ADNOC HSE STANDARDS TRAINING

HAZARD AND OPERABILITY STANDARD (HSE-RM-ST04)
HAZOP LEADER / CHAIR MAN

ABU DHABI NATIONAL OIL COMPANY

Common Rules and Regulations

Complete attendance register

Rest rooms

Class Schedule - Breaks

Smoking

Mobile switched off or silent mode

Emergency Evacuation

Upon hearing any alarm, control yourself.

Find your safest route of evacuation

Go to the assembly point and wait for further instruction.

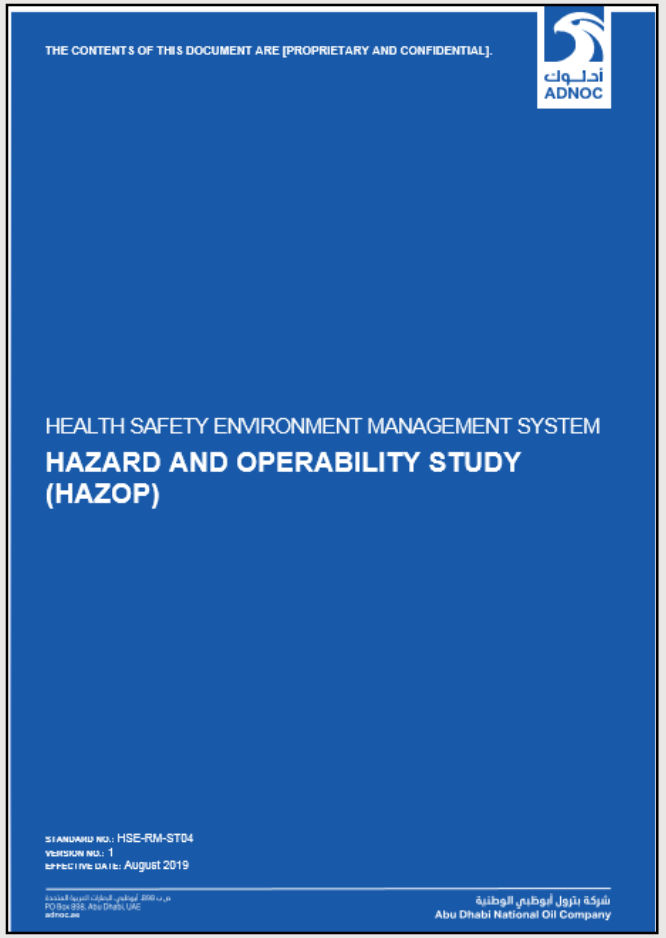
Introspection Moment

- In our Industry we are constantly faced with risk.
  Daily we encounter hazards that can cause harm; whether from a simple trip and fall, a road accident, a leak, or an explosion and fire.
- One of our key responsibilities, and a clear duty, is to manage this risk, and ensure that we protect:
  - Our Selves
  - Our Colleagues
  - Our Company
  - Our Future

- What are the critical enablers, that we need to have, to help us effectively achieve the goal of zero accidents?

INTRODUCTION

- ADNOC Hazard and Operability Study (HAZOP) Standard (HSE-RM-ST04)
- New Standard (No Legacy CoP)



PURPOSE

- Provides an overall understanding of the HAZOP processes and their application within the ADNOC Group
- Establishes the consistent requirements for planning, conducting and documenting HAZOP Studies within ADNOC Group
- Provides a formal system of review and authorization for the close-out of HAZOP action recommendations.

SCOPE

The Standard stipulates the mandatory requirements applicable to ADNOC Group (Directorates & Functions at HQ, Group Companies and Affiliates) and its Contractors.

ADNOC Group and Contractors shall ensure that all expectations listed herein are fully understood, implemented and thoroughly monitored.

