14th Chemical Process Safety Sharing (CPSS)

Topic: Strengthen Practice
HAZOP & SIL alignment in Tank farm

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TEPS Process Safety Management

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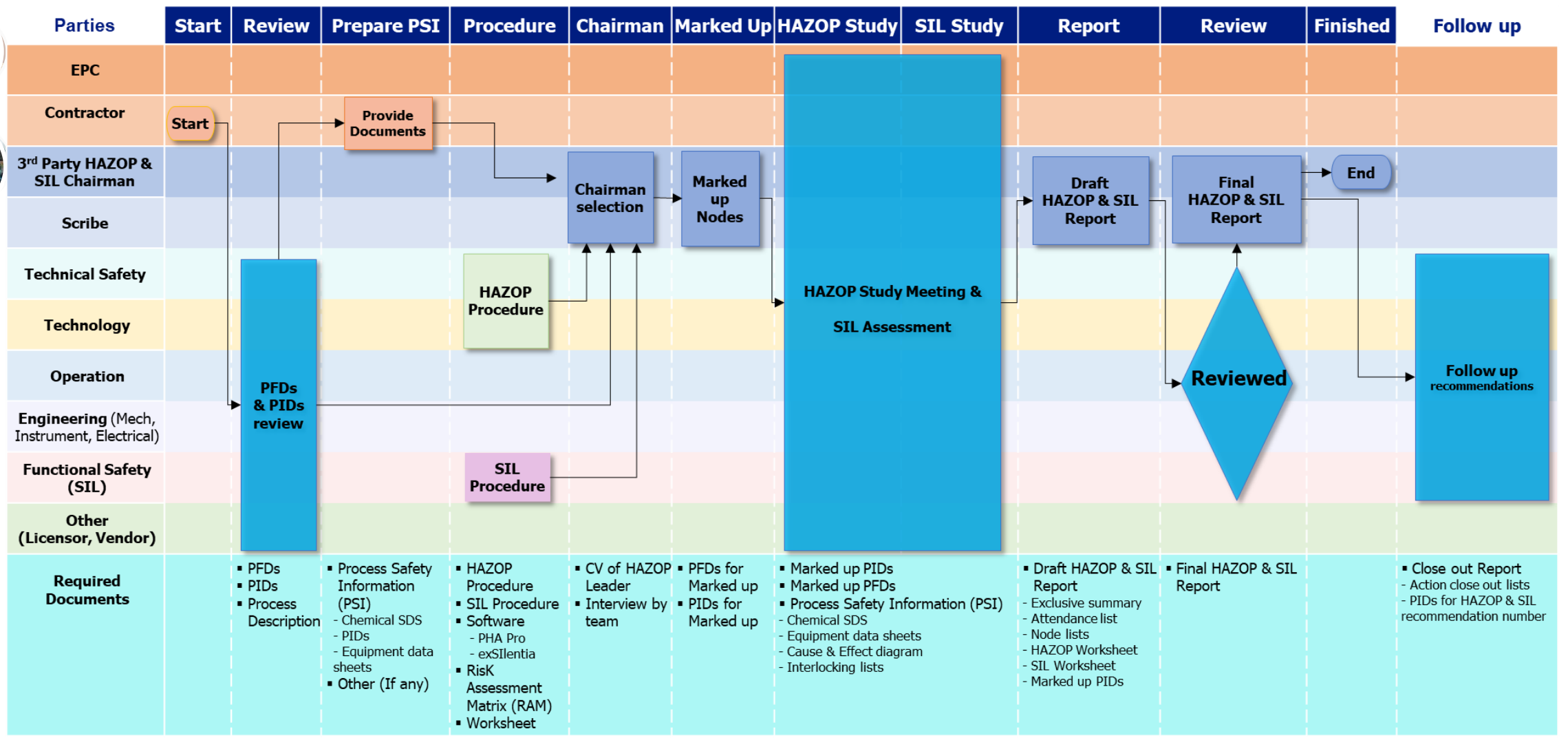
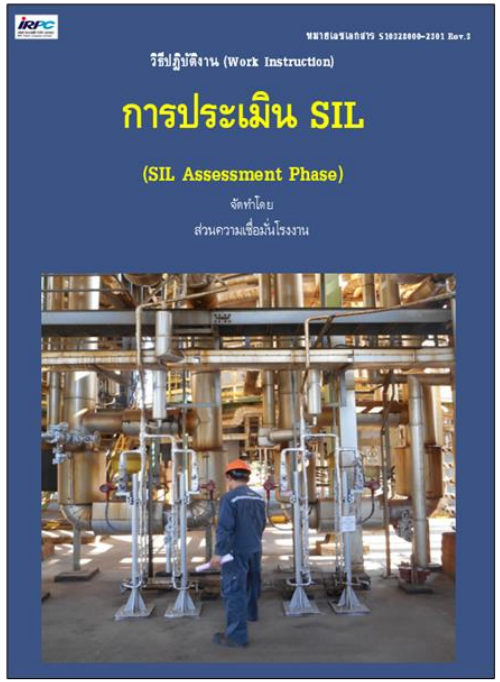
Flowchart of HAZOP & SIL

