SAFETY:
FREEDOM FROM
UNACCEPTABLE
RISK

Boiling Liquid Expanding
Vapor Explosion (BLEVE)

Flash Fire

Jet Fire

Pool Fire

Fireball

HAZOP, SIL and LOPA Course

Prepared by: Sadra Khoshbazm

Kermanshah Polymer Company

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Content

- Section 1: Protection Layers
- Section 2: Introduction to P&ID document
- Section 3: HAZOP Study
- Section 4: SIL Study (LOPA Method)

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Main References

Reference	Title
IEC-61511 part 1-3	Functional safety – Safety instrumented systems for the process industry sector.
IEC-61508 part 5	Functional Safety of Electrical/Electronic/Programmable Electronic (E/E/PE) Safety Related Systems.
CCPS	Layer of Protection Analysis - Simplified Process Risk Assessment.
OREDA	Offshore Reliability Data Handbook-2002.
GS-EP-SAF-041	Technological risk assessment methodology

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Course in a Glance

Layers of Protection

P&ID → HAZOP → SIL (LOPA)

Also other Studies such as:

- RAM (Reliability, Availability and Maintainability)
- QRA (Quantitative Risk assessment)

are P&ID base.

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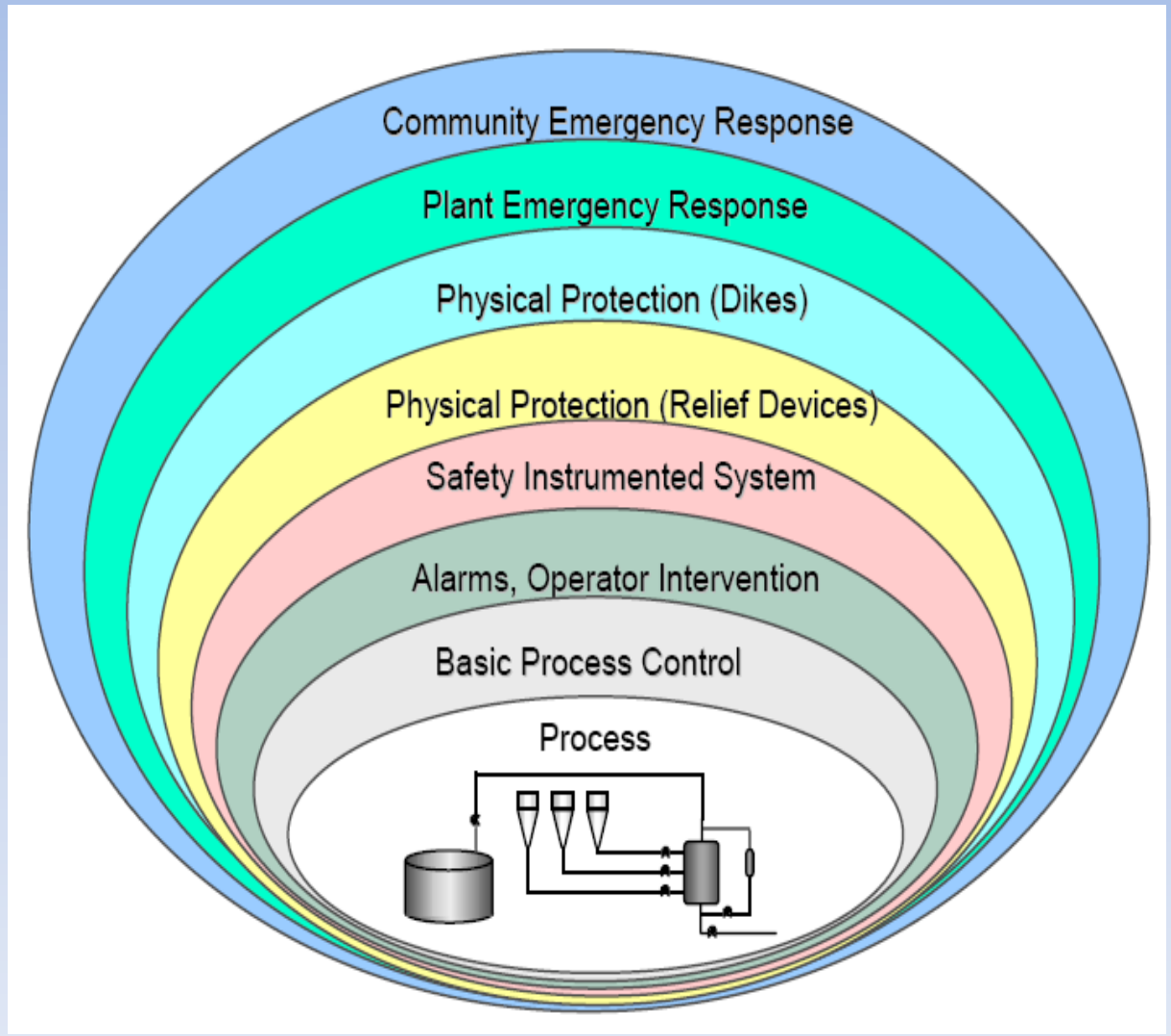
Section 1

Protection Layers



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1st Layer: Process Design

➢ Process Design (Inherently Safe Design):

- Design of wellhead and flow lines for maximum shut-in pressure of wellhead
- Design of compressor suction line for settle out pressure, etc.
- Batch size might be limited
- Inventory lowered
- Chemistry modified
- etc.

Video

Question:

which principles (minimization, substitution, moderate, simplicity) of inherently safe design could be study and recommended in HAZOP?

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2st Layer: Basic Process Control Systems

- The first level of protection during normal operation.
- Composed of Measuring Means (Sensor + Transmitter), Logic Solver (Controller) and Final element (e.g. Valve+ actuator)
- The failure of the BPCS can be an initiating event or cause.
- Flow, Pressure, Temperature and Level are most importance process variables which control by BPCS.
- BPCS **cant** prevent all process upsets so needs other safeguards such as shutdown system to prevent hazardous situation

Video

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3rd Layer: alarms, Operator Interventions

- Second level of protection during normal operation
- Alarm has an annunciator and visual indication
- No action is automated!
- require analysis by a person - A plant operator must decide.
- Digital computer stores a record of recent alarms

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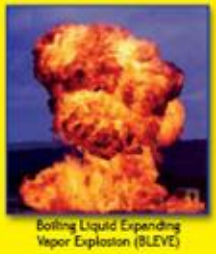
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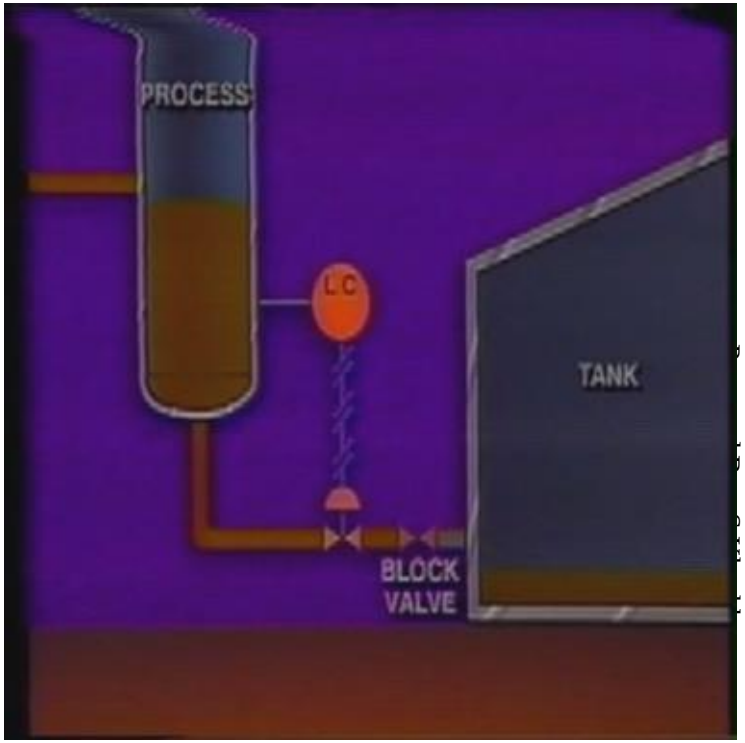
4th Layer: Safety Instrumented Systems

Hazardous Scenario:

1) Block valve closed
2) BPCS opens but cant prevent high level
3) So we need another safeguard such as shutdown system to prevent very high level
4) Shutdown system could be a independent LT that close a SDV on inlet line to column when level is very high.



Questions:
How much shutdown system should be reliable?
How much money to be spent for buying shutdown system?

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4th Layer: Safety Instrumented Systems

- SIS را می توان به صورت "سیستم ابزار دقیق ایمنی" ترجمه نمود و عبارت است از یک سیستم متشکل از سنورها، کنترلر های منطقی و اجزای نهایی با هدف این که در زمانی که از شرایط نرمال فرایندی انحراف به وجود بیاید (که بتواند آسیبی به سیستم برساند) فرایند را به صورت اتوماتیک به شرایط ایمن برساند.
- به طور کلی از مصداق های SIS (در صنایع فرایندی) می توان به موارد زیر اشاره نمود:

- Emergency Shutdown System (ESD) / Shutdown System (SD)
- High Integrity Protection System (HIPS)
- Burner Management System
- Fire and Gas System (F&G)

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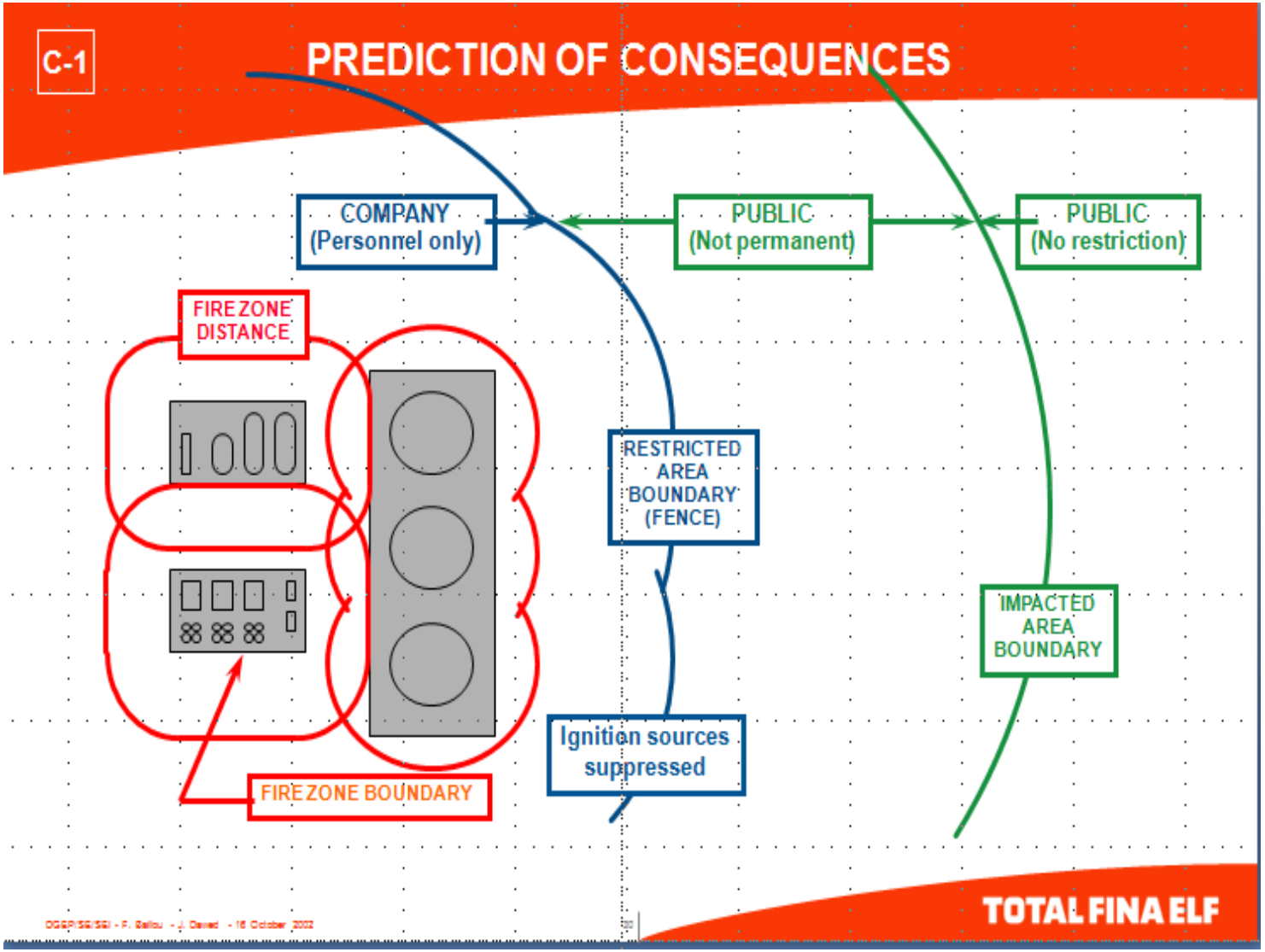
4th Layer: Schematic of Restricted Area/ Fire Zone / Unit/ equipment