Training Agenda

TRAINING AGENDA

Day 1

Hazards, accidents,
Process Safety Management (PSM) &

Process Hazard Analysis (PHA)

Day 2

HAZOP Studies

Day 3

Continued HAZOP Studies Recording and Reporting, FTA

Day 4

FMEA , LOPA

Day 5

HAZOP Studies workshops

DAY 1

Hazards, accidents, Process Safety Management (PSM) & Process Hazard Analysis (PHA)

LECTURE TOPICS

- Hazards and Accidents
- Process Safety Management (PSM)
- Process Hazard Analysis (PHA)

LEARNING OBJECTIVES

- Describe the hazard and accident-driven stimulus for, and main components of *Process Safety Management* standard
- Define *Process Hazard Analysis* and related terminology
- Describe major hazard analysis methods
- Assess applicability (via pros and cons) of major hazard analysis methods

HAZARDS

An inherent physical or chemical characteristic that has the potential for causing harm to people, the environment, or property.[1]

Hazards are intrinsic to a material, or its conditions of use

Examples

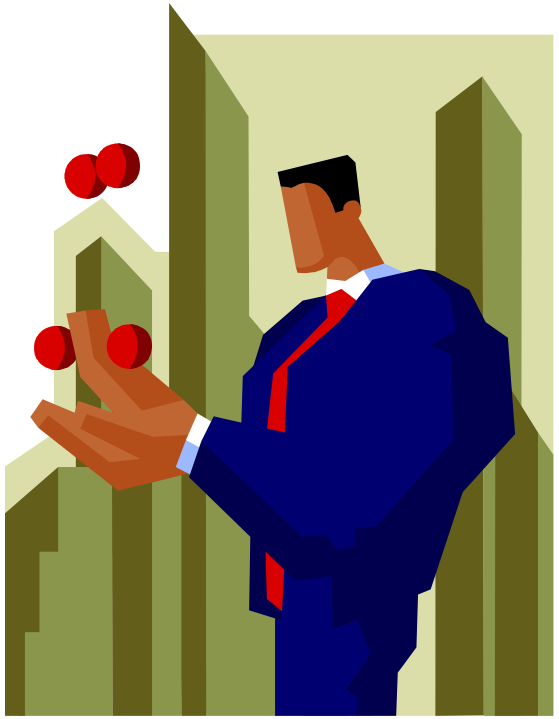
- Hydrogen sulfide – toxic by inhalation
- Gasoline – flammable
- Moving machinery – kinetic energy, pinch points

[1] *AICHE Center for Chemical Process Safety*

HAZARD MANAGEMENT:
THE WORLD AS IT WAS BEFORE

Good people

… doing good things



THE RISING CASE FOR CHANGE

- 1984 – Bhopal, India – Toxic Material Released

- 2,500 immediate fatalities; 20,000+ total
- Many other offsite injuries

THE RISING CASE FOR CHANGE

1984 – Mexico City, Mexico –Explosion

- 300 fatalities

  (mostly offsite)

- $20M damages

THE RISING CASE FOR CHANGE

1988 – Norco, LA – Explosion

- 7 onsite fatalities, 42 injured
- $400M+ damages

THE RISING CASE FOR CHANGE

1989 – Pasadena, TX – Explosion and Fire

- 23 fatalities, 130 injured; damage $800M+

ENTER … PROCESS SAFETY MANAGEMENT

Integral part of OSHA Occupational Safety and Health Standards since 1992

Known formally as: *Process Safety Management of Highly Hazardous Chemicals* (29 CFR 1910.119)

PSM applies to most industrial processes containing 10,000+ pounds of hazardous material

IN A FEW WORDS, WHAT IS PSM?

The ***proactive*** and ***systematic*** identification, evaluation, and mitigation or prevention of chemical releases that could occur as a result of failures in process, procedures, or equipment.

WHAT'S COVERED BY PSM?