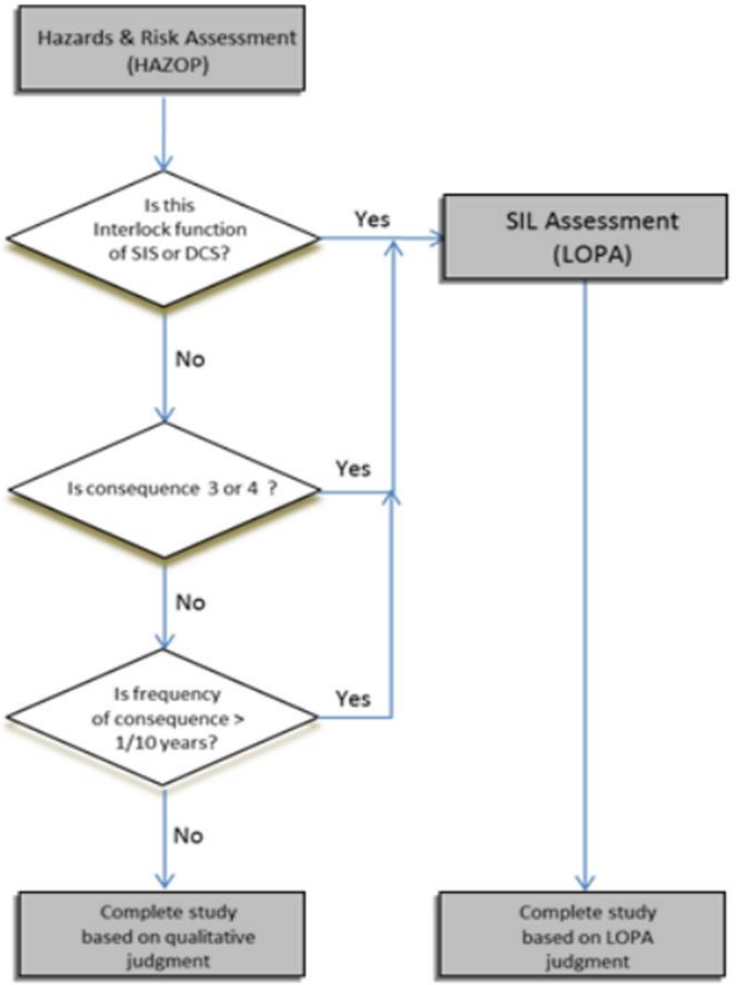


HAZOP & SIL Methodology

HAZOP & SIL Procedure Manual



Flowchart for deciding which risk analysis method to use



HAZOP & SIL Methodology

HAZOP Procedure Manual

HAZOP Deviation Lists

1. No/Less Flow
2. More Flow
3. Reverse Flow
4. Misdirected Flow
5. More Pressure
6. Less Pressure
7. More Temperature
8. Less Temperature
9. More Level
10. Less Level
11. Equipment Trip/ Equipment Failure
12. Utility Failure such as Instrument Air, Power, Steam, Cooling Water, Nitrogen, etc.
13. Heat Exchanger Tube Rupture
14. Contamination
15. Composition Change
16. Exothermic Reactions
17. Corrosion/ Erosion
18. Special Requirement for Start-up / Shutdown
19. Special Maintenance
20. Other