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4th Layer: Shutdown Levels

Generally 4 Levels:

- ESD Levels :
  - ESD 0 (Restricted Area)
  - ESD 1 (Fire Zone)
- SD Levels :
  - SD 2 (Unit)
  - SD 3 (equipment)

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4th Layer: Shutdown Levels

CAUSES	SHUT-DOWN TYPE			
Push button	ESD-0	ESD-1	SD-2	SD-3
ESD-0 (direct action)		ESD-1		
Gas detection in tech. room		ESD-1		
Outdoors gas detection		ESD-1		
Outdoors fire detection		ESD-1		
Low UPS battery voltage		ESD-1		
ESD-1 (direct action)			SD-2	
Relevant process fault			SD-2	
Loss of containment			SD-2	
LSHH flare KO drum, PSLL air			SD-2	
Low fuel gas pressure			SD-2	
SD-2 (direct action)				SD-3
Equipment Fault				SD-3
Fire detection inside package				SD-3
Gas detection inside package				SD-3

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5th Layer: Physical Protections (Pre-release Protection)

1) **Pressure Safety/Relief Valve**

Safety Valve is a one type of valve that automatically actuates when the pressure of inlet side of the valve increases to a predetermined pressure, to open the valve disc and discharge the fluid (steam or gas) ; and when the pressure decreases to the prescribed value, to close the valve disc again.

Video

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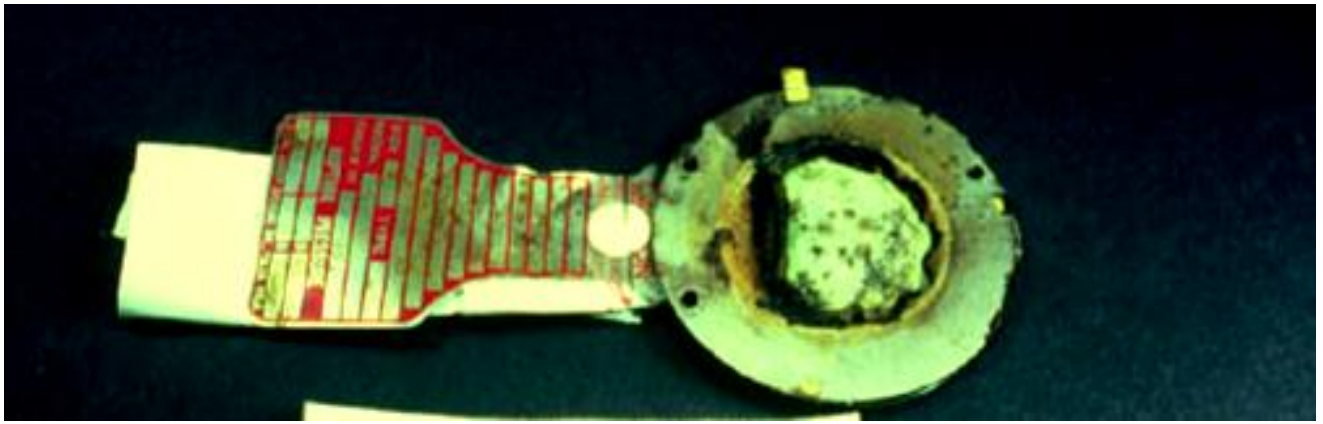
5th Layer: Physical Protections (Pre-release Protection)

2) **A rupture disc** is a thin diaphragm (generally a solid metal disc) designed to rupture (or burst) at a designated pressure. It is used as a weak element to protect vessels and piping against excessive pressure (positive or negative).



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6th Layer: Physical Protection (Post release Protection)

- Passive devices which provide a high level of protection if designed and maintained correctly.
- **Passive fire protection** such as firewall, blast wall, fireproofing, dike, etc.
- **Active fire protection** such as automatic deluge systems, foam systems, or gas detection systems, etc.

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7th Layer: Plant Emergency Response

- E.g. fire brigade, facility evacuation ,etc.

- are not normally considered as IPLs since they are activated after the initial release and there are too many variables (e.g., time delays) affecting the overall effectiveness in mitigating a scenario.

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8th Layer: Community Emergency Response

- E.g. evacuation, shelter in place

- are not normally considered as IPLs since they are activated after the initial release and there are too many variables (e.g., time delays) affecting the overall effectiveness in mitigating a scenario.

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Prevention Layers vs. Mitigation Layers

- Which layers can prevent release of fluid from an equipment?
- Which layers can mitigate effects of release from an equipment?
- Which layers to be considered in HAZOP?

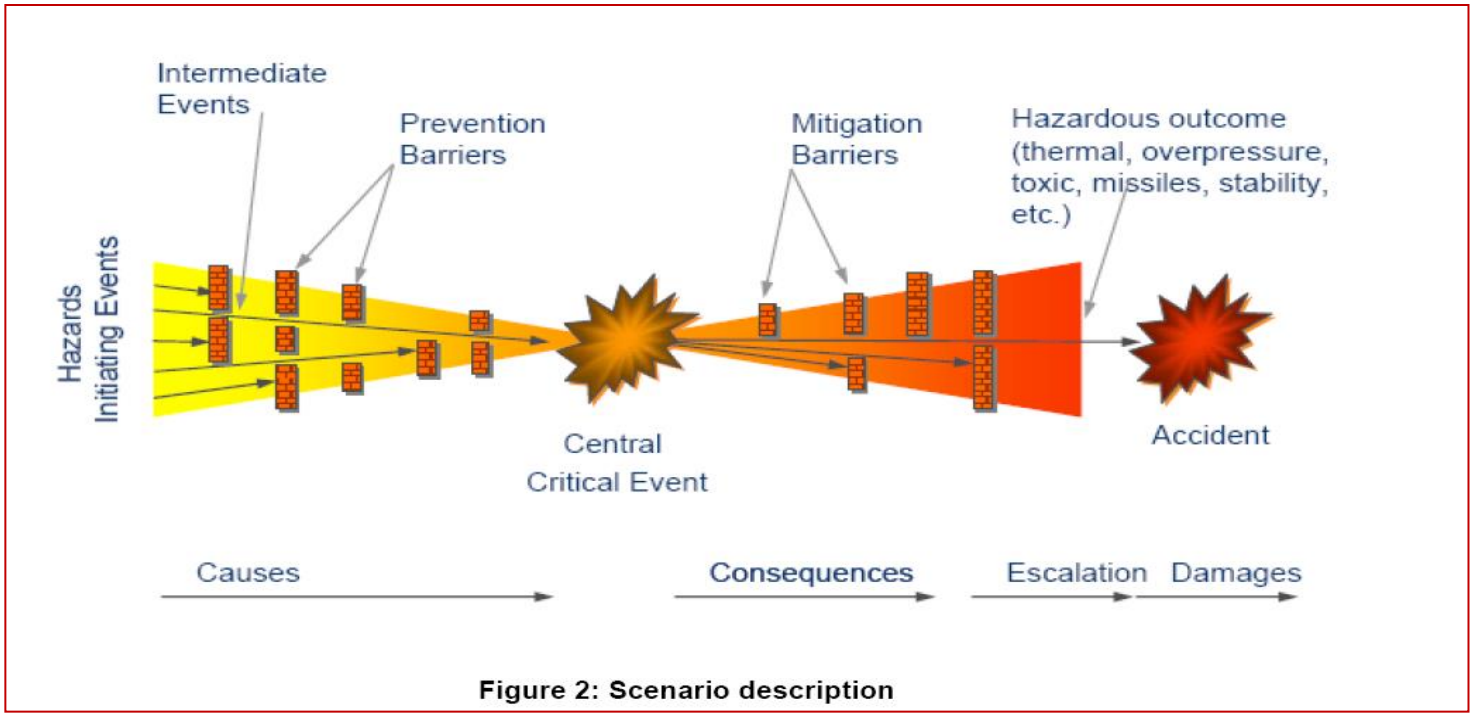

Figure 2: Scenario description

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Section 2

Piping and Instrumentation Diagram

(P&ID Development)

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What is P&ID?

- A Piping and Instrument Diagram (P&ID) is a detailed, pictorial representation of a process showing
  - All equipment including spares
  - All piping and valving
  - All instrumentation

  necessary to design, construct, and operate the facility.

P&ID is basis for HAZOP Study

- **Process engineer**
- **Instrument and Control Engineer** → **P&ID Preparation**
- **Piping Engineer**

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What is P&ID Development?

- Instructions document that defines the general **standards** and rules for presentation and identification of equipment, piping and instrumentation on the P&I diagram's to be applied as a basis.

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Example: **Instrument Nozzle Sizes**

Basically, the instrument nozzle size should be determined based on the following criteria. (The following criteria should be confirmed by Instrument dept.)