Process Safety Information

Employee Involvement

Process Hazard Analysis

Operating Procedures

Training

Contractors

Pre-Startup Safety Review

Mechanical Integrity

Hot Work

Management of Change

Incident Investigation

Emergency Planning and Response

Compliance Audits

Trade Secrets

PROCESS HAZARD ANALYSIS

- Simply, PHA allows the employer to:
- Determine locations of potential safety problems
- Identify corrective measures to improve safety
- Preplan emergency actions to be taken if safety controls fail

PHA REQUIREMENTS

- Use one or more established methodologies appropriate to the complexity of the process
- Performed by a team with expertise in engineering and process operations
- Includes personnel with experience and knowledge specific to the process being evaluated and the hazard analysis methodology being used

PHA MUST ADDRESS …

- The hazards of the process
- Identification of previous incidents with likely potential for catastrophic consequences
- Engineering and administrative controls applicable to the hazards and their interrelationships

PHA MUST ADDRESS … (CONT'D)

- Consequences of failure of engineering and administrative controls, especially those affecting employees
- Facility siting; human factors
- The need to promptly resolve PHA findings and recommendations

HAZARD ANALYSIS METHODOLOGIES

- What-If
- Checklist
- What-If/Checklist
- Hazard and Operability Study (HAZOP)
- Failure Mode and Effects Analysis (FMEA)
- Fault Tree Analysis
- An appropriate equivalent methodology

WHAT-IF

- Experienced personnel brainstorming a series of questions that begin, "What if…?”
- Each question represents a potential failure in the facility or misoperation of the facility
- The response of the process and/or operators is evaluated to determine if a potential hazard can occur
- If so, the adequacy of existing safeguards is weighed against the probability and severity of the scenario to determine whether modifications to the system should be recommended

WHAT-IF – STEPS

1. Divide the system up into smaller, logical subsystems
2. Identify a list of questions for a subsystem
3. Select a question
4. Identify hazards, consequences, severity, likelihood, and recommendations
5. Repeat Step 2 through 4 until complete

WHAT-IF QUESTION AREAS

Equipment failures	– What if … a valve leaks?
Human error	– What if … operator fails to restart pump?
External events	– What if … a very hard freeze persists?

WHAT-IF – SUMMARY

- Perhaps the most commonly used method
- One of the least structured methods
  - Can be used in a wide range of circumstances
  - Success highly dependent on experience of the analysts
- Useful at any stage in the facility life cycle
- Useful when focusing on change review

CHECKLIST

- Consists of using a detailed list of prepared questions about the design and operation of the facility

- Questions are usually answered “Yes” or “No”

- Used to identify common hazards through compliance with established practices and standards

CHECKLIST QUESTION CATEGORIES

- Causes of accidents
  - Process equipment
  - Human error
  - External events

- Facility Functions
  - Alarms, construction materials, control systems, documentation and training, instrumentation, piping, pumps, vessels, etc.

CHECKLIST QUESTIONS

- Causes of accidents

  - Is process equipment properly supported?
  - Is equipment identified properly?
  - Are the procedures complete?
  - Is the system designed to withstand hurricane winds?

- Facility Functions

  - Is is possible to distinguish between different alarms?
  - Is pressure relief provided?
  - Is the vessel free from external corrosion?
  - Are sources of ignition controlled?

CHECKLIST – SUMMARY

- The simplest of hazard analyses
- Easy-to-use; level of detail is adjustable
- Provides quick results; communicates information well
- Effective way to account for ‘lessons learned’
- **NOT** helpful in identifying new or unrecognized hazards
- Limited to the expertise of its author(s)

- Should be prepared by experienced engineers
- Its application requires knowledge of the system/facility and its standard operating procedures
- Should be audited and updated regularly

WHAT-IF/CHECKLIST

- A hybrid of the What-If and Checklist methodologies

- Combines the *brainstorming* of What-If method with the *structured features* of Checklist method

WHAT-IF/CHECKLIST – STEPS

- Begin by answering a series of previously-prepared ‘What-if’ questions

- During the exercise, brainstorming produces additional questions to complete the analysis of the process under study

WHAT-IF/CHECKLIST – SUMMARY

- Encourages creative thinking (What-If) while providing structure (Checklist)
- In theory, weaknesses of stand-alone methods are eliminated and strengths preserved – not easy to do in practice
- E.g.: when presented with a checklist, it is typical human behavior to suspend creative thinking

HAZOP

- ***Haz****ard and* ***Op****erability Analysis*
- Identify hazards (safety, health, environmental), and
- Problems which prevent efficient operation