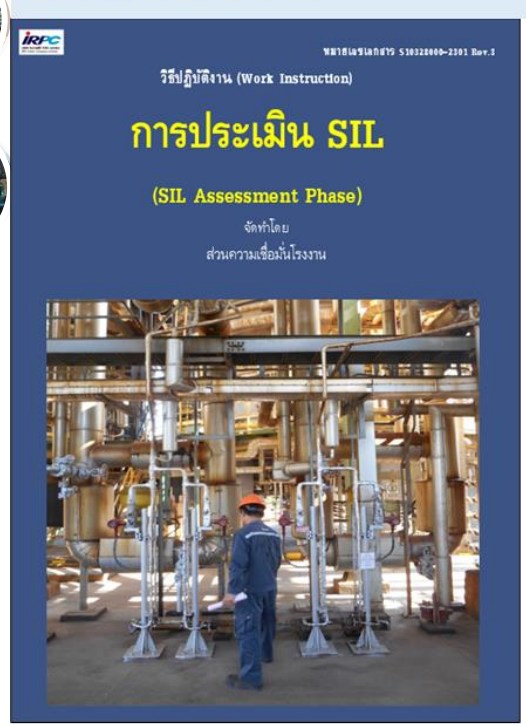
HAZOP Risk Assessment Matrix (RAM)

Sevirity	Frequency or Occurrence			
	(1) Rare	(2)Less	(3)Moderate	(4)High
None(0)				
Minor (1)	1	2	3	4
Moderate (2)	2	4	6	8
High (3)	3	6	9	12
Extreamly high (4)	4	8	12	16

Risk Level	Socre	Description
1	1-2	Minor Risk (No action required)
2	3-6	Acceptable risk but need to review a procedure for control risk (Shall have plan for risk control).
3	8-9	**High risk**, required to have mitigation or additional plan to reduce risk (Shall have plan control and reduce risk)
4	12-16	**Unacceptable risk** required to stop production immidiatly and require to have plan for correction plan inorder to reduce risk (Shall have plan control and reduce risk)

HAZOP & SIL Methodology

SIL Procedure Manual



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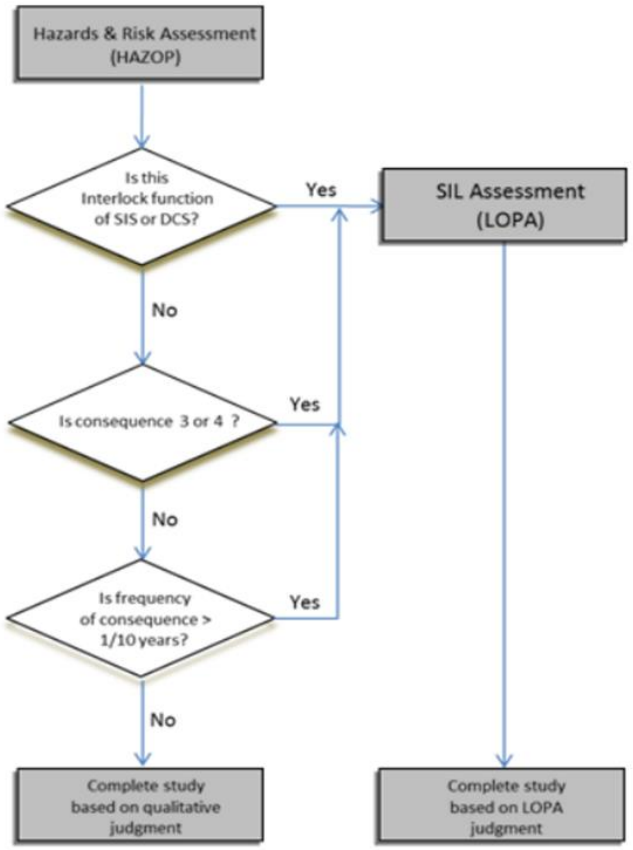
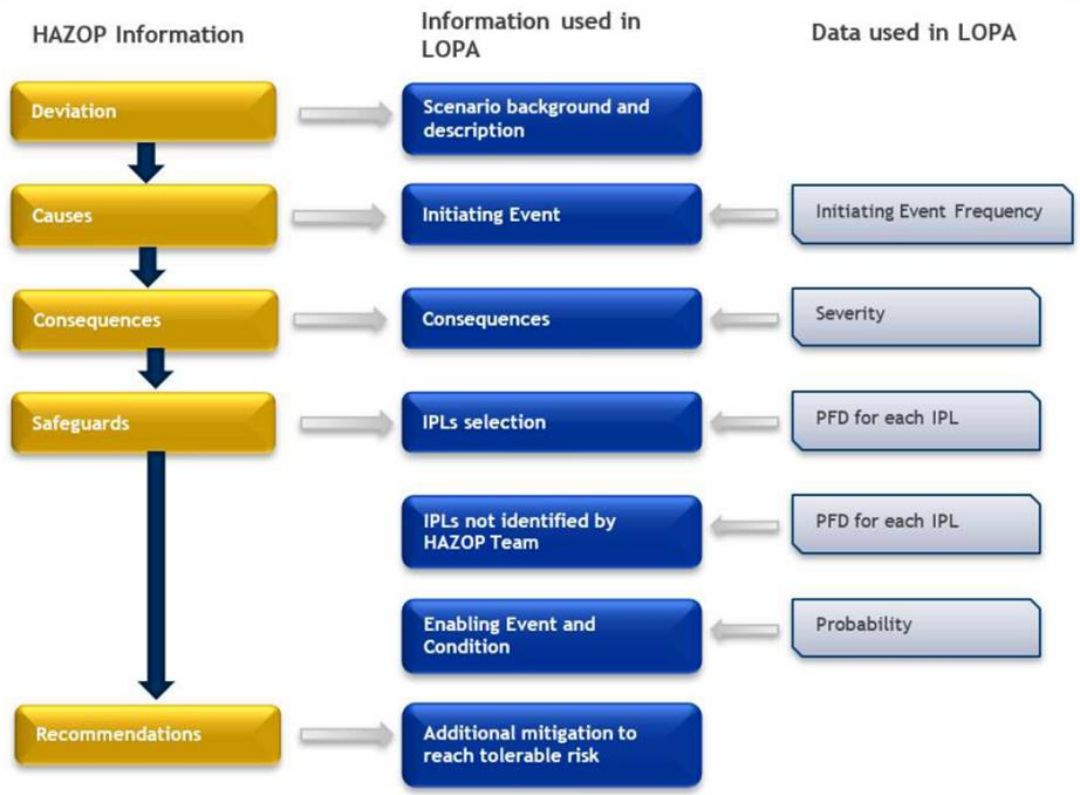