Nozzle	Size	Service
PG, PI, PIC	2"	Vessel, H/Ex
PG, PI, PIC	1"	Piping
PDI	2"	Vessel
PDT	1"	Piping
TW, TG, TI, TIC	2"	Line, Vessel, H/Ex
LG	2"	Ordinary Service
LG	2"	Cold Service(Large chamber)
LG	2"	To stand piping connection
LI, LIC	2"	External displacement type
LI,LIC	4" or6"	Internal displacement type
LI,LIE	2"	DP cell type
LI, LIC	3"	DP with remote seal
LI	2"	Float type
LI guide	2" x2"	- ditto -
Analyzer	2"	Ordinary Service
S, SC	2"	All Service

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Example : **Control Valve Type Selection Guide lines**

Globe Valve	general use
Butterfly Valve	large line diameter, low differential pressures
Angle Valve	high differential pressures, slurry service
Diaphragm Valve	corrosive service, toxic service
Ball Valve	on/off control

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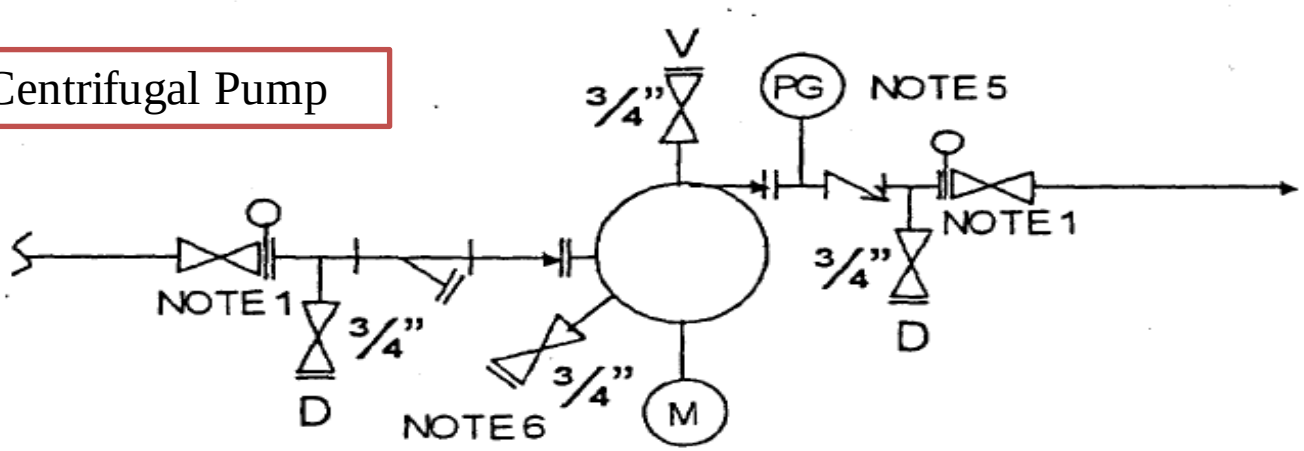
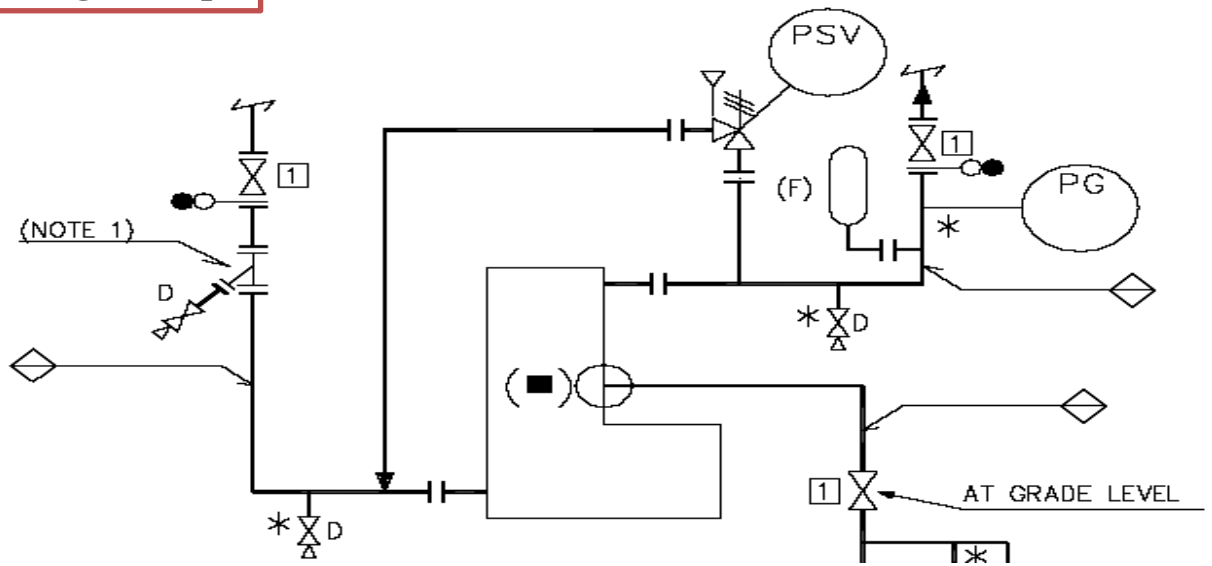
Example 3: **Pump Isolation**

Centrifugal Pump



Reciprocating Pump



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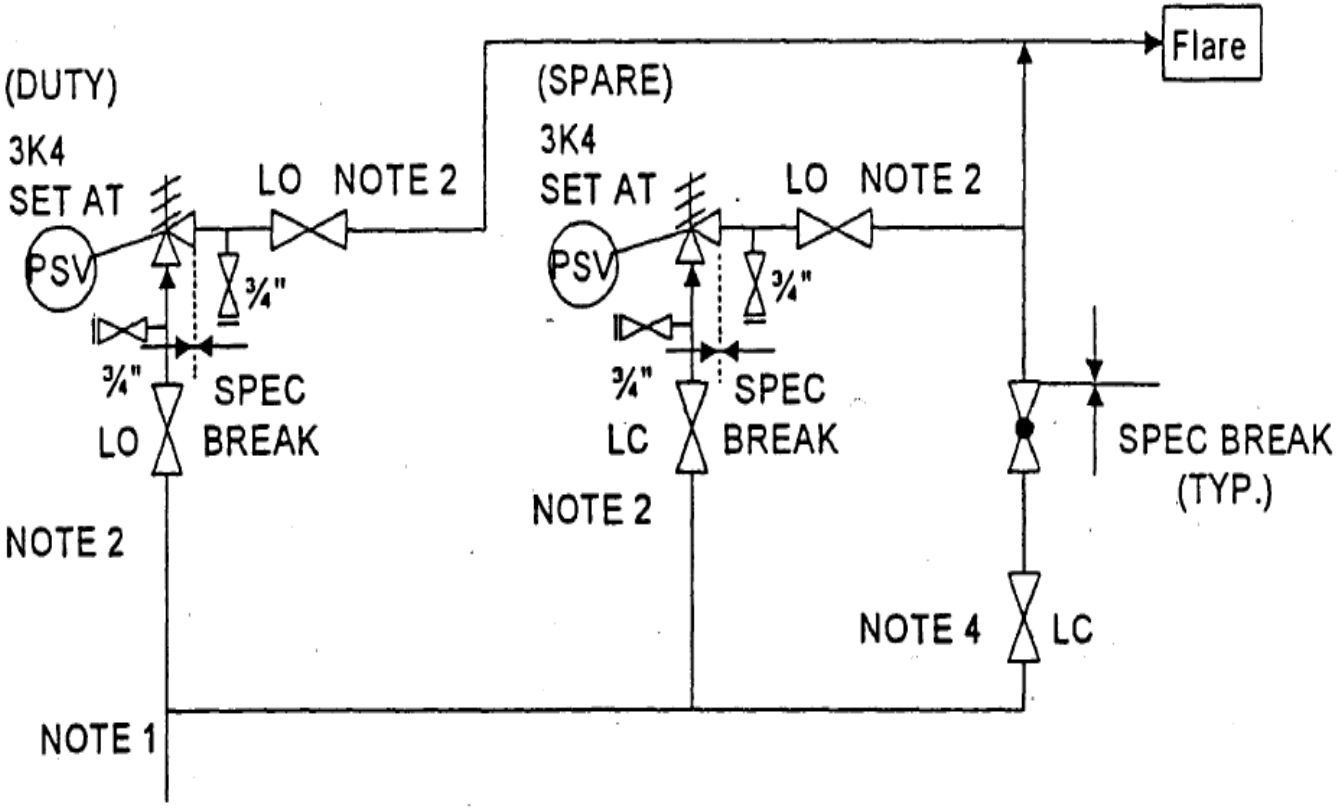
Example: Relief Valve Isolation

Closed Relief System



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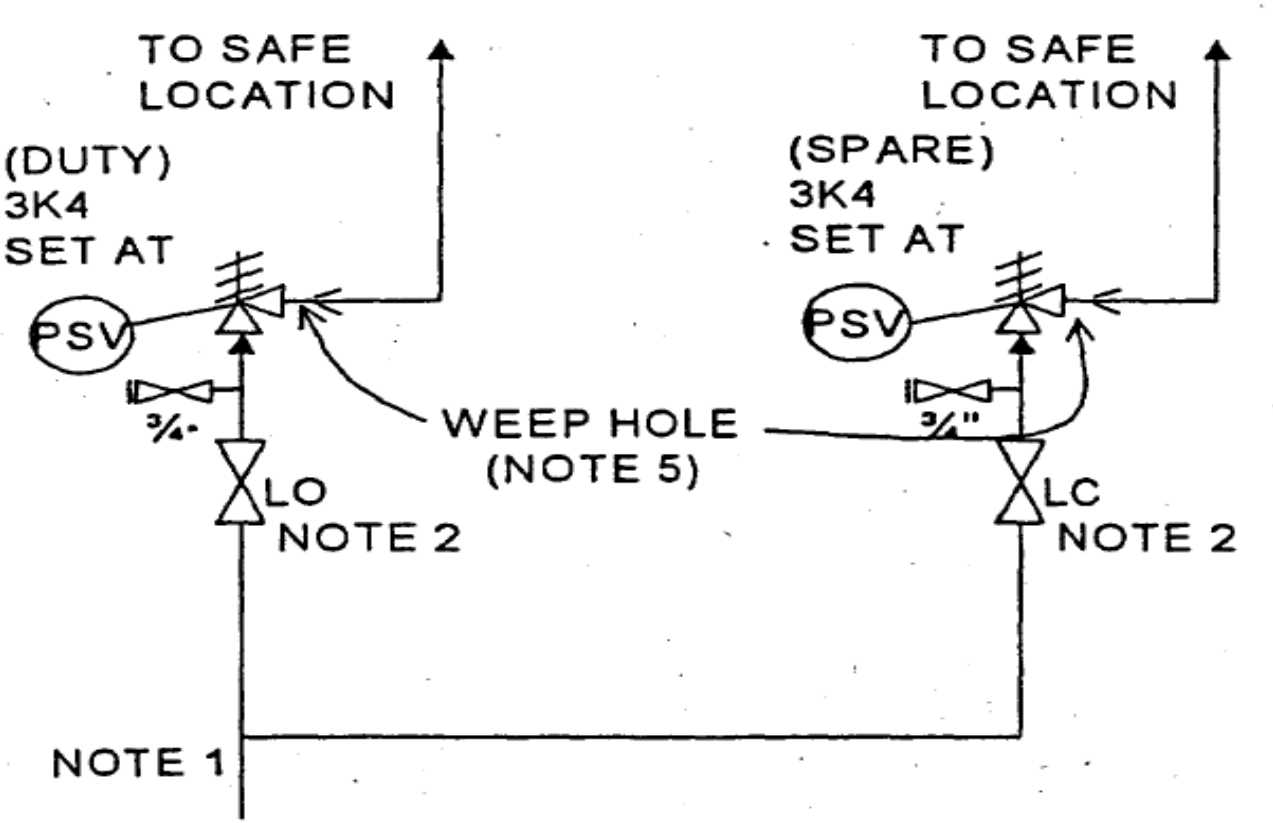
Example: Relief Valve Isolation

Open Relief System



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Example: Size of Drain and Vent

•Vessel/Tower

Vessel Volume, m^3	Vent	Drain	Pump-out	Steam-out	Blow-down
Up to 1.4	1"	1"	1"	1"	2"
1.4 to 5.7	1"	1.5"	1.5"	1"	3"
5.7 to 17	2"	2"	2"	1"	3"
17 to 71	2"	3"	3"	2"	4"
71 and over	2"	3"	3"	3"	4"

•Heat Exchange

Size of vent and drain should be 3/4", otherwise instructed.