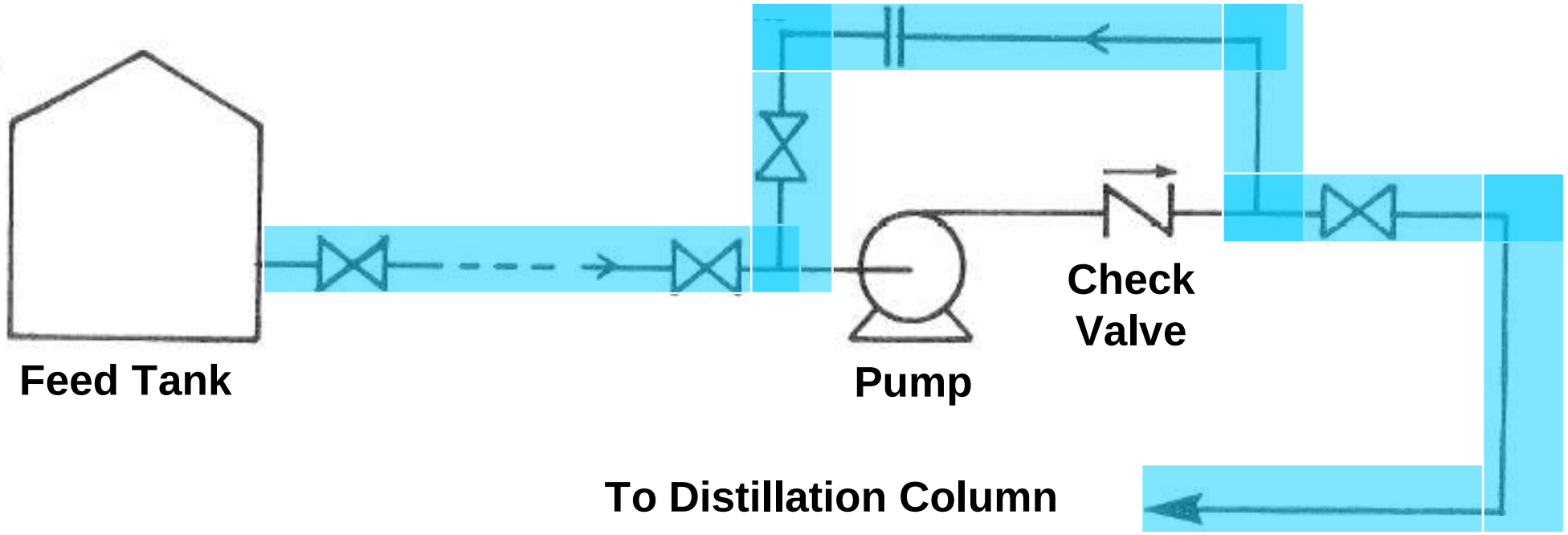
HAZOP

- Choose a vessel and describe intention
- Choose and describe a flow path
- Apply ***guideword*** to ***deviation***
  - Guidewords include **NONE, MORE OF, LESS OF, PART OF, MORE THAN, OTHER THAN, REVERSE**
  - Deviations are expansions, such as **NO FLOW, MORE PRESSURE, LESS TEMPERATURE, MORE PHASES THAN** (there should be),