HAZOP & SIL relationship



HAZOP & SIL Methodology

SIL Level

Safety integrity level (SIL)	PFDavg (Average Probability of Failure on Demand) (Low demand mode of operation)
4	$\geq 10^{-5}$ to $<10^{-4}$
3	$\geq 10^{-4}$ to $<10^{-3}$
2	$\geq 10^{-3}$ to $<10^{-2}$
1	$\geq 10^{-2}$ to $<10^{-1}$
a	$\geq 10^{-1}$ to <1
0	≥ 1

Layer of protection analysis using a risk matrix

IEC 61511-3:2016

Severity level and Target Event Frequencies

Severity	People[1]	Assets	Community	Environment	Target Event Frequency (Occurrences per year, per event)
5	**More than 3 fatalities.** Multiple illnesses with irreversible health effects.	**Massive Damage** (>US$100m)	**Massive Effect:** • Persistent, severe impact on livelihood, social and cultural assets, community security, health, Vulnerable or Indigenous Peoples and/or human rights infringements. • Intonational public concern.	**Massive Effect:** Persistent severe environmental damage that will lead to loss of natural resources over a wide area.	1.00E-05
4	**Permanent total disability or up to 3 fatalities.** Serious Injuries. Irreversible health effects.	**Major Damage** (US$10-$100m)	**Major Effect:** • Persistent effects on livelihood and/or social and cultural assets, community health. • National public concern. • National govemment and/or NGO involvement	**Major Effect:** Severe environmental damage that will require extensive measures to restore beneficial uses of the environment.	1.00E-04
3	**Major Injury or health effect** (lost workday or restricted work case, exceeds 5 days duration)	**Moderate Damage** (US$1-$10m)	**Moderate Effect:** • Persistent nuisance. • Local or Regional public concern. • Local stakeholders, e.g., community, NGO, industry and govemment, are aware.	**Moderate Effect:** Limited environmental damage that will persist or require cleaning up.	1.00E-03
2	**Minor Injury or health effect** (Medical treatment case, lost workday or restricted work case, up to 5 days duration)	**Minor Damage** (US$100k-$1m)	**Minor Effect:** • Limited short-term nuisance • Local public concern.	**Minor Effect:** Minor environmental damage, but no lasting effed.	1.00E-02
1	**Slight injury or health effect** (no treatment case or first aid case)	**Slight Damage** (<US$100k)	**Slight Effect:** • Infrequent slight nuisance. • Local public awareness but no dissemble concern	**Slight Effect:** Slight environmental damage contained within the premises.	1.00E-01

