Process Safety Risk Index calculation based on Historian data

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Prasad Goteti

Safety Engineering Consultant

P.Eng, CFSE, TUV (Rheinland) FS Expert

P2SAC
Purdue Process Safety & Assurance Center

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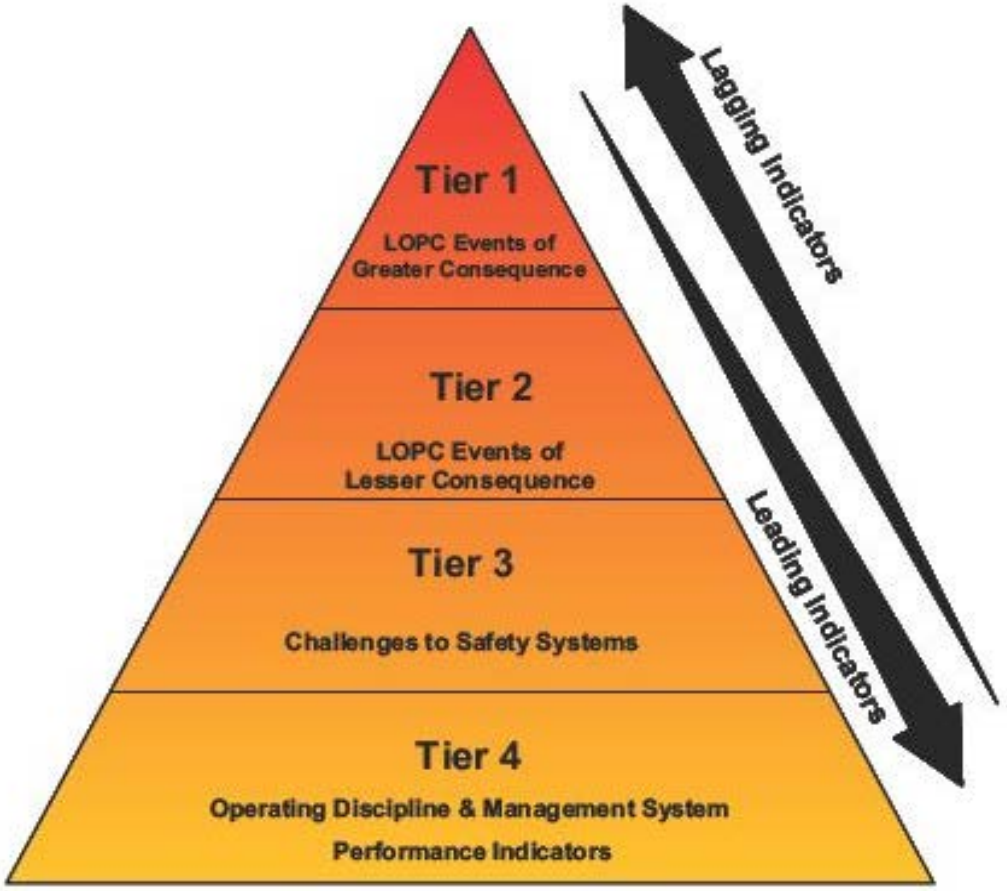
Abstract

- Introduce API RP 754 and ISA 61511
- Briefly walk though the concepts of KPIs, define and explain Leading and Lagging indicators,
- Define Risk Index (Short term and Long term)
- Demonstrate by example how these indices are calculated based on “Design” data and “Real” (Historian) data

API RP 754

- API RP 754 is titled "**Process Safety Performance Indicators for the Refining and petrochemical Industries**", the second edition of which came out in April 2016.
- With reference to Safety life Cycle of ISA 61511, this RP is applicable during the Operation and Maintenance phase.
- The purpose of the Recommended Practice (RP) is to identify leading and lagging indicators in the refinery and petrochemical industries whether for public reporting or for use at individual facilities including methods for the development of Key Performance Indicators (KPI).
- As a framework for measuring activity, status or performance, the RP classifies Process Safety Indicators (PSI) into four tiers of leading and lagging indicators. Tiers 1 and 2 are suitable for public reporting while Tier 3 and 4 are meant for internal use at individual sites.

API RP 754



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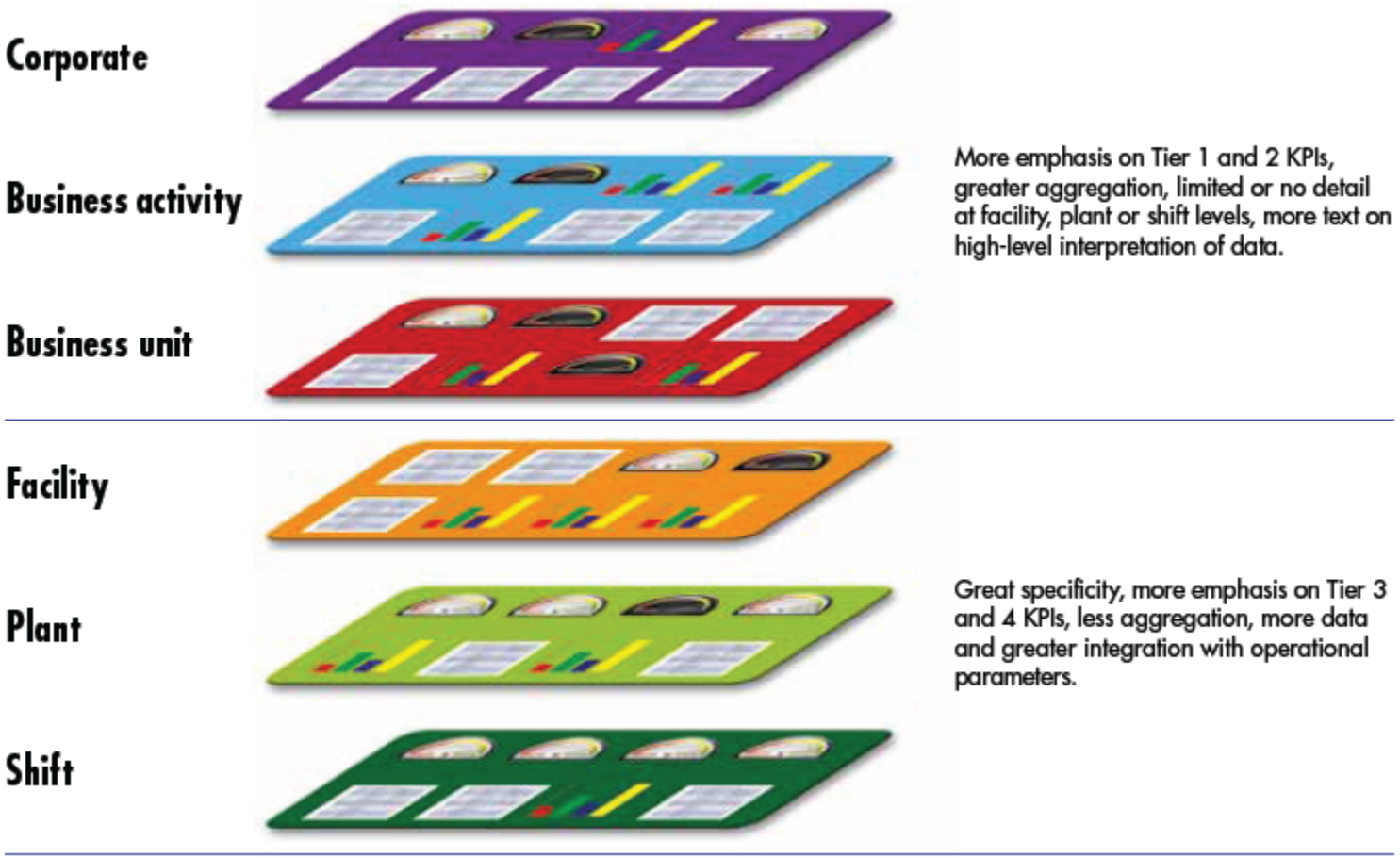
Key Performance Indicators (KPI)