•Pump and Compressors

Basically, size of vent and drain should be 3/4". However, size of vent and drain on pump and compressor casing should being accordance with vendor's standard..

•Piping

Size of vent and drain should be 3/4", otherwise instructed.

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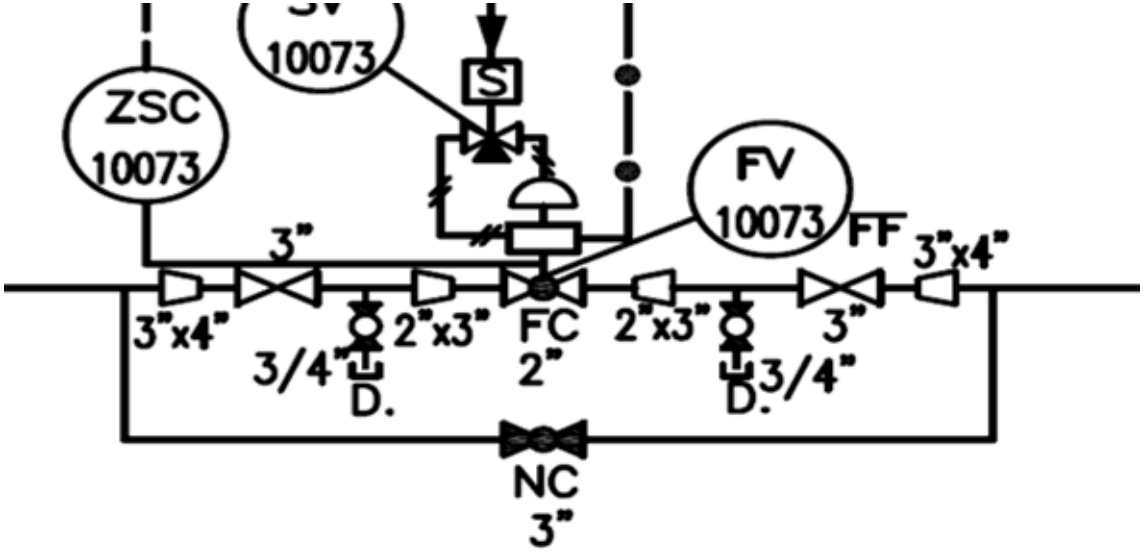
Example: Valve failure mode

Valve failure action on interruption of the operating medium (pneumatic, electric or hydraulic supply) should be generally determined as follows in principle.

- **Shut down/isolating valves** to take "**fail to close**" position
- **Blow-down valves** to take "**fail to open**" position
- **Compressor anti-surge valve** to take "**fail to open**" position.
- Pump **minimum flow valve** to take "**fail to open**" position



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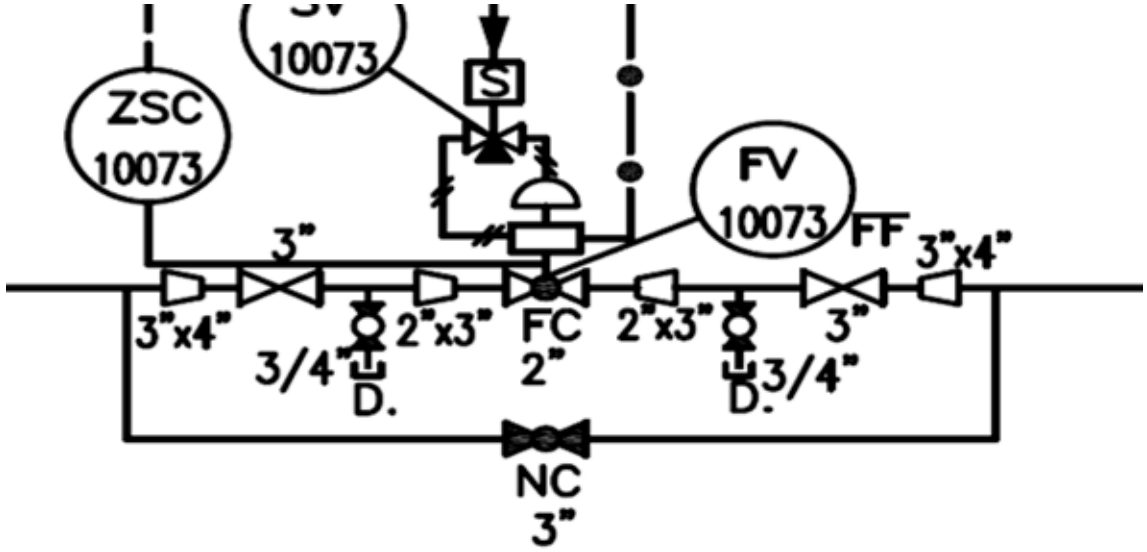
Example: Drain/Purge for Control Valves

- If the control valve is fail-to-close (FC) type, bleeds (purge) should be provided both upstream and downstream of the control valve.
- 1f the control valve is fail-to-open (FO) type, only one downstream bleed shall be installed.
- For the control valve sizes below or equal to 6", however, only one downstream bleed is provided regardless of the valve fail action modes (either FC or FO).



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Section 3

HAZOP Study

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What is HAZOP?

•HAZOP is abbreviation for **HAZ**ard and **Op**erability.

➢**Which one of the following items to be considered in HAZOP?**

•Decreasing temperature and pressure operating condition (Moderate)
•Substitution of Hazardous material with less hazardous materials
•Replace batch reactor with plug reactor (minimization)
•Closure of a 20 inch manual valve by failure or error
•Opening of a capped drain valve of a Pump
•Atmospheric Corrosion due to air humidity
•Opening of control valve bypass valve
•Opening of a Locked Closed Valve
•Closure of a Locked Open valve
•Vehicle (Third party damage)
•Strike, storm, Wind
•Dropped object
•Sabotage

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Strength/ Weakness

Basis:

A hazard does not occur if the process is always operated within its <u>design intention</u>

- **Strengths:**

-Multi-disciplinary team effort (brainstorming)
-Systematic and qualitative method
-Cost effective
-Easy to learn

- **Weakness**

-You don't know what you don’t know
-Time Consuming

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HAZOP Steps

Step 1
Receive and Study of Documents

Step 2
Node Definition

Step 3
Deviations Definition

Step 4
Causes Identification

Step 5
Consequence Identification

Step 6
Safeguards Identification

Step 7
Recommendation

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HAZOP Worksheets

Node:	**(Step 2)**		
Deviation:	(Step 3)		
Cause	Consequence	Safeguards	Recommendation
(Step 4)	(Step 5)	(Step 6)	(Step 7)

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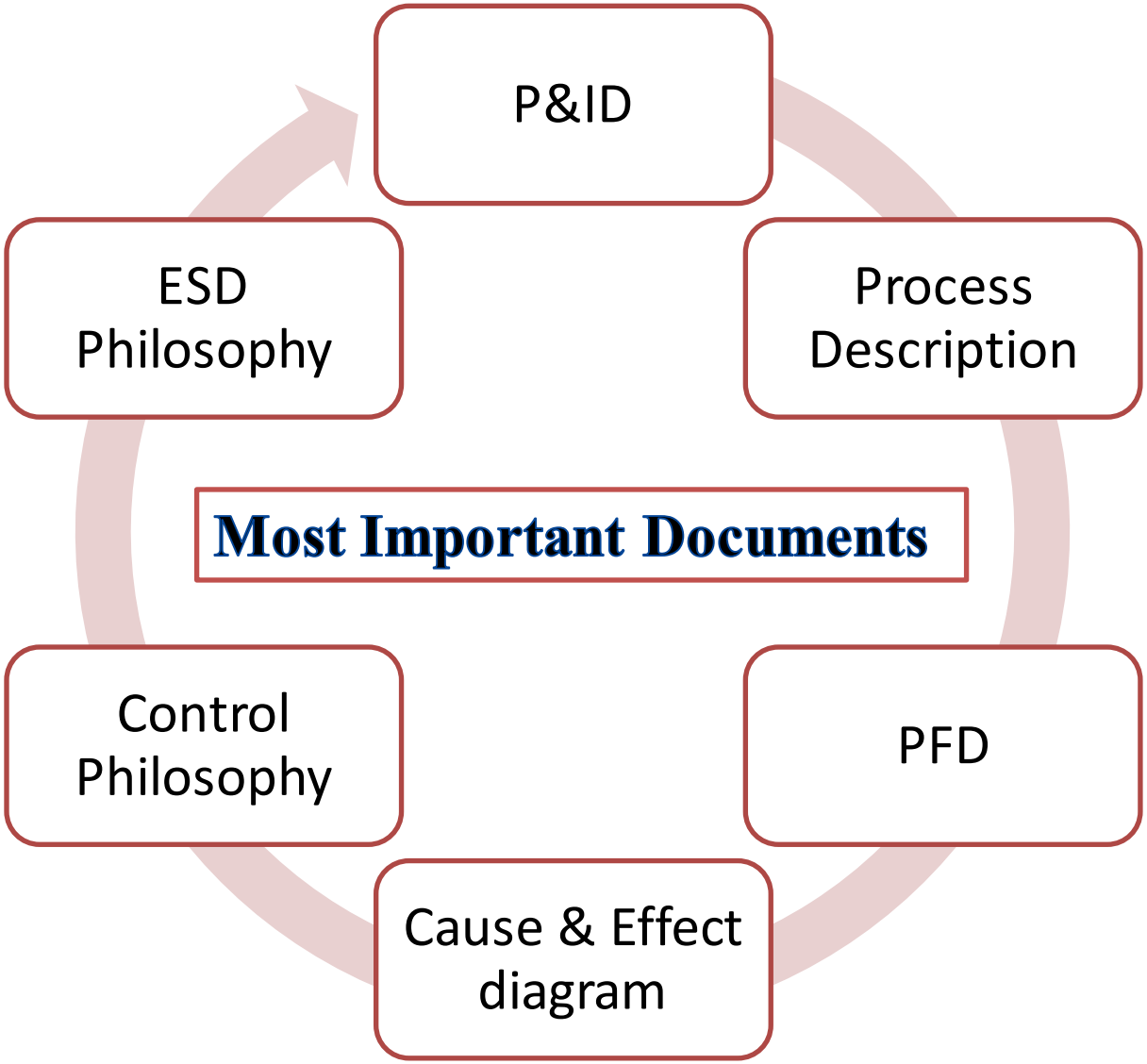
Step 1: Receive and Study of Documents



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Step 1: Receive and Study of Documents

Other required documents:

- Process Design Criteria
- Isolation Philosophy
- Process datasheet
- Design Basis
- Plot Plan
- MSDS
- Etc.

And each document which help us to better understanding of P&ID

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Step 2: Node Definition

➢A node is a specific location in the process in which (the deviations of) the design/process intent are evaluated.

Examples might be:

•Separator

•Storage tanks with relevant pumps

•K.O drum, compressor and air cooler

•etc

There is not a general rule for Node definition and strongly depends on HAZOP leader experience, stage of project, complexity of process and available time.

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Step 2: Node Definition

Two important note in Node definition

1) Size of Node

More equipment in a node leads to increase number of deviations and causes so decreasing performance of team members in HAZOP meetings, also less equipment in a node leads to increase time of HAZOP Study.

2) Dependability of equipments in a Node

Equipment which changing their process parameters (level, flow, pressure, etc) affect on other equipment brought in one Node.

for example decreasing level in a storage tank leads to pump damage due to suction lose so tank and pump considered in one node.