Notes
1. Where public injuries or fatalities are involved the target risk frequency should be reduced by a factor of 10 (e.g., 1E-5 becomes 1E-6)

HAZOP & SIL Methodology

Initiating Event

Initiating Event (IE)	Likelihood of Failure (per year)
Pressure vessel residual failure	1×10^{-6}
Piping residual failure – 100m – Full Branch	1×10^{-5}
Piping leaking (10% section) – 100m	1×10^{-3}
Atmospheric tank failure	1×10^{-3}
Gasket / packing blowout	1×10^{-2}
Turbine / diesel engine over speed with casing breach	1×10^{-4}
Third party intervention (external impact by backhoe, vehicle, etc.)	1×10^{-2}
Crane load drop	1×10^{-4} per lift
Lightning strike	1×10^{-3}
Safety valve opens spuriously	1×10^{-2}
Cooling water failure	1×10^{-1}
Pump seal failure	1×10^{-1}
Pump failure*	3.2×10^{-2}
Compressor failure*	2.4×10^{-1}
Unloading / loading hose failure	1×10^{-1}
BPCS instrument loop failure	1×10^{-1}
Regulator failure	1×10^{-1}
Small external fire (aggregate causes)	1×10^{-1}
Large external fire (aggregate causes)	1×10^{-2}
Operator failure (to execute routine procedure, assuming well trained, unstressed, not fatigued)	1×10^{-2} per opportunity
Other initiating events	Develop using experience of personnel

* Based on OREDA Data

Independent Protection Layer (IPL)

Independent Protection Layer (IPL)	Probability of Failure on Demand (PFD, per year)
Basic process control system, if not associated with the initiating event being considered	1×10^{-1}
Relief valve (Clean Service)*	1×10^{-2}
Relief valve (Dirty Service)*	1×10^{-1}
Rupture disc*	1×10^{-2}
Flame / detonation arrestors*	1×10^{-2}
Dike*	1×10^{-2}
Underground drainage system*	1×10^{-2}
Open vent (no valve)*	1×10^{-2}
Fireproofing*	1×10^{-2}
Blast-wall / bunker*	1×10^{-3}
Alarm required human actions within 10 min.	1×10^{-1}
Deluge system	1×10^{-1}
Gas & Fire alarm (when no process alarm is available)	1×10^{-1}
Other events	Use experience of personnel

*Based on the data in "Layer of Protection Analysis" (See Table 6.3 & 6.4 in CCPS)

HAZOP & SIL Methodology

Total Risk

Conditional Likelihood Modifier: Generic Ignition Probabilities

Material released above auto ignition temperature and for pyrophoric material	1
Releases of heavy liquids	0.1
Volatile liquids	0.2
Flammable liquids/gas	0.3

Example : Generic Ignition Probabilities

- Material released above AIT : LPG
- Releases of Heavy Liquids : Lube base oil
- Volatile Liquids :Benzene, Toluene, Xylene
- Flammable Liquids / gas : Naphtha

Conditional Likelihood Modifier: People present

People are present all the time	1
People are present for less than 12 hours per day	0.5
People are present for less than 1 ~ 2 hours per day	0.1

Conditional Likelihood Modifier: People present

- All time : Shifted staff
- Less than 12 Hr./day : Daytime staff
- Less than 1-2 Hr./day : Visitors

HAZOP & SIL Methodology

HAZOP Assumption

- The potential for hazard and operability problems does not exist when the process is operating within its design envelope.
- Everything is running well and then "SOMETHING" happens.
- HAZOP study looks at all of these "something" scenarios and analyses them (what can result, how do we know, how do we prevent and protect).
- Plant will be well maintained and operated in accordance with sound, internationally acceptable standards.
- Equipment or machinery is designed, manufactured and properly inspected with no defect and deemed suitable for design conditions
- Mechanical protection devices (PSV, rupture disc, etc.) are expected to function on demand
- Single check valve is adequate to prevent backflow, unless reverse flow/pressure may cause upstream pressure to exceed piping test pressure.
- Global utility failures (e.g. IA, PA, electrical power, steam, cooling water or N2) shall be discussed separately from the studies for the respective nodes (sub-systems). Local failure associated with control valve failures to each will be examined one by one at each HAZOP node.
- Malfunction of control valve (e.g.TV-XXXX malfunction closed) is caused by any failure in control loop including sensing element failure, transmitter failure, controller failure, actuator failure, valve itself failure, etc.