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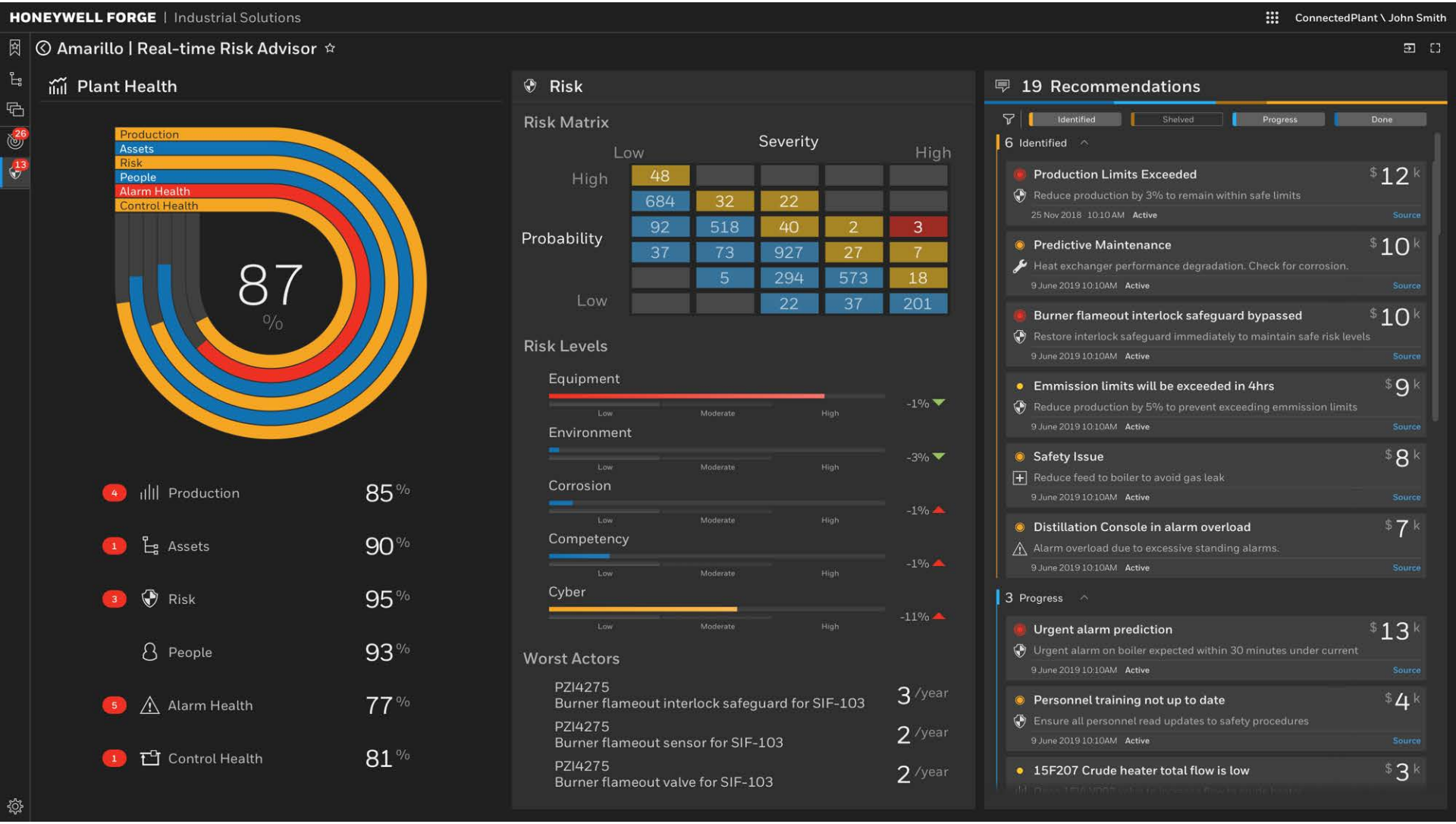
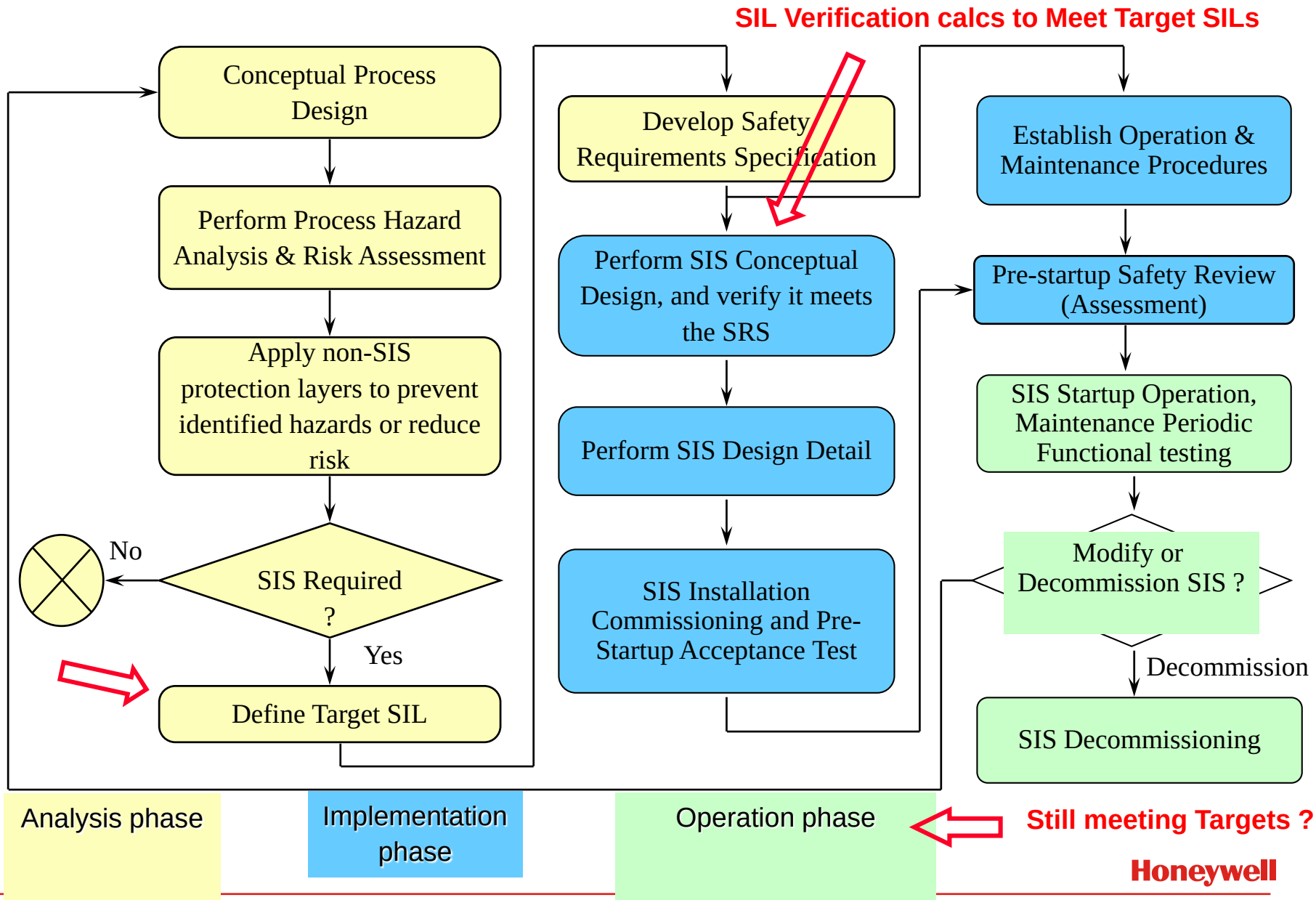
Plant Health % – Opposite of Risk Index



