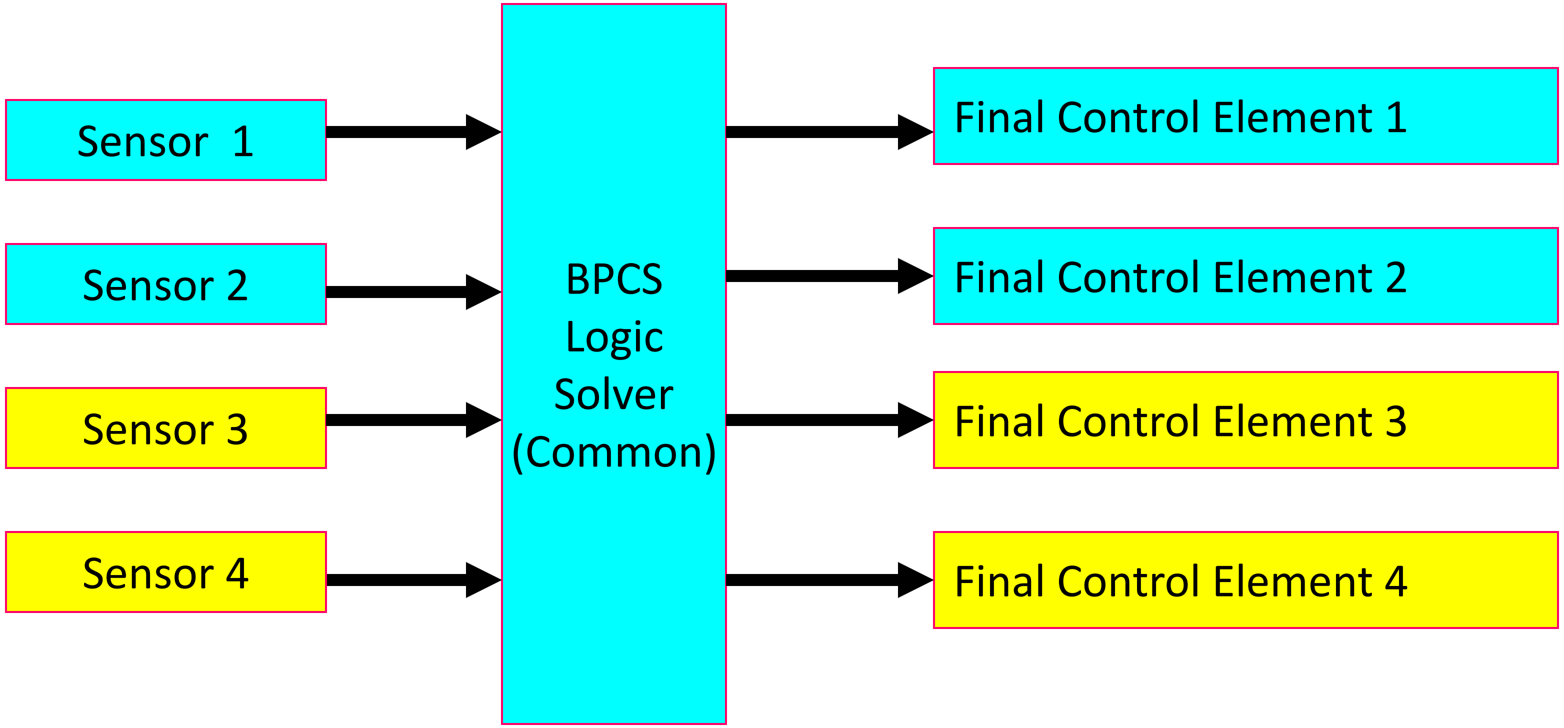
Multiple IPLs from a single BPCS - Examples

<ins>**How many levels of BPCS credit can this system achieve?**</ins>



Multiple IPLs from a single BPCS - Examples

CAN WE COUNT ALL FOUR OF THESE LOOPS AS IPLs?



Questions/Comments