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Step 3: Deviation Definition

➢**Design Intent**

designer's desired, or specified range of behavior for elements and characteristics (e.g. pressure, temperature, composition, pH, etc)

➢The verification of design intent (see IEC 61160), is outside of the scope of the HAZOP study.

Practice

According to PFD and P&ID explain the design intent

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Step 3: Deviation Definition

Deviation = Guidewords + Parameter

Most Applicable Deviations in HAZOP Study		
Deviations	**Guide Word**	**Parameter**
No/Less Flow	No/Less	Flow
More Flow	More	Flow
Reverse/Misdirected Flow	Reverse/Misdirected	Flow
High Temperature	High	Temperature
Low Temperature	Low	Temperature
High Pressure	High	Pressure
Low Pressure	Low	Pressure
High Level	High	Level
Low Level	Low	Level

Define these 9 deviations for each node even if no causes to be identified

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Boiling Liquid Expanding Vapor Explosion (BLEVE)


Flash Fire


Jet Fire


Pool Fire


Fireball

Step 3: Deviation Definition

Deviation = Guidewords + Parameter

Less Applicable Deviation ins HAZOP Study		
Deviations	**Guide Word**	**Parameter**
High/Low pH	High/Low	pH
Impurities Present	As well as	Purity
High Reaction Rate	More	Reaction
Low Reaction Rate	Less	Reaction
Start-up/Shutdown hazards	Other than	Start-up/Shutdown
High Agitation/Recirculation	High	Agitation
Contaminants	As well as	Composition
High vibration	High	Vibration
Isolation Problem	Other than	Maintenance
Purging Problem	Other than	Maintenance
Evacuation Problem	Other than	Maintenance
Maintenance Hazards	Other than	Maintenance
Etc.		

Define these deviations if necessary

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Fireball

Step 3: Deviation Definition

HAZOP Assumption:

In the lines that their flow is controlled either by a simple loop or a cascade one, the deviation that is studied is the one that is related to the main design objective of the control valve. **It means that the deviation is not always the flow deviation and can be temperature, pressure, liquid level, etc**. It is a convention that gives the best result and also keeps the volume of the report from becoming unnecessarily large.

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Step 4: Causes Identification

- The reason(s) why the deviation could occur.
- Several causes may be identified for one deviation.

➢Most important and applicable causes during HAZOP study are as following:

1) Closure or/and Opening of Valves
2) Failure of Machinery (e.g. Rotary Equipments)

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Fireball

Step 4: Causes Identification

1) Closure or/and Opening of Valves

Valves could be classified to 3 types:

a) Control Valves (BPCS)

b) On/Off Valves (SDV, ESDV, XV, MOV, etc)

c) Manual Valves

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Fireball

Step 4: Causes Identification

a) Control Valves (BPCS)

"Failure of TV/PV/FV/LV/etc or any element in its control system to close/open more"|

Example:

- Failure of LV-101 or any element in its control system to close more.
- Failure of LV-101 or any element in its control system to open more.

- Failure of PV-103 or any element in its control system to close more.
- Failure of PV-103 or any element in its control system to open more.

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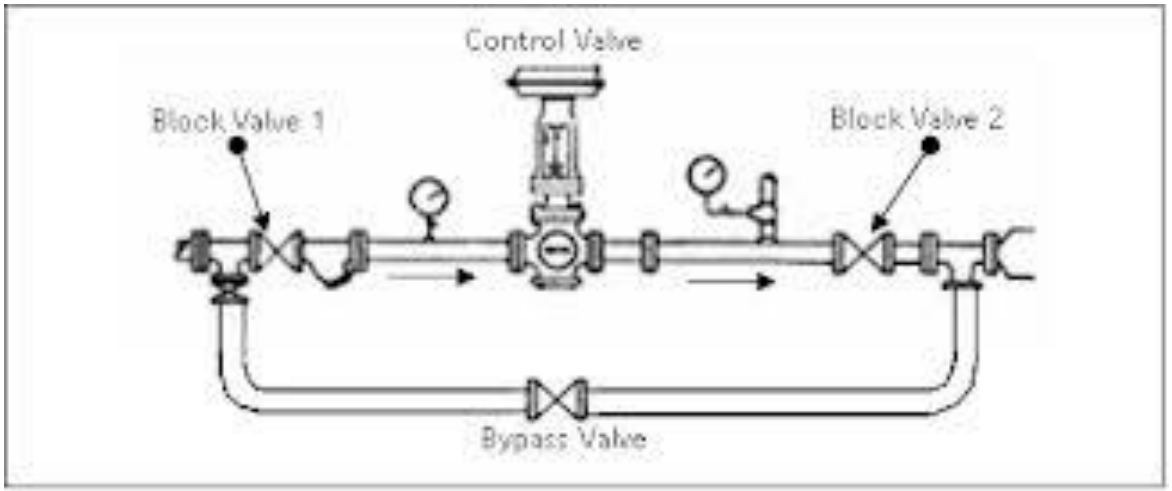
Step 4: Causes Identification

a) Control Valves (BPCS)

HAZOP Assumption:

1) Leaving a control valve bypass open can cause MORE FLOW to occur. However, this is a remote possibility, and furthermore, the control valve itself will compensate for such an event. So, this is not recorded as a cause.



Valve dan Piping System

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Flash Fire


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Fireball

Step 4: Causes Identification

2) Only loop failures will be considered, not individual control valve/electronic failures.

3) Both fail safe position and the opposite position will be considered fore control valves separately

4) Erroneous opening of two valves in series or valves with poor access is considered to be rare cases and are omitted from the study.

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Fireball

Step 4: Causes Identification

b) On/Off Valves

"Closure of SDV/ESDV/XV/MOV/etc by failure or error"

Example:

- Closure of SDV-0231 by failure or error.
- Closure of ESDV-0456 by failure or error.
- Closure of MOV-102 by error.
- Closure of XV-0531 by failure or error.
- Etc

HAZOP Assumption:

1) Opening of PSV's, BDV's is a consequence of overpressure, so it has not been considered as a cause of "Less Pressure" or "Misdirected Flow". Opening of BDV/PSV could be considered in low temperature deviation.

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Step 4: Causes Identification

c) Manual Valves
"Closure of any manual valve by failure or error"

HAZOP assumption:

1) All drain and bleed valves are plugged or capped on their open ends. Thus, drains or vent valves are not normally considered a potential hazard source except in special cases.
2) The inadvertent opening/closing of LC/LO/CSC/CSO valves is not considered because administrative controls like permit to work system are considered adequate safeguards to prevent this situation.
3) Closure of valves greater than 8 inch is remote possible and are not considered in HAZOP Study

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Fireball

Step 4: Causes Identification

2) Failure of Machinery (e.g. Rotary Equipments)

- Pump failure or trip due to any reason.
- Compressor failure or trip due to any reason.
- Blower failure or trip due to any reason.
- Air Cooler failure or trip due to any reason.
- Etc.

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Step 4: Causes Identification

Practice

Show on P&ID which valves to be considered in HAZOP study as causes and which valves are not considered.

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Fireball

Step 4: Causes Identification

Other common causes in HAZOP Study:

- Decreased/cut-off of flow from upstream.
- Not receiving in downstream.
- Increasing flow/pressure from upstream due to any reason.
- Plugging of strainer/ demister pad/ filter due to any reason.
- Low ambient temperature
- Equipment (pump, air cooler, etc) not start due to any reason (during start up)
- Not opening a valve (during start up)
- Contamination
- Leakage/Rupture due to corrosion, erosion, TPD,
- Less heat transfer in heat exchanger/air cooler due to any reason
- etc.

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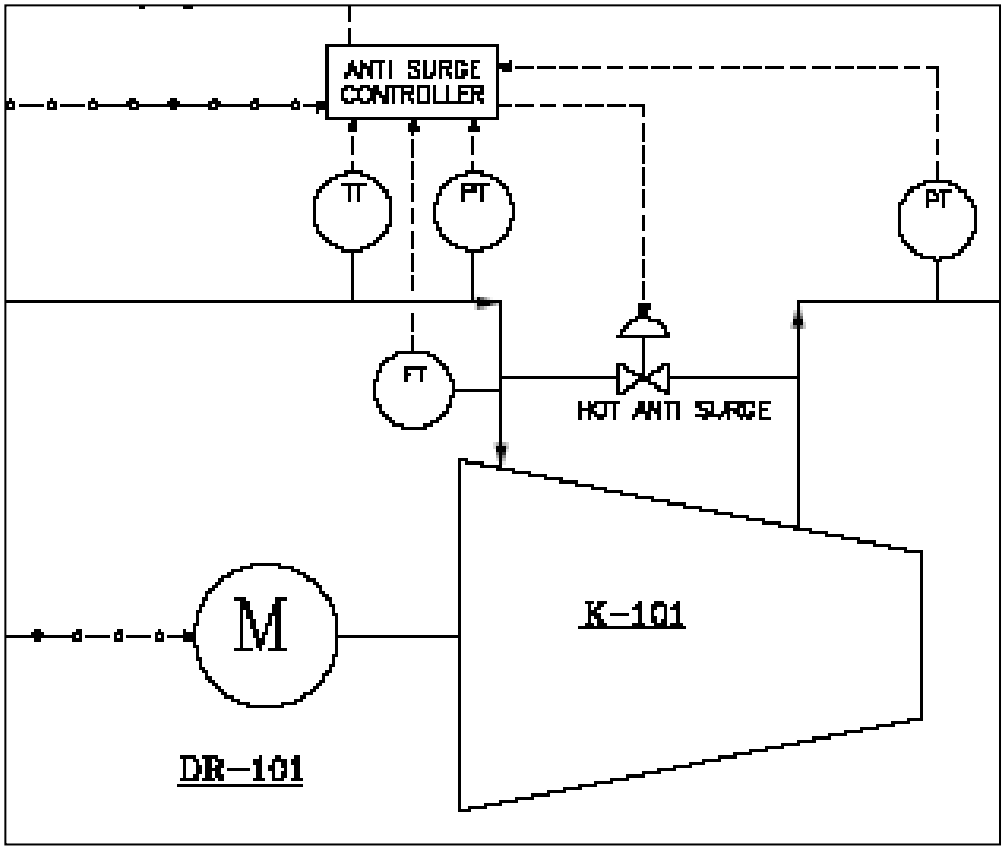
Step 5: Consequence Identification

How to write consequence?

Example: what happens if a valve upstream of a Centrifugal Compressor closes?



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Flash Fire


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Fireball

Step 5: Consequence Identification

How to write consequence?

Decreased flow and pressure of gas to compressor so possibility of damage to Compressor due to surge condition leading to leakage of gas to atmosphere so possibility of fire and explosion that leads to personnel injury and asset damage.

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Flash Fire


Jet Fire


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Fireball

Step 6: Safeguards Identification

➢ **Most important safeguards during HAZOP study:**

1) BPCS
2) Alarms
3) Operator
4) Interlocks and shutdown
5) Mechanical Protection (prevention)
6) Other equipment safeguards

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Flash Fire


Jet Fire


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Fireball

How to write safeguard?
1) BPCS

e.g.

PIC-201 tries to adjust pressure through PV-201

LIC-203 tries to adjust level through LV-203

TIC-01 tries to adjust temperature through TV-01

FIC-700 tries to adjust pressure through FV-700

Etc.

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Jet Fire


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How to write safeguard?
2)Alarms

e.g. TAH-201; PAL-102; LAH-506

Level Alarm High = LAH
Temperature Alarm High = TAH
Pressure Alarm Low= PAL
.

Practice

Show and write alarms on P&ID.