The Safety Life Cycle as defined in ISA61511



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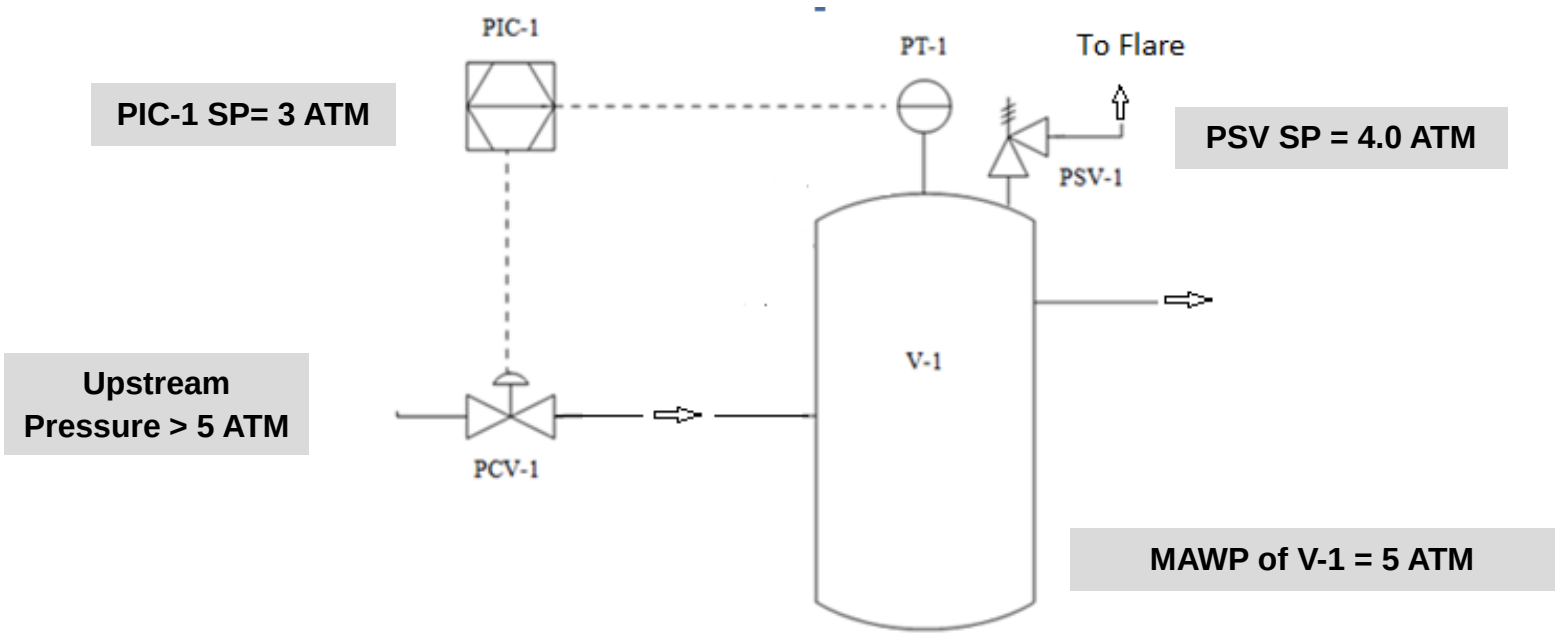
Hazop



- **Node:** Vessel V-1
- **Guideword:** HIGH PRESSURE
- **Consequence:** High Pressure, possible vessel rupture & fire
- **Cause of failure:** PIC-1 (BPCS), Control valve (PCV-1) stuck open
- **Existing Safeguards :** PSV-1
- **Additional Protection Layers :** No recommendation

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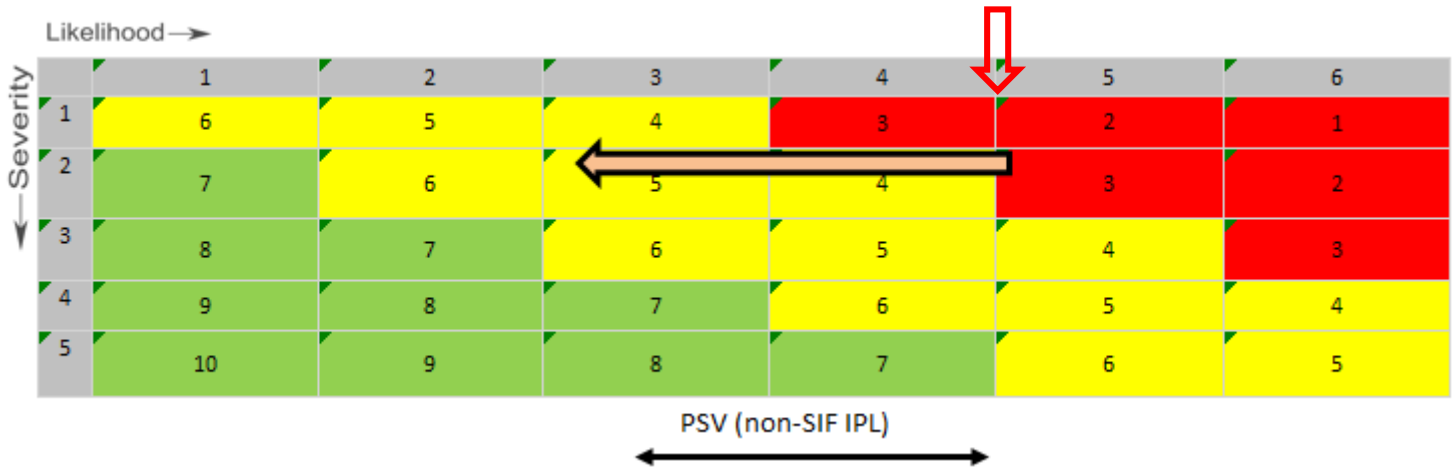
Risk Reduction (with PSV only)

From the HAZOP risk matrix for this Process, with PSV as safeguard :

1. Frequency of Initiating Event (IE) – **(L=3)** (L=5 without any safeguards)
2. Severity – Single fatality **(S=2)**
3. Risk (with PSV as safeguard) = **(Box 5)** (Base Risk without PSV, Box 3)



	Likelihood
1	Once in 10000 years
2	Once in 1000 years
3	Once in 100 years
4	Once in Ten Years
5	Once a year
6	Multiple times per year

	Severity
1	Multiple fatilities
2	Single Fatility
3	Serious injury
4	First Aid
5	First Aid

LOPA TMEL (Single Fatality) :