HAZOP

1. Vessel

2. FLOW PATH



3. REVERSAL OF FLOW

HAZOP

4. Can deviation initiate a hazard of consequence?

5. Can failures causing deviation be identified?

6. Investigate detection and mitigation systems

7. Identify recommendations

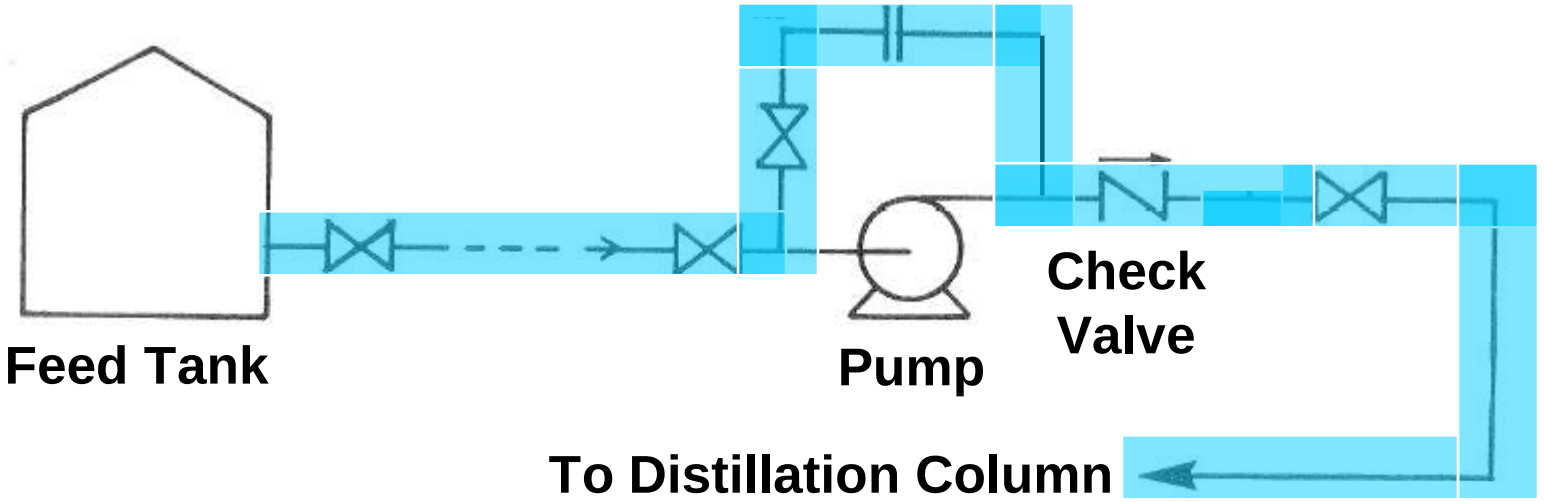
8. Document

9. Repeat 3-to-8, 2-to-8, and 1-to-8 until complete

HAZOP

1. Vessel

2. FLOW PATH



3. REVERSAL OF FLOW
4. Distillation materials returning via pumparound
5. Pump failure could lead to REVERSAL OF FLOW
6. Check valve located properly prevents deviation
7. Move check valve downstream of pumparound

LOSS OF CONTAINMENT DEVIATIONS

- Pressure too high
- Pressure too low (vacuum)
- Temperature too high
- Temperature too low
- Deterioration of equipment

HAZOP'S INHERENT ASSUMPTIONS

- Hazards are detectable by careful review
- Plants designed, built and run to appropriate standards will not suffer catastrophic *loss of containment* if ops stay within design parameters
- Hazards are controllable by a combination of equipment, procedures which are *Safety Critical*
- HAZOP conducted with openness and good faith by competent parties

HAZOP – PROS AND CONS

PROS

- Creative, open-ended
- Completeness – identifies all process hazards
- Rigorous, structured, yet versatile
- Identifies safety ***and*** operability issues

CONS

- Can be time-consuming (e.g., includes operability)
- Relies on having right people in the room
- Does not distinguish between low probability, high consequence events (and vice versa)

FMEA – FAILURE MODES, EFFECTS ANALYSIS

- **Manual analysis** to determine the consequences of component, module or subsystem failures

- Bottom-up analysis

- Consists of a spreadsheet where each failure mode, possible causes, probability of occurrence, consequences, and proposed safeguards are noted.

FMEA – FAILURE MODE KEYWORDS

- Rupture
- Crack
- Leak
- Plugged
- Failure to open
- Failure to close
- Failure to stop
- Failure to start
- Failure to continue
- Spurious stop
- Spurious start
- Loss of function
- High pressure
- Low pressure
- High temperature
- Low temperature
- Overfilling
- Hose bypass
- Instrument bypassed

FMEA ON A HEAT EXCHANGER

Failure Mode	Causes of Failure	Symptoms	Predicted Frequency	Impact
Tube rupture	Corrosion from fluids (shell side)	H/C at higher pressure than cooling water	Frequent – has happened 2x in 10 yrs	Critical – could cause a major fire

- Rank items by risk (frequency x impact)
- Identify safeguards for high risk items