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Flash Fire


Jet Fire


Pool Fire


Fireball

Step 6: Safeguards Identification

How to write safeguard?
3) Operator Intervention

e.g.

Operator will be informed by pressure condition in T-201.

Operator may be informed by FAL-201.

Operator will be informed by TAH-304.

Operator will be informed by operating condition.

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Flash Fire


Jet Fire


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Fireball

Step 6: Safeguards Identification

How to write safeguard?
4) Interlocks and shutdown

e.g.

- Software PSHH-101 actuates alarm and activates ESD-2
- Software LSHH-101 actuates alarm and activates SD-3
- Software FSLL-101 actuates alarm and activates ESD-0
- Software TSHH-101 actuates alarm and activates SD-3

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How to write safeguard?
5) Mechanical Protection (Prevention)

e.g. PSV-102; TSV-1002; RD-02

PSV = Pressure Safety Valve
TSV = Temperature Safety Valve
RD = Rupture Disk

Practice
Regarding to P&ID show and write mechanical protection systems

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Flash Fire


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Fireball

Step 6: Safeguards Identification

6) Other important equipment safeguards

- Limit switch on the valve (such as ESDV/XV/BDV/SDV, etc)
- Design temperature of lines or equipment
- Design pressure of equipment or line
- Common failure alarm on air cooler
- Standard Operating Manual (SOP)
- Anti surge valve for compressors
- Common failure alarm on pump
- Minimum flow for pumps
- Running status of pumps
- Supervision of operator
- Sampling and testing
- LO/LC/CSO/CSC
- Overflow line
- Check valve
- Open vent
- etc

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Jet Fire


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Step 7: Recommendation

If safeguards are not adequate for prevention of hazard so team members (with brain storming) should addition safeguards for decreasing risk or increasing operability.

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Flash Fire

Jet Fire

Pool Fire

Fireball

Section 4:

SIL Study (LOPA Method)

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Flash Fire


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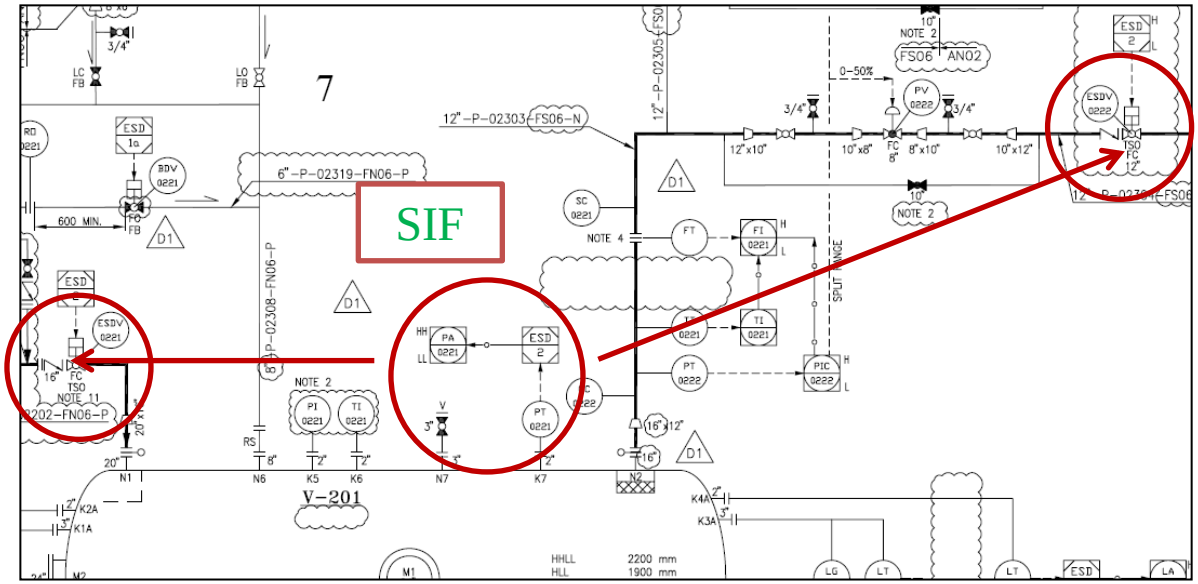
Fireball

Safety Instrumented Function (SIF)

❖ SIF به صورت "کارکرد ابزاردقیق ایمنی" قابل ترجمه است و عبارت است از یک کارکرد ایمنی با یک سطح یکپارچگی ایمنی (SIL) که جهت رسیدن به ایمنی کارکرد لازم می باشد!

❖در شکل زیر PT-0221 ، کنترلر منطقی ESD و دو شیر قطع جریان ESDV-0221A و ESDV-0222A یک SIF محسوب می شود .



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Flash Fire


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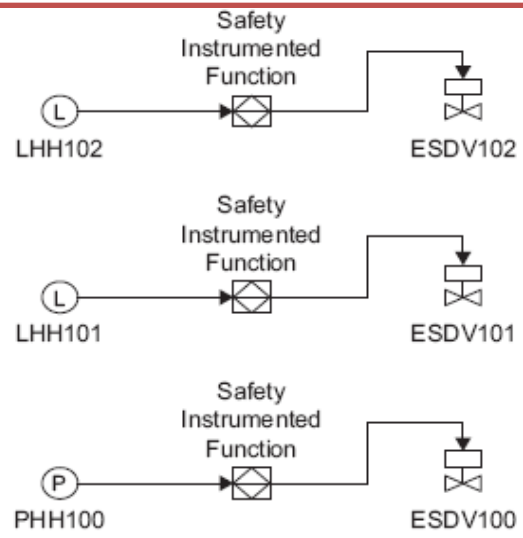
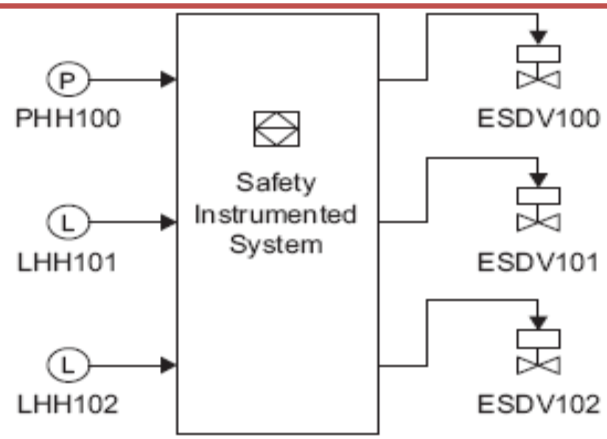
Fireball

SIS vs. SIF

Safety Instrumented Function (SIF)



The individual SIFs together form the overall SIS:



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Boiling Liquid Expanding Vapor Explosion (BLEVE)


Flash Fire


Jet Fire


Pool Fire


Fireball

Safety Integrity Level (SIL)

SIL به صورت "سطح یکپارچگی ایمنی " قابل ترجمه است و در حقیقت نشان دهنده میزان کاهش ریسکی (RRF) است که یک SIF بایستی داشته باشد تا مقدار ریسک به مقدار قابل قبول برسد و طبق استاندارد به چهار سطح 1،2،3و 4 تقسیم می گردد.

SIL برای تجهیزات غیر ابزار دقیقی از قبیل Pressure Safety Valve ، Rupture Disk ، Dike و غیره قابل تعریف نیست. همچنین طبق IEC-61511برای سیستم های کنترلی فرایندی که از DCS به عنوان کنترلر منطقی استفاده می نمایند SIL تعریف نمی شود اما برای آن حداکثر RRF=10 تعریف می گردد.

SIL Safety Integrity Level	PFDavg Average probability of failure on demand per year (low demand)	RRF Risk Reduction Factor
SIL 4	≥ 10^{-5} and < 10^{-4}	100000 to 10000
SIL 3	≥ 10^{-4} and < 10^{-3}	10000 to 1000
SIL 2	≥ 10^{-3} and < 10^{-2}	1000 to 100
SIL 1	≥ 10^{-2} and < 10^{-1}	100 to 10

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Fireball

Safety Integrity Level Types (SIL)

- در مطالعات تعیین SIL جهت پوشش دادن به همه جنبه های ریسک (انسانی، مالی و زیست محیطی) معمولا سه نوع SIL برای هر SIF به صورت زیر تعریف می گردد:

  - **Safety to life Integrity Level (sIL)**
  - **Environmental Integrity Level (eIL)**
  - **Asset Integrity Level (aIL)**

  و بیشترین مقدارSIL از بین سه مقدار بدست آمده انتخاب می گردد.

- هزینه های ناشی از قطع تولید در Asset Integrity Level دیده می شود.

مثال

SIL --- = sIL

➢eIL= SIL ---

➢aIL= SIL 1

SIL 1 Selected

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Probability of Failure on Demand (PFD)

❖PFD نشان دهنده احتمالی است که یک سیستم یا جز در زمانی که به آن نیاز است و فعال گردیده است به وظیفه خود درست عمل نکند.

❖در حالت کلی PFD تابع زمان می باشد لذا در مطالعات SIL از مقدار متوسط آن در بازه زمانی مشخص (معمولا زمان تست) استفاده می شود.

❖لازم به ذکر است که PFD و RRF کمیت های بدون بعد می باشند

❖آنچه که در مورد PFD بسیار مهم است رابطه کلیدی زیر جهت تبدیل PFD به RRF (Risk Reduction Factor) و بالاعکس است:

$$RRF=1/PFD$$

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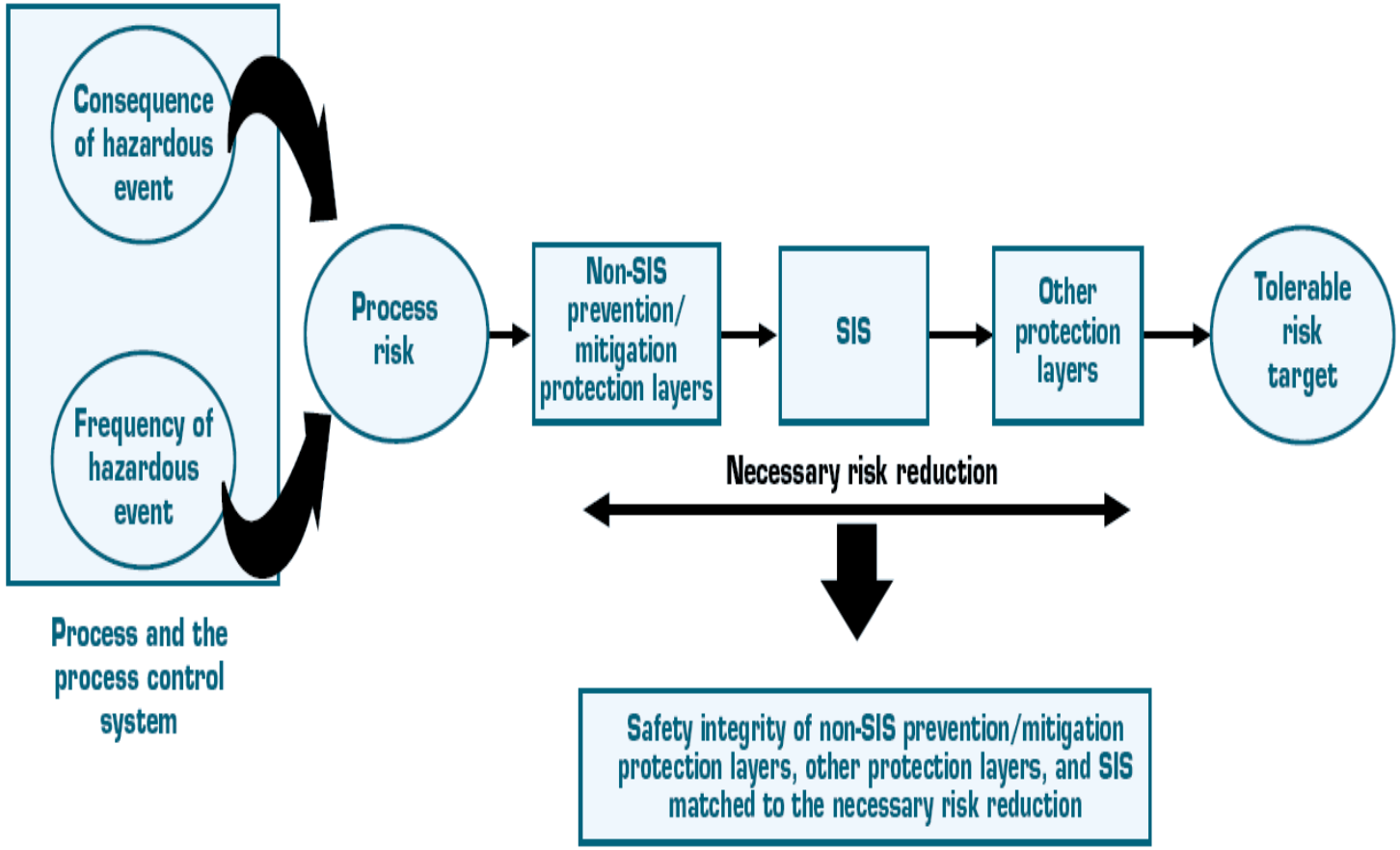
LOPA Concept