1E-05 per year

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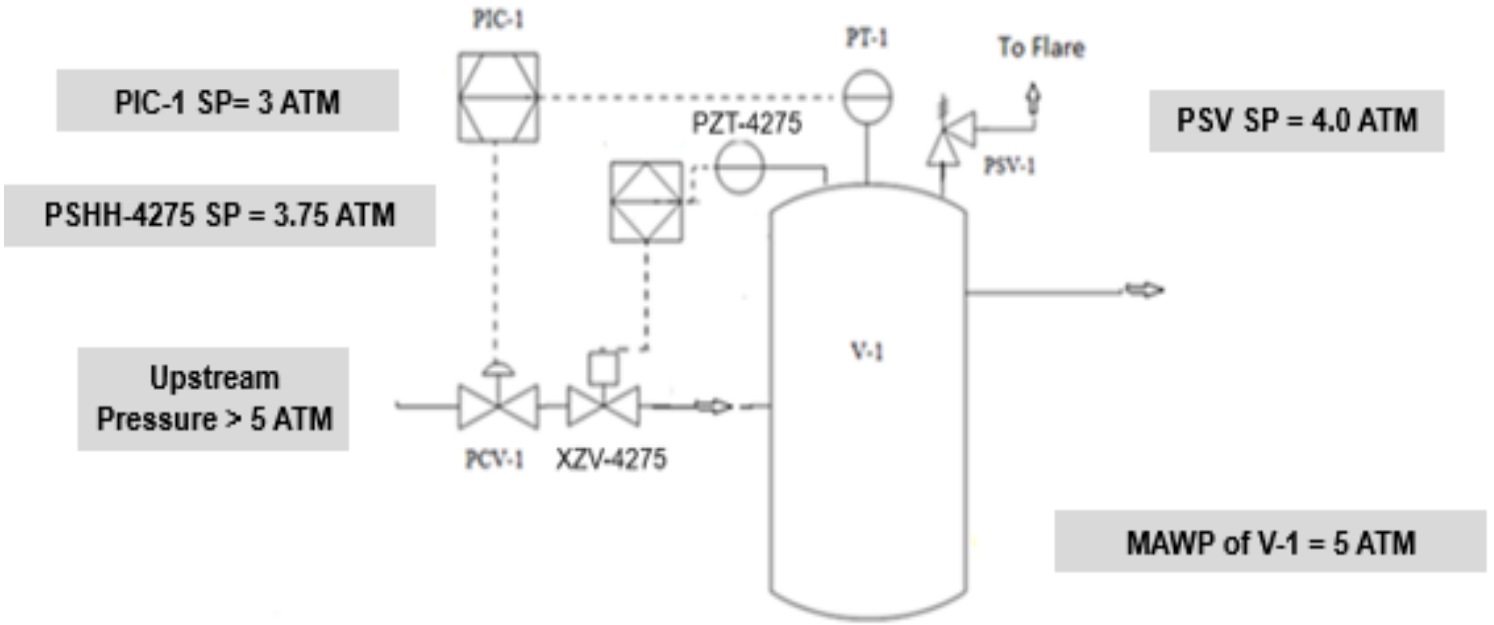
Add a SIF-1 (SIL2, RRF>100)



- High Pressure Trip PSHH-4275 added
  - Shuts off XZV-4275 when PZT-4275 detects Pressure in Vessel V-1 > 3.75 ATM
  - XZV-4275 will be a De-energized To Trip (DTT) Fail Close valve, Open when Pressure is less than 3.75 ATM

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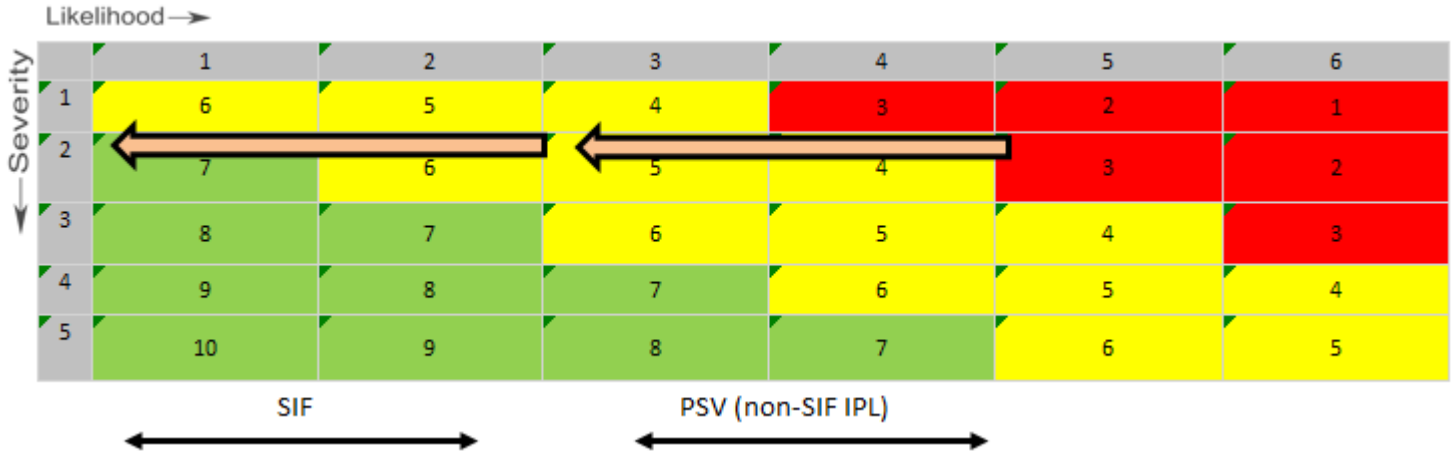
Risk Reduction (with PSV and SIF)

From the HAZOP risk matrix for this Process, with the Two safeguards :

1. Frequency of Initiating Event (IE) – **(L=1)**
2. Severity – **(S=2)**
3. Risk (with Two safeguards) = **(Box 7)** (Acceptable Risk level)



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LOPA TMEL (Single Fatality) :

1E-05 per year

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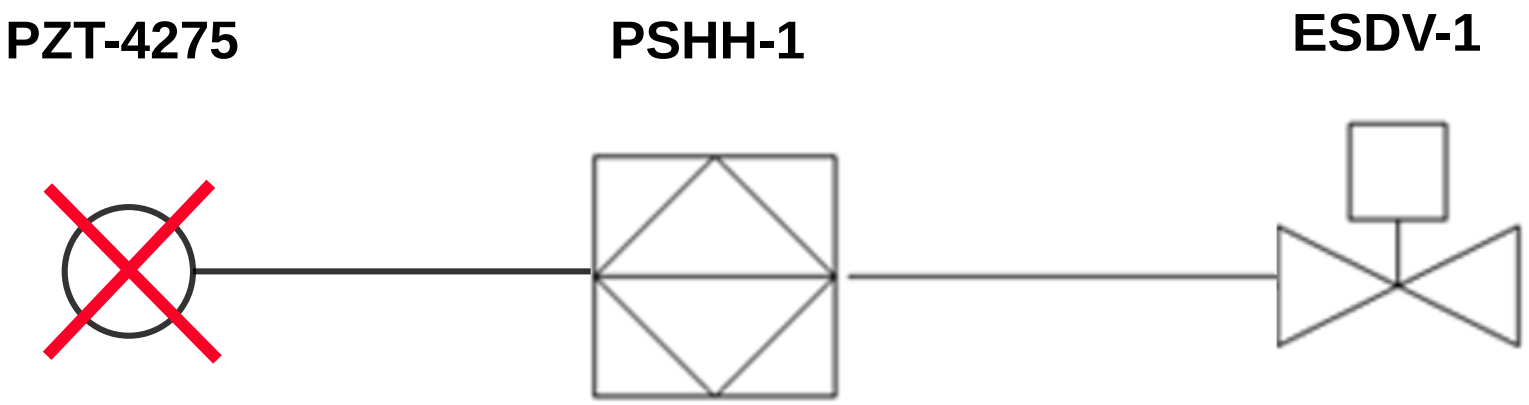
What if PZT-4275 Transmitter is Bypassed ?