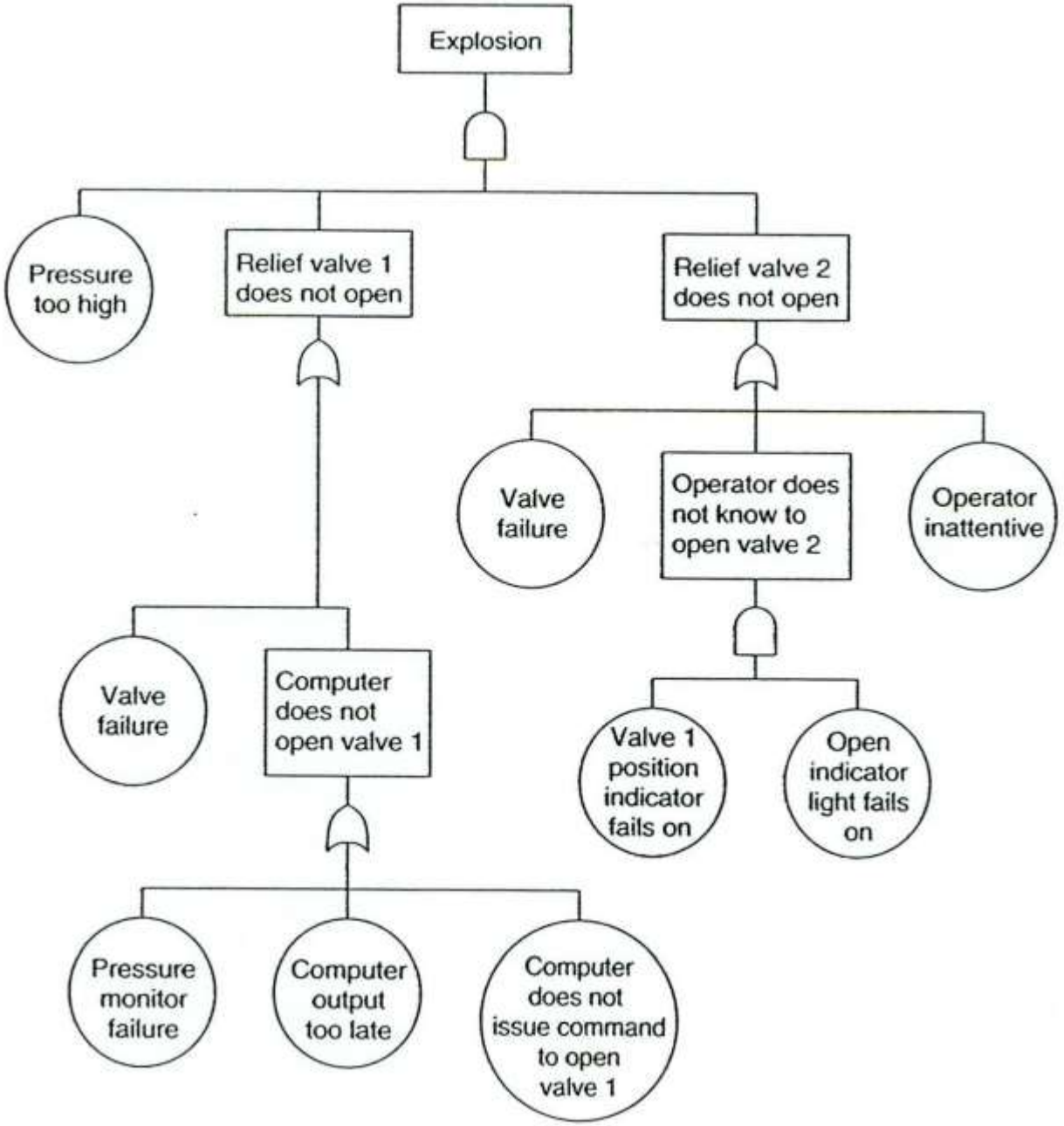
FMEA – FAILURE MODES, EFFECTS ANALYSIS

- FMEA is a very structured and reliable method for evaluating hardware and systems.
- Easy to learn and apply and approach makes evaluating even complex systems easy to do.
- Can be very time-consuming (and expensive) and does not readily identify areas of multiple fault that could occur.
- Not easily lent to procedural review as it may not identify areas of human error in the process.