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Flash Fire


Jet Fire


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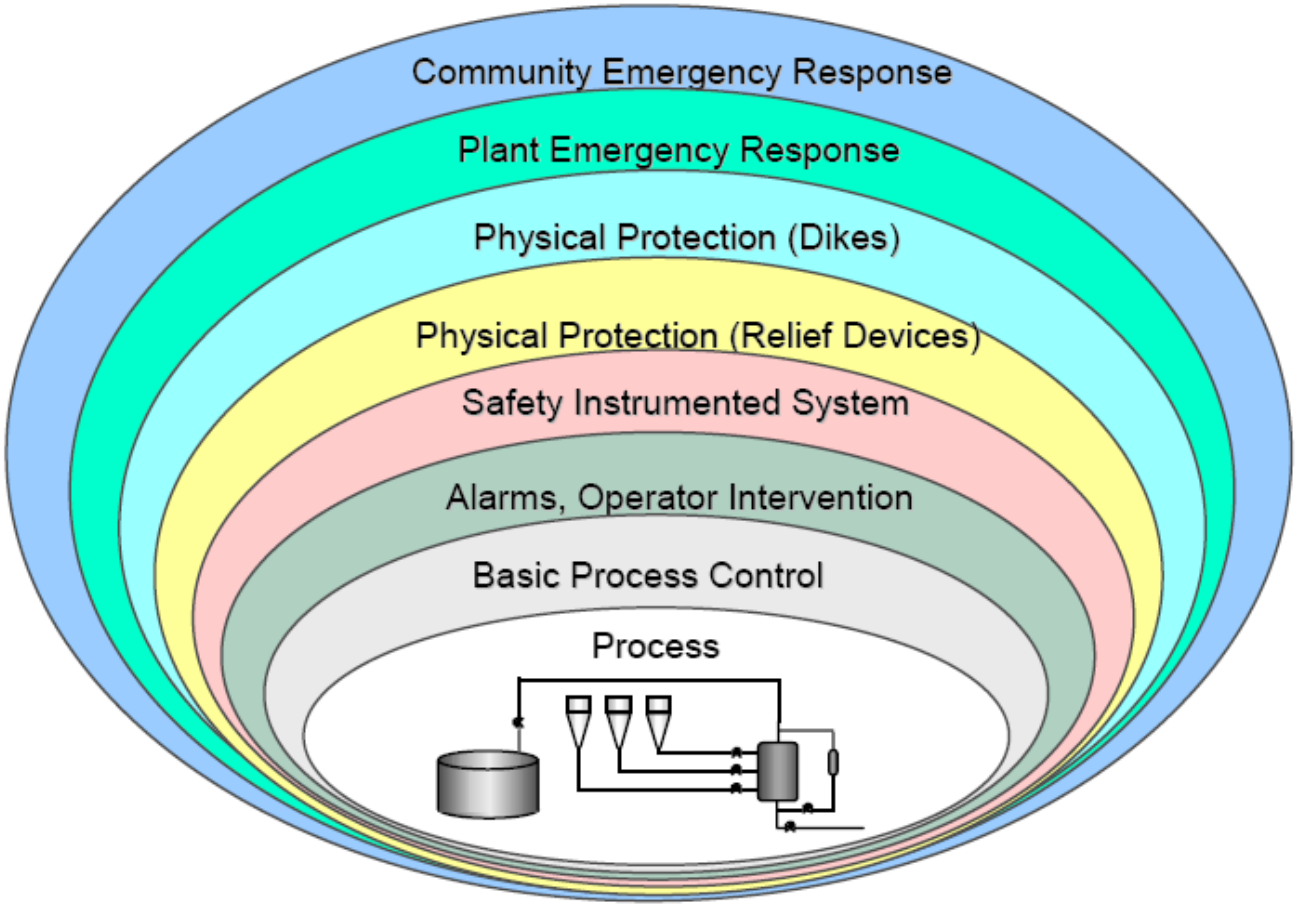
Fireball

LOPA Concept

➢The Layer Of Protection Analysis (LOPA) uses calculation to measure the adequacy of protection layers against the potential consequences of process deviations.



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Flash Fire


Jet Fire


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Fireball

Layer of Protection Analysis (LOPA) Procedure

Layer of Protection Analysis Procedure	
Step 0	Pre requisites (Risk Matrix / Target Likelihood / Documents/ LOPA Worksheet)
Step 1	SIF and Hazardous Scenario Definition
Step 2	Identification of Initiating Events (determination of Event Likelihood)
Step 3	Identification and Evaluation of Consequences (Safety/Environment/Asset)
Step 4	Identification of IPLs
Step 5	Time at Risk (TAR)
Step 6	Exposure Time Parameter (ETP)
Step 7	Calculation of Likelihood
Step 8	Calculation of RRF/PFD/SIL

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Fireball

Step 0: Pre requisites (Risk Matrix / Documents)

➢**Risk Matrix Selection**

•Your Organization

•Your Company

•Standards (e.g. ISO 17776/ IEC-61511)

•Guidelines (e.g. CCPS)

•Companies (e.g. Total/ Shell/ Exida)

➢**Most Required Documents**

•P&ID

•Cause and Effect Diagram

•HAZOP Study

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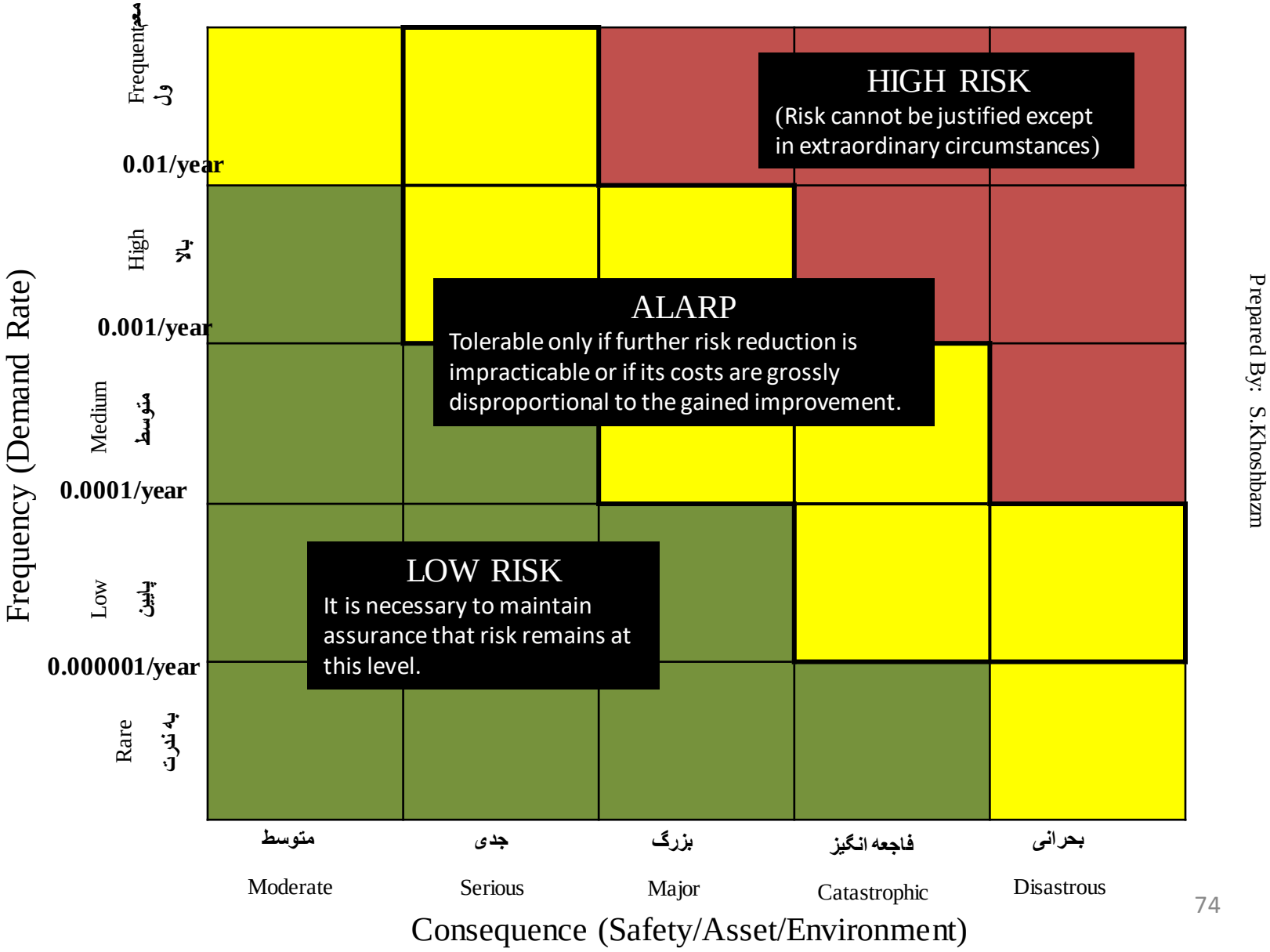
Step 0: Pre requisites (Risk Matrix/ GS-EP-SAF-041)



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Fireball

Step 0: Pre requisites (Risk Matrix/ GS-EP-SAF-041)

نرخ یا فراوانی تقاضا (Demand Rate) معادل Frequency یا Likelihood در مطالعات آنالیز ریسک می باشد و معمولا دارای واحد "بر سال" می باشد.