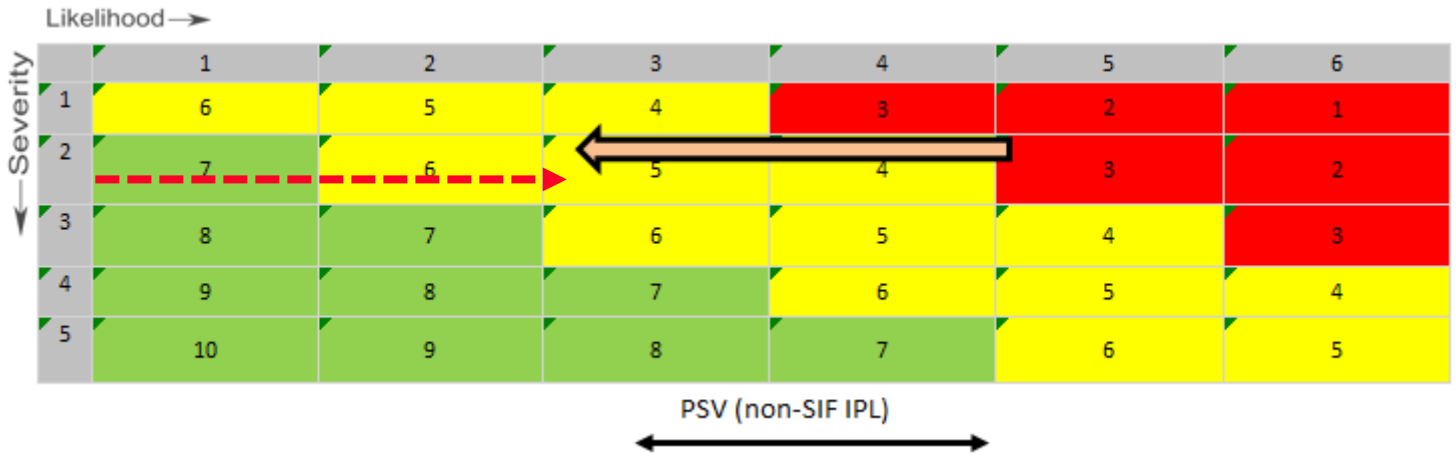


If PZT-4275 is bypassed, then there is no active SIF

Risk Reduction (with SIF in Bypass)

From the HAZOP risk matrix for this Process, if SIF is Bypassed:

1. Frequency of Initiating Event (IE) – **(L=3)**
2. Severity – Single fatality **(S=2)**
3. Risk (with only PSV as safeguard) = **(Box 5)**



	Likelihood
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1	Multiple fatilities
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3	Serious injury
4	First Aid
5	First Aid

LOPA TMEL (Single Fatality) :

1E-05 per year

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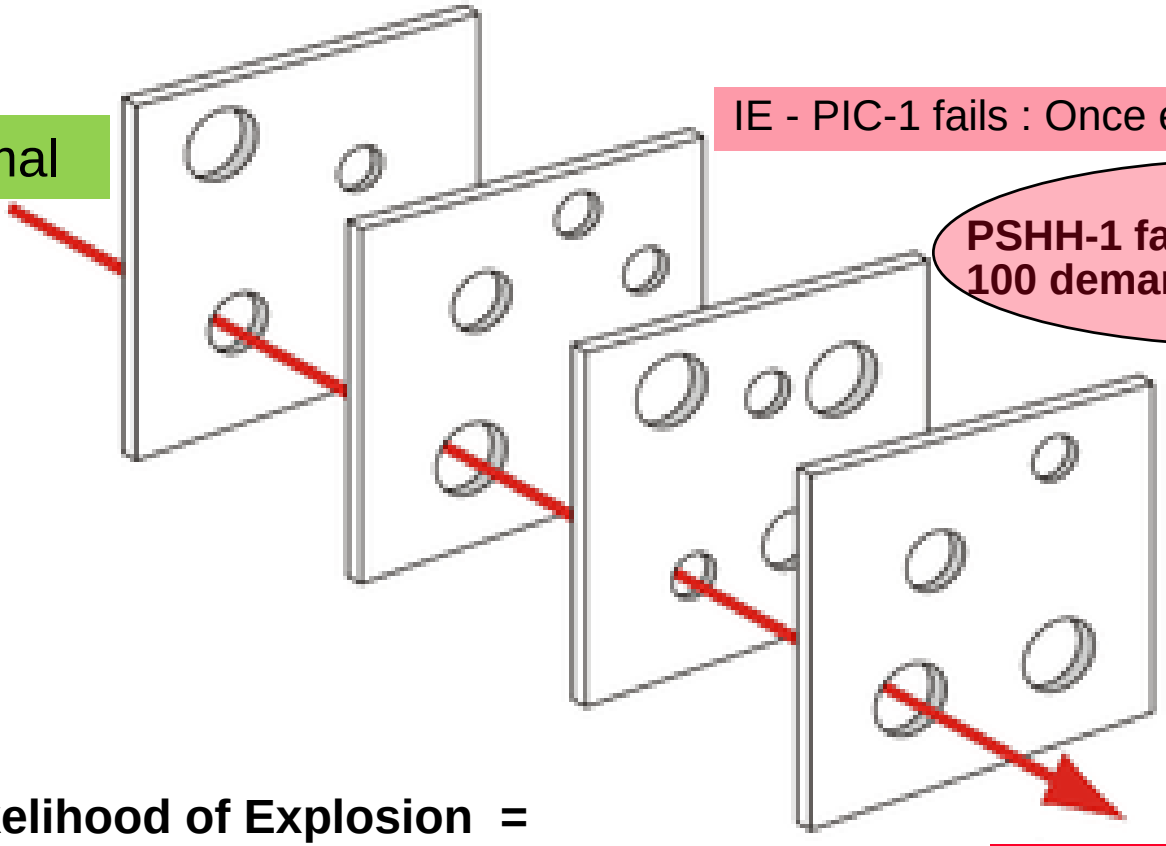
When SIF Not Bypassed

System normal



IE - PIC-1 fails : Once every 10 years (0.1)

PSHH-1 fails : Once every 100 demands (PFD = 0.01)

PSV fails : Once every 100 demands (PFD = 0.01)

Probable Likelihood of Explosion =
PL(Loss Of Containment) x P(Ignition) =
0.1 x 0.01 x 0.01 x 1 = 1E-05 per year = TMEL

Vessel V-1 ruptures and finds a source of ignition (100%)