The followings will not be considered in HAZOP;

- Simultaneous occurrence of two unrelated incidents, or simultaneous failure of more than one independent protection devices (double jeopardy)
- External fire
- Failure of safety devices (e.g. PSV failure, Closure of ESD valve)
- Operator's negligence (except common human error)
- Natural event (flood, earthquake) except where it is a design case
- Sabotage

SIL Assumption

1) Proper operating, maintenance and inspection procedures are available and adhered to.

2) Critical spares (such as parts for or complete pot counted pumps, spare rotor for compressors) are available on-site to ensure short turnaround times.

3) Proper mechanical maintenance and inspection are carried out to ensure mechanical integrity of equipment and piping.

4) After fire or other incident that requires authorities to witness any inspections, the representatives of the authorities are available locally within 24 hours.

5) Pressure Safety Valves (PSVs) are assumed to be fully sized and provide adequate protection against overpressure. It is assumed that the Probability of Failure on Demand (PSV fails to open when required) is 0.01 and therefore could reduce the SIL of the SIF by 2.

6) If PSV opens, it is assumed that the PSV will need to be removed and overhauled at the workshop for re-certification. Turnaround time is assumed to be 8 hours.

7) Default dangerous failure rate for an initiator or final element is assumed to be "once in the lifetime of the plant". A different (higher or lower) dangerous failure rate could be used if there are specific failure rate data available or from applicable experience.

8) Cost of repair (including parts & labour) is assumed to be negligible compared to downtime.

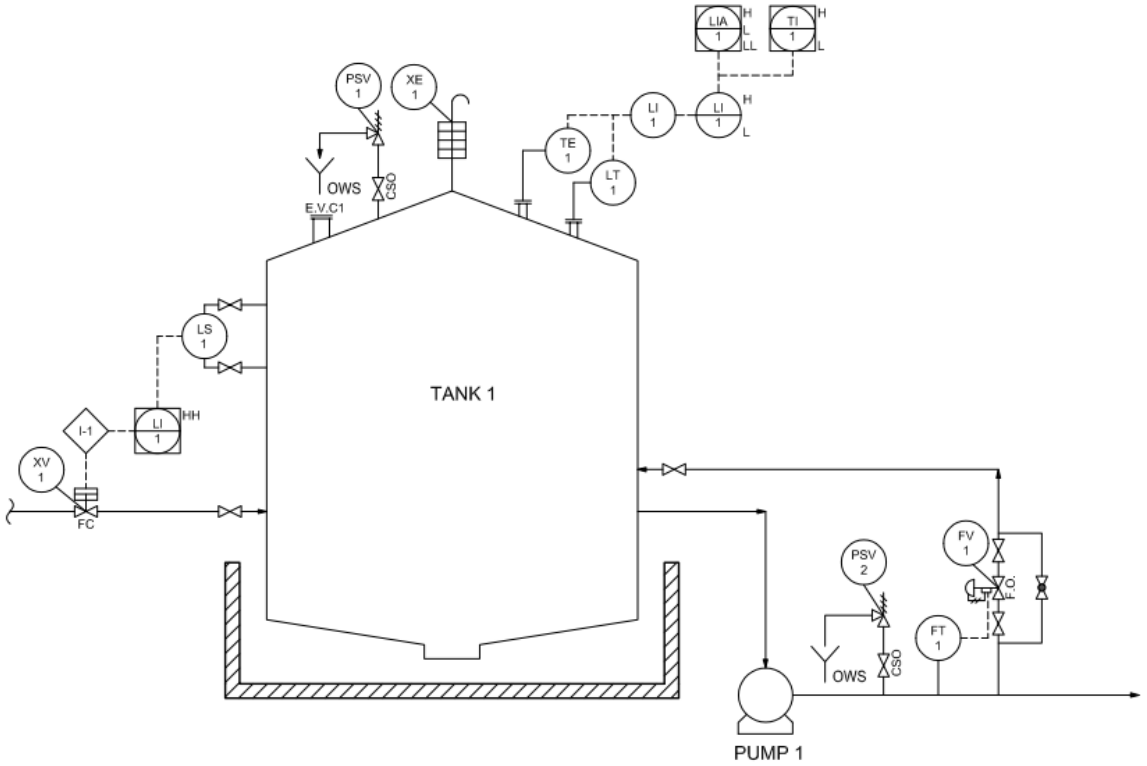
9) For release (both flammable & toxic) as a result of SIF failure on demand, that is routed safely to a safe location, it is assumed that there will be no danger to personnel.