طبقه‌بندی فرکانس یا نرخ تقاضا (Demand Rate)				
ردیف	سطوح نرخ تقاضا		تعریف کیفی	محدوده
1	Likely	معمول	بیشتر از 2 بار در سال	$>10^{-2}$/سال
2	Unlikely	بالا	به طور معمول یک بار در سال	10^{-2}/سال - 10^{-3}/سال
3	Very Unlikely	متوسط	به طور معمول یک بار در 10 سال	10^{-3}/سال - 10^{-4}/سال
4	Extremely Unlikely	پایین	به طور معمول یک بار در 100 سال (یک بار برای 2 تا 20 واحد صنعتی مشابه با عمر متوسط 25 سال رخ می دهد)	10^{-4}/سال - 10^{-6}/سال
5	Remote	به ندرت	کمتر از 500 سال یک بار	$<10^{-6}$/سال

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Fireball

Step 0: Pre requisites (Risk Matrix/ GS-EP-SAF-041)

ستون	سطوح شدت	پیامدانسانی
و		صدمات قابل صرف نظر (جزئی)
و		صدمات جدی
ی		یک نفر کشته
ی		2 تا 5 نفر کشته
ي		بیشتر از 5 نفر کشته

ستون	سطوح شدت	پیامدزیست محیطی
و		نشت یا انتشار آلاینده نیاز به اطلاع‌رسانی به مسئولین دارد، اما پیامدهای زیست‌محیطی ندارد.
و		-نشت متوسط در محدوده سایت -تخلیه مواد آلاینده گزارش می‌شود.
ی		-نشت و انتشار قابل توجه مواد آلاینده به خارج از سایت. -تخلیه افراد از سایت.
ی		-آلودگی های مهم زیست‌محیطی با عواقب قابل برگشت در خارج از سایت
ي		آلودگی عمده و پایداری که به خارج از سایت گسترده شده است/ و یا موجب از دست رفتن گسترده زندگی آبزیان می‌شود.

ستون	سطوح شدت	پیامدمالی (با در نظر گرفتن وقفه در تولید)
و		کمتر از 200،000 یورو
و		200،000-2،000،000 یورو
ی		2،000،000-10،000،000 یورو
ی		10،000،000-100،000،000 یورو
ي		بیشتراز 100،000،000 یورو

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SAFETY: FREEDOM FROM UNACCEPTABLE RISK


Boiling Liquid Expanding Vapor Explosion (BLEVE)


Flash Fire


Jet Fire


Pool Fire


Fireball

Step 0: Pre requisites (Target Likelihood)

➢Target Likelihood

- The target likelihood of a scenario is a direct result of the severity of its consequences.
- Calibration factor=0.2

	SAFETY		ENVIRONMENT		ASSET **	
Consequences	Severity	Target Likelihood	Severity	Target Likelihood	Severity	Target Likelihood
Moderate	SA	2.E-03	EA	2.E-03	AA	2.E-03
Serious	SB	2.E-04	EB	2.E-04	AB	2.E-04
Major	SC	2.E-05	EC	2.E-05	AC	2.E-05
Catastrophic	SD	2.E-06	ED	2.E-06	AD	2.E-06
Disastrous	SE	**1.E-08	EE	**1.E-08	AE	**1.E-08

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Step 0: Pre requisites (LOPA Worksheet)

Layer of Protection analysis (LOPA) Worksheet

Step 1			
Initiators	Interlock ID	Final Elements	SIF

Hazardous Scenario	Safety to Life														
	Initiating Event		Consequences		Protection Layers (RRF)					Time at Risk	Exposure Time	Cal. Likelihood	Target Likelihood	RRF	SIL
	Desc.	Likelihood	Desc	Severity	BPCS	ALARM and Intervention of Operator	Mechanical Barrier	IPL 1	IPL 2						
Step 1	Step 2		Step 3		Step 4					Step 5	Step 6	Step 7	Step 3	Step 8	

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Step 0: Pre requisites (LOPA Worksheet)

Hazardous Scenario	Environmental Damage														
	Initiating Event		Consequences		Protection Layers (RRF)					Time at Risk	Exposure Time	Cal. Likelihood	Target Likelihood	RRF	eIL
	Desc.	Likelihood.	Desc	Severity	BPCS	ALARM and Intervention of Operator	Mechanical Barrier	IPL 1	IPL 2						
Step 1	Step 2		Step 3		Step 4					Step 5	Step 6	Step 7	Step 3	Step 8	

Hazardous Scenario	Asset Damage														
	Initiating Event		Consequences		Protection Layers (RRF)					Time at Risk	Exposure Time	Cal. Likelihood	Target Likelihood	RRF	aIL
	Desc.	Likelihood.	Desc	Severity	BPCS	ALARM and Intervention of Operator	Mechanical Barrier	IPL 1	IPL 2						
Step 1	Step 2		Step 3		Step 4					Step 5	Step 6	Step 7	Step 3	Step 8	

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Step 1: SIF and Hazardous Scenario Definition

Step 1			
Initiators	**Logic Solver**	**Final Elements**	**SIF**
PT-0221	**ESD2**	**ESDV-0221; ESDV-0222**	**On high high pressure in V-201, ESDV-0221 and ESDV-0222 closes**

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Step 2: Identification of Initiating Events (determination of Likelihood)

HAZOP WORKSHEET			
Node:			
Deviation:			
Cause	Consequence	Safeguards	Recommendation

Initiating events Such as:

1) Closure or/and Opening of Valves

2) Failure of Machinery Equipments

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Step 2: Identification of Initiating Events (determination of Likelihood)

Initiating Event	Likelihood (per year)
BPCS loop failure	0.1
Closure of a manual valve by failure	0.001
Closure of MOV/ESDV/SDV	0.01
Control valve fail to fail-safe position	0.1
Control valve fail to non-fail-safe position	0.01
Failure of rotating equipment such as pumps, fan, compressor, etc	0.1
Strainer/filter plugging	0.1
Mechanical Regulator Valve (PCV)	0.1
Loss of fuel supply	0.1
Loss of water supply	0. 1
TPD (Third Party Intervention)	0.01
External fire	0.01
Human error (Non-routine task, low stress)	0.01/ oppurtunity
Human error (Non-routine task, high stress)	0.1/ oppurtunity

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Step 3: Identification and Evaluation of Consequences

HAZOP WORKSHEET			
Node:			
Deviation:			
Cause	Consequence	Safeguards	Recommendation

Consequences

❖در این مرحله بعد از مشخص شدن شدت پیامد مقدارTarget Likelihood قابل اندازه گیری است.

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Step 3: Identification and Evaluation of Consequences

ستون	سطوح شدت	پیامدانسانی (S)	پیامدزیست محیطی (E)	پیامدمالی (با در نظر گرفتن وقفه در تولید) (A)
1	متوسط (A)	صدمات قابل صرف نظر (جزئی) (SA)	نشت یا انتشار آلاینده نیاز به اطلاع‌رسانی به مسئولین دارد، اما پیامدهای زیست-محیطی ندارد. (EA)	کمتر از 200،000 یورو (AA)
2	جدی(B)	صدمات جدی (SB)	نشت متوسط در محدوده سایت (EB) تخلیه مواد آلاینده گزارش می‌شود.	200،000-2،000،000 یورو (AB)
3	بزرگ(C)	یک نفر کشته (SC)	نشت و انتشار قابل توجه مواد آلاینده به خارج از سایت. تخلیه افراد از سایت. (EC)	-10،000،000 2،000،000 یورو (AC)
4	فاجعه‌انگیز(D)	2 تا 5 نفر کشته (SD)	آلودگی‌های مهم زیست‌محیطی با عواقب قابل برگشت در خارج از سایت (ED)	-100،000،000 10،000،000 یورو (AD)
5	بحرانی(E)	بیشتر از 5 نفر کشته (SE)	آلودگی عمده و پایداری که به خارج از سایت گسترده شده است/ و یا موجب از دست رفتن گسترده زندگی آبزیان می-شود. (EE)	بیشتراز 100،000،000 یورو (AE)

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Step 3: Target Likelihood

➢Target Likelihood

- The target likelihood of a scenario is a direct result of the severity of its consequences.

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Disastrous	SE	**1.E-08	EE	**1.E-08	AE	**1.E-08

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Step 4: Identification and Evaluation of Independent Protection Layers

HAZOP WORKSHEET			
Node:			
Deviation:			
Cause	Consequence	Safeguards	Recommendation

Independent Protection Layers such as:

1) BPCS
2) Alarm and Operator Intervention
3) Shutdown System
4) Mechanical Protection (PSV/RD)
5) Other equipment safeguards

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Step 4: Identification and Evaluation of Independent Protection Layers

Protection Layer	PFD
Basic Process Control System (BPCS), if not associated with the initiating event being considered	0.1
Independent SIF (SIL=1,2,3)	0.1,0.01,0.001
Operator response to alarm with sufficient time available to respond	0.1
Pressure relief valve	0.01
Rupture Disk	0.01
Vacuum breaker	0.01
Overflow line	0.1
Open vent (not including valve)	0.01
Open vent (including valve)	0.1
Flame arrestor	0.01

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Step 5: Time at Risk (TAR)

Certain causes may lead to consequence only under specific circumstances or operations.

For example:

- a reverse flow scenario is credible only on "low pressure operation mode",
- leakage may contain H2S only during start-up or shutdown
- incident during pigging activities

The reduction factor used is called Time At Risk (TAR).

The Time At Risk to be expressed in the range from 0.01 to 1.

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Step 6: Exposure Time Parameter (ETP)

➢ این پارامتر تنها مختص به پیامد انسانی می باشد و مشابه پارامتر FA/FB در روش Calibrated Risk Graph می باشد. مقدار ETP برای پیامد های مالی و زیست محیطی می بایست 1 در نظر گرفته شود.

➢The ETP shall be equal to 1 in the following cases:

• If the hazard being analyzed is related to an operation which requires personnel to be present in the affected area to perform the operation;

• Any main event whose consequences can affect a large area of a normally manned installation (e.g. large gas release);

• If operator is required to intervene locally in response to the hazard.

➢The ETP shall be expressed in the range from 0.1 to 1; e.g. a not normally manned offshore, platform where personnel are present 20 hours per week has an ETP of 0.119.

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Step 7: Calculated Likelihood

For a single initiating event, the calculated likelihood is then the multiplication of the initiating event likelihood by the Probability of Failure on Demand (PFD) of each Independent Layer of Protection (IPL) associated to this initiating event.

Calculated Likelihood = ∑(Initiating Event likelihood x TAR x ETP) x PFD1 x PFD2 x … x PFDn.

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Step 8: Calculation of RRF/PFD/SIL

The Risk Reduction Factor (RRF) required for the additional SIF is then the ratio between the total calculated likelihood and the target likelihood.

RRF= (Calculated likelihood/ Target likelihood)

PFDavg =1/RRF

Target SIL Level	Requirements	RRF
a	No Special Safety Requirements	1<RRF<=10
---	No Safety Requirements	(Without ESD Loop Risk is Acceptable)

SIL Safety Integrity Level	PFDavg Average probability of failure on demand per year (low demand)	RRF Risk Reduction Factor
SIL 4	≥ 10^{-5} and < 10^{-4}	100000 to 10000
SIL 3	≥ 10^{-4} and < 10^{-3}	10000 to 1000
SIL 2	≥ 10^{-3} and < 10^{-2}	1000 to 100
SIL 1	≥ 10^{-2} and < 10^{-1}	100 to 10

At the end of the LOPA the 3 following parameters are essential for the next phase in Safety Life Cycle (SIL Verification???):

- SIL assignment
- PFDavg
- RRF.

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Personal Information

For any questions in any time about following expertise, please let me know and contact to me.

Expertise:

- Hazard identification by HAZOP Method
- Safety Integrity Level (SIL)
- Reliability, Availability and Maintenance (RAM)
- Functional Safety
- Consequence Modeling and Analysis (PHAST Software)
- Quantitative Risk Assessment (PHAST Risk Software)
- Qualitative/semi-qualitative Risk Assessment

For more information please see my LinkedIn profile

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