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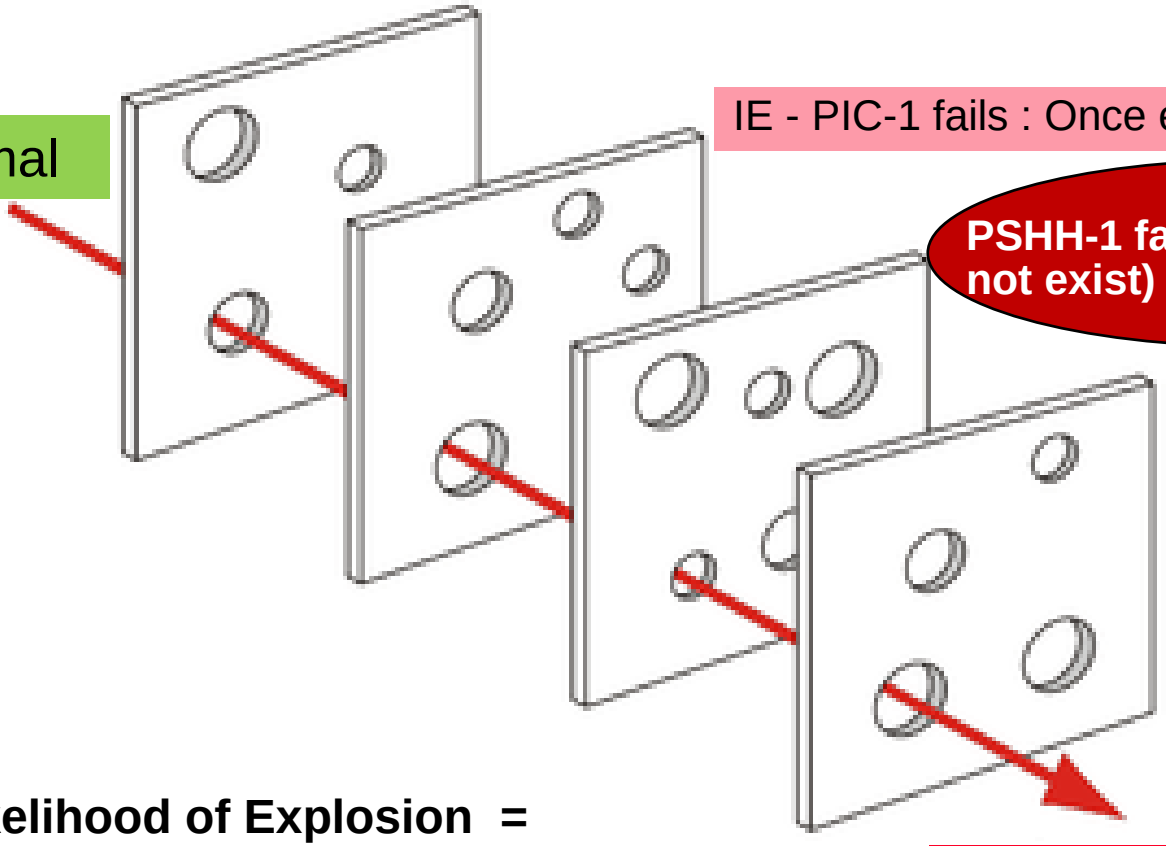
When SIF Bypassed

System normal



IE - PIC-1 fails : Once every 10 years (0.1)

PSHH-1 fails : PFD = 1 (does not exist)

PSV fails : Once every 100 demands (PFD = 0.01)

Probable Likelihood of Explosion =
PL(Loss Of Containment) x P(Ignition) =
0.1 x 1 x 0.01 x 1 = 1E-03 per year > TMEL

Vessel V-1 ruptures and finds a source of ignition (assume 100%, ie 1)

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Process Risk Index (Tier 2 KPI)

- **Process Risk Index (PRI)** is one number which indicates the Process Risk profile of a Process Plant during a small period (Short term) or over a period of time (Long term)

- **Short Term (ST) PRI** is for a period of **One shift or One day**. This is for the Plant Operations Manager to get an idea how their Process plant is doing based **SIFs that have been bypassed**

- **Long Term (LT) PRI** is for a period of a **few months and above**. This is for the senior management (and plant management) to know how the Process plant has been doing in the long term based on **SIF demands, SIF bypass and On Time testing of SIF components**

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Short Term Risk Index

Assumptions for ST Risk Index equations:

- “Safety” is the driver for this hazardous event (not Commercial and Environment)
- PFDactual of SIF and non-SIF IPL is the same as PFD per design
- The SIF has 1oo1 input voting
- All other IPLs are working per design

Variable which effects Short Term (ST) Risk Index

- **SIF “Time in Bypass”** over the Short term period.

This data is collected from the Historian over the specified Short term.

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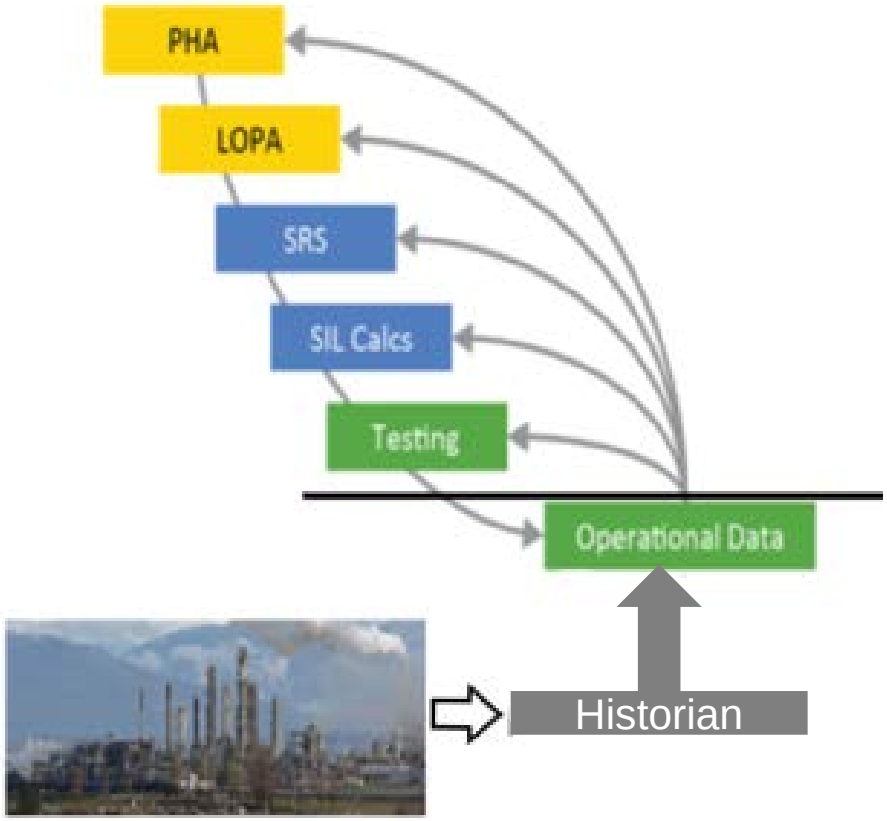
Design and Historian data compared – Short Term



SIF Time in Bypass

Short Term Risk Index (One scenario)

Designed ST Safety Risk = **TMEL (for safety) x Safety Severity**
(the assumption here is that with the designed IPLs, the TMEL has been met)

Actual ST Safety Risk = **IEF x [(PFD of non-SIF IPL x SIF PFD) x (Time SIF NOT in Bypass/SST) + (PFD of non-SIF IPL) x (Time SIF in Bypass/SST)] x Safety Severity**

where :
IEF = Initiating Event Frequency
SST = Short Sample Time

ST Safety Risk Index = **[Log of (Designed Safety Risk/Actual Safety Risk) / Log of Designed Safety Risk)]*100**