10) For release (both flammable & toxic) as a result of SIF failure on demand, that is not routed safely to a safe location or released at a non-safe location, it is assumed that there will be substantial danger to personnel. It is therefore assumed that personnel present within a 25-meter radius will be injured fatally. The number of people likely to be present at a given time is to be estimated during the SIL Classification Study meeting.

11) The complex is assumed to shut down every five-year for turnaround.

HAZOP & SIL Performing

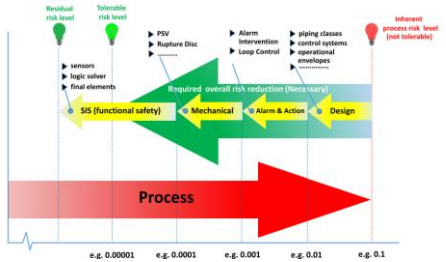
Example: Marked up PIDs for HAZOP & SIL



Deviation	Cause	Possible Consequence	Existing Safeguards	Owner RAM				Actions Required	Actions By	Remark
				L	S	R	RL			
More Level	Failure of level indication (LT-1, ATG)	High level in Tank-1 and overfilling to atmosphere. Potential fire if ignited and injury of personnel	LSHH-1 initiates I-1 to close XV-1	1	4	4	2	-	-	-

HAZOP & SIL Performing

SIF	Consequnce						Frequency		UEF (events per yr)	Independent Protection Layers				MEF (events per yr)	LOPA GAP	LOPA Recommendations
	HAZOP Consequence	CAT	S	TEF (events per yr)	Conditional Modifier		Initiating Event	Freq. (events per yr)		IPL Description	Types of IPLs	PFD	Tatal PFD for all IPLs		Target SIL Level	
					Description	Prob										
LSHH-1 (1oo1, I-1)	High level in Tank-1 and overfilling to atmosphere. Potential fire if ignited and injury of personnel	People	4	1.00E-04	1. Ignition probability	0.30	1. Failure of level indication (LT-1, ATG)	1.00E-01	1.50E-02	1. N/A	No IPLs	1.00E+00	1.00E+00	1.50E-02	SIL 2	Add layer of protection such as 1. SIF (SIL1) and level alarm high 2. Add SIF (SIL2)
					2. Presence of personnel	0.50										
		Asset	3	1.00E-03	1. Ignition probability	0.30			3.00E-02					3.00E-02	SIL 1	



How to improvement ?

LSHH-1 (1oo1, I-1) 1 ✓	High level in Tank-1 and overfilling to atmosphere. Potential fire if ignited and injury of personnel	People	4	1.00E-04	1. Ignition probability	0.30	1. Failure of level indication (LT-1, ATG)	1.00E-01	1.50E-02	1. LAH	alarm and operator action	1.00E-01	1.00E-01	1.50E-03	SIL 1	
					2. Presence of personnel	0.50										
		Asset	3	1.00E-03	1. Ignition probability	0.30			3.00E-02					3.00E-03	SIL a	

LSHH-1 (1oo1, I-1) 2 ✗	High level in Tank-1 and overfilling to atmosphere. Potential fire if ignited and injury of personnel	People	4	1.00E-04	1. Ignition probability	0.30	1. Failure of level indication (LT-1, ATG)	1.00E-01	1.50E-02	1. Dike	Additional Mitigation, Restricted Access	1.00E-02	1.00E-02	1.50E-04	SIL a	
					2. Presence of personnel	0.50										
		Asset	3	1.00E-03	1. Ignition probability	0.30			3.00E-02					3.00E-04	No SIL	

Key takeaways

- HAZOP & SIL shall be alignment
- SIL team shall join PHA in early stage (FEED Phase)
- How to manage Hazards and risk management
- HAZP & SIL shall be developed in technical competency

Key Person for strong one team

Mr. Chaiyot Seeanukul

HAZOP Chairman

Mr. Taweesak Tipnak

SIL Champion

Mr. KASANA Lajarochana

Technical Safety /Facility Siting / QRA

Chemical Process Safety Sharing

THANK YOU

" Process Safety is everyone Responsibility in everyday "

IRPC SHAPE WHAT'S GOOD FOR TOMORROW