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ST Risk Indication calculation (One scenario)

In our example, if SIF-1 input (PZT-4275) in **24 Hours period :**

- **bypassed for 8 Hours**
- SIF design PFD = 4.94E-03

Example for Scenario 1 for SAFETY only :				
	Given	TMEL (safety)	1.00E-05	(once in 100,000 years)
	Given	SI	1	(one fatality)
	Given	SST	24	Hrs
	Consider	IEF	0.1	(once in 10 years)
	Design	non-SIF IPL PFD	0.01	
	Design	SIF PFD	0.00494	
	From Historian	SIF input BYP time Hrs	8	
Designed Risk		1.00E-05		
Log of Designed Risk		-5		
Actual Risk		3.37E-04		
(Designed/Actual) Risk		0.029706		
Log of (Designed/Actual)		-1.52715		
ST Safety RI %		30.54297		

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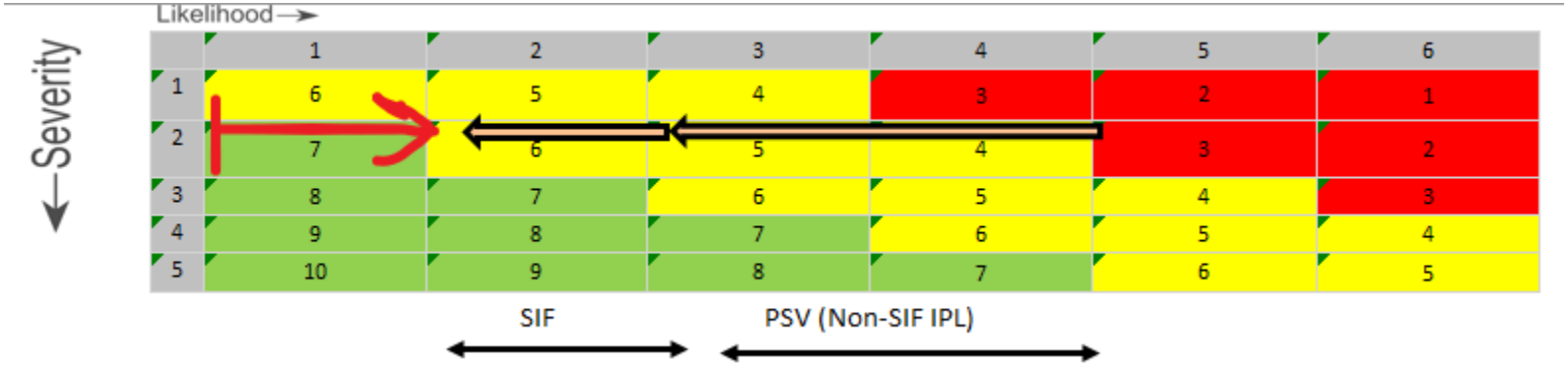
Risk Reduction (Based on ST Risk Index)

From the HAZOP risk matrix for this Process :

1. Short Term sample time : 24 Hours
2. SIF Bypass time : 8 hours
3. **Calculated Safety ST RI = 30% (Approx)**



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3	Serious injury
4	First Aid
5	First Aid

LOPA TMEL (Single Fatality) :

1E-05 per year

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Short Term Risk Index (Multiple scenarios)

Designed ST Safety Risk (Multiple) =
∑ (TMEL (for safety) x Safety Severity)
(the assumption here is that with the designed IPLs, the TMEL has been met for all scenarios)

Actual ST Safety Risk (Multiple) =
∑ (IEF x [(PFD of non-SIF IPL x SIF PFD) x (Time SIF NOT in Bypass/SST) + (PFD of non-SIF IPL) x (Time SIF in Bypass/SST)] x Safety Severity)

where :
IEF = Initiating Event Frequency
SST = Short Sample Time

ST Safety Risk Index (Multiple) = **[Log of (Designed Safety Risk (Multiple)/Actual Safety Risk(Multiple)) / Log of Designed Safety Risk(Multiple))]*100**

Worst actor of ST Safety Risk Index = **Highest ST Safety Risk Index (ONE scenario)**

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Long Term Risk Index

Assumptions for LT Risk Index equations:

- "Safety" is the driver for this haz. event (not Commercial and Environment)
- PFDactual of SIF and non-SIF IPL may not be the same as PFD per design
- The SIF input has 1oo1 input voting

Variable which effects Long Term (LT) Risk Index

- **SIF demand rate**. If this is greater than the assumed IEF, then SIF demand rate will be considered in the "Actual LT Safety Risk" equation
- **SIF "Time in Bypass"** over the Long Term period
- **IPLs On time testing**. If this is different than what was considered during design, then this will effect the PFDactual of the IPLs

This data is collected from the Historian and plant CMMS (Computer Maintenance Management System) over the specified Long term.

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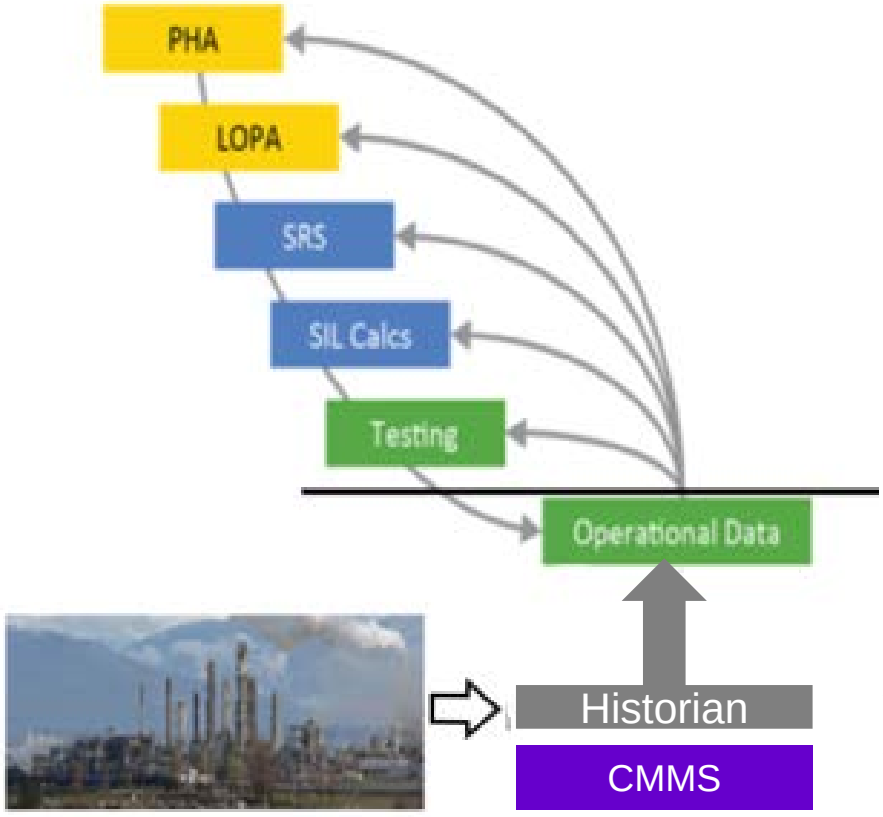
Design and Historian data compared – Long Term



SIF Time in Bypass
SIF Demands
SIF OnTime testing

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Long Term Risk Index (One Scenario)

Designed Long Term Safety Risk = **TMEL (for safety) x Safety Severity**
(the assumption here is that with the designed safeguards,TMEL has been met)

Actual LT Safety Risk = **SIF demands x [(PFDactual of non-SIF IPL x SIF PFDactual) x (Time SIF NOT in Bypass/LST) + (PFDactual of non-SIF IPL) x (Time SIF in Bypass/LST)] x Safety Severity**

where :
SIF demands considered as Initiating Event Frequency if SIF demands > IEF
LST = Large Sample Time
PFDactual (for SIF and IPL) varies based on “Real test intervals” vs “Design Test intervals”

LT Safety Risk Index = **[Log of (Designed Safety Risk/Actual Safety Risk) / Log of Designed Safety Risk)]*100**

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LT Risk Indication calculation (One scenario)

In our example, if SIF-1 input (PZT-4275) in ONE year period :

- bypassed for ONE month
- SIF has ONE demand (design IEF = 0.1 per year)
- SIF PFDactual = 0.1 (design PFD = 4.94E-03)

Example for Scenario 1 for SAFETY only :

Given	**TMEL (safety)**	**1.00E-05**	**(once in 100,000 years)**
Given	**SI**	**1**	**(one fatality)**
Given	**LST**	**10**	**Years**
Consider	IEF	0.1	(once in 10 years)
Design	non-SIF IPL PFD	0.01	
Design	SIF PFD	0.01	
from CMMS	non-SIF IPL PFDactual	0.01	
from CMMS	SIF PFDactual	0.1	
From Historian	SIF input BYP time years	0.083	
From Historian	SIF demands per year	1	

Designed Risk	1.00E-05	(assume working per design)
Log of Designed Risk	-5	
Actual Risk	1.07E-03	
(Designed/Actual) Risk	0.009305	
Log of (Designed/Actual)	-2.03129	
LT Safety RI %	40.62574	

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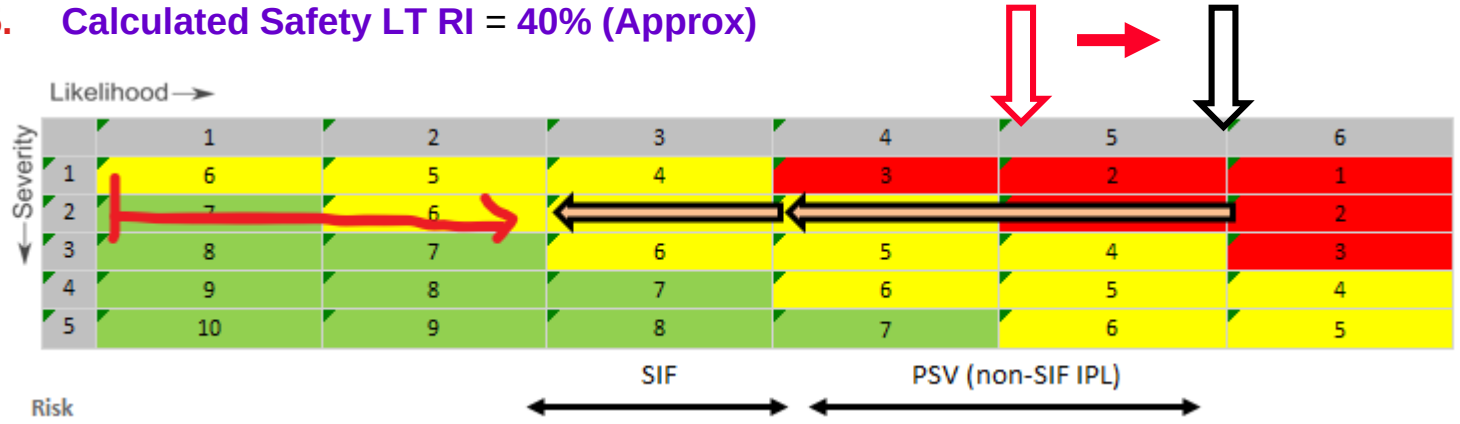
Risk Reduction (Based on LT Risk Index)

From the HAZOP risk matrix for this Process :

1. Long Term sample time : ONE year
2. SIF Bypass time : ONE month
3. SIF demand : ONE demand in ONE year
4. SIF PFDactual = 0.05
5. **Calculated Safety LT RI = 40% (Approx)**



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LOPA TMEL (Single Fatality) :

1E-05 per year

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Long Term Risk Index (Multiple scenarios)

Designed LT Safety Risk (Multiple) =
∑ (TMEL (for safety) x Safety Severity)
(the assumption here is that with the designed safeguards, the TMEL has been met for all scenarios)

Actual LT Safety Risk (Multiple) =
∑ (SIF demands x [(PFDactual of non-SIF IPL x SIF PFDactual) x (Time SIF NOT in Bypass/LST) + (PFDactual of non-SIF IPL) x (Time SIF in Bypass/LST)] x Safety Severity)
Where :
SIF demands considered as Initiating Event Frequency if SIF demands > IEF
LST = Large Sample Time
PFDactual (for SIF and IPL) varies based on “Real test intervals” vs “Design Test intervals”

LT Safety Risk Index (Multiple) = **[Log of (Designed Safety Risk (Multiple)/Actual Safety Risk(Multiple)) / Log of Designed Safety Risk(Multiple))]*100**

Worst actor of LT Safety Risk Index = Highest LT Safety Risk Index (ONE scenario)

Process Plant Safety Risk Index

- **At the Corporate level and Plant level:**

  - **Process Plant Safety Risk Index (Long Term) = LT Safety Risk Index (Multiple)**
  - **Worst actor for Process Plant Safety Risk Index (Long Term) = Scenario with Highest LT Safety Risk Index**
  - This will give Senior management at the corporate an insight on how the plant has been running based on the Long Term safety track record
  - The Long Term Safety Risk Index will help the Plant / Operations Manager to reanalyze risk and take appropriate action based on some of the worst actors which are driving the Safety Risk index up.

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Process Plant Safety Risk Index

- **At the Plant Level only:**

  - **Process Plant Safety Risk Index (Short Term) = ST Safety Risk Index (Multiple)**
  - **Worst actor for Process Plant Safety Risk Index (Short Term) = Scenario with Highest ST Safety Risk Index**
  - The Short Term Safety Risk Index will help the Plant / Operations Manager to decide on maintenance priorities on a shift or day basis

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Current limitations and Path forward

- **The current Risk Index calculator considers :**
  - Only Safety Risk Index as it assumes Safety as the Risk driver
  - Only SIFs in the calculation (not other IPLs)
  - For a SIF only 1oo1 input voting has been considered
  - Only SIF status (Bypassed, Ontime test, Demands)
  - All SIF demands are “Real” demands (not spurious)
- **Path Forward :**
  - Risk Index will be considered for scenarios which are driven by Commercial or Environmental during the HAZOP stage
  - Non-SIF IPL status will also be included (assuming their status is digitally available)
  - SIFs with MooN input voting, where M>=N and N>1, will also be considered
  - Real failure rates of SIF instruments based on collected data

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Conclusion

Process plant Safety Risk Index, both Short and Long term can provide valuable information to both the Corporate and Plant Managers and Engineers.

Based on these Risk Indices, Corporate and plant teams can monitor and improve the Process Safety solutions currently being used in a plant.

…….and hopefully reduces the likelihood of process incidents and increases plant reliability

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Thank You...

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