FAULT TREE ANALYSIS

- **Graphical method** that starts with a hazardous event and works backwards to identify the causes of the ***top event***
- Top-down analysis
- Intermediate events related to the top event are combined by using logical operations such as AND and OR.

FTA


Explosion
Pressure too high
Relief valve 1 does not open
Relief valve 2 does not open
Valve failure
Operator does not know to open valve 2
Operator inattentive
Valve failure
Computer does not open valve 1
Valve 1 position indicator fails on
Open indicator light fails on
Pressure monitor failure
Computer output too late
Computer does not issue command to open valve 1

FAULT TREE ANALYSIS

- Provides a traceable, logical, quantitative representation of causes, consequences and event combinations
- Amenable to – but for comprehensive systems, requiring – use of software
- Not intuitive, requires training
- Not particularly useful when temporal aspects are important

ACCIDENT SCENARIOS MAY BE MISSED BY PHA

- No PHA method can identify all accidents that could occur in a process
- A scenario may be excluded from the scope of the analysis
- The team may be unaware of a scenario
- The team consider the scenario but judge it not credible or significant
- The team may overlook the scenario

SUMMARY

Despite the aforementioned issues with PHA:

- Companies that rigorously exercise PHA are seeing a continuing reduction is frequency and severity of industrial accidents

- ***Process Hazard Analysis*** will continue to play an integral role in the design and continued examination of industrial processes

USING WHAT YOU LEARN

- The ideas and techniques of Process Hazard Analysis will be immediately useful in upcoming recitation exercise on **Hazard Evaluation**

- Expect to be part of a Process Hazard Analysis Team early on in your professional career

WHERE TO GET MORE INFORMATION

Chemical Safety and Hazard Investigation Board's web site: *www.csb.gov*

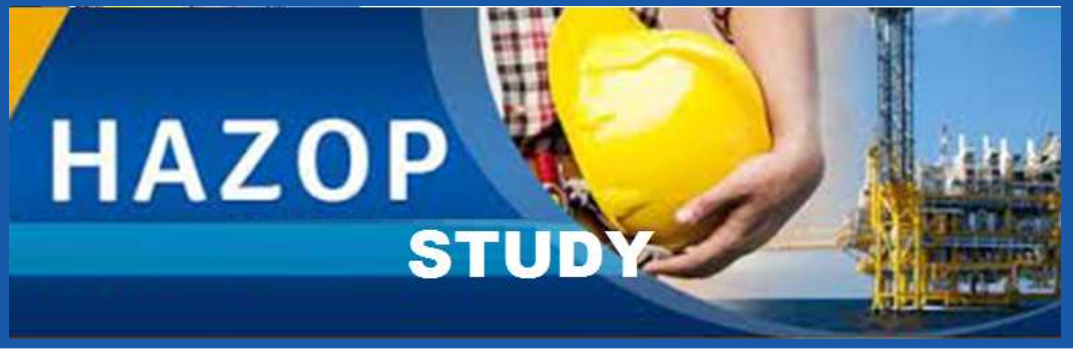
MPRI web site: *www. Mpri.lsu.edu/main/*

Crowl and Louvar – *Chemical Process Safety: Fundamentals with Applications*

Kletz – *HAZOP & HAZAN: Notes on the Identification and Assessment of Hazards*

DAY 2

HAZARD AND OPERABILITY STUDY



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KEY CONTENTS

- HAZOP Through Project / Facility Lifecycle *– Refer Section 7.1 of the Standard*
- Overview of HAZOP Process *– Refer Section 7.3 of the Standard*
- HAZOP Study Methodology *– Refer Section 7.5 of the Standard*
- HAZOP Study Team *– Refer Section 7.5.11 of the Standard*
- HAZOP Recording and Reporting *– Refer Section 7.6 of the Standard*
- HAZOP Action Tracking and Follow-Up *– Refer Section 7.7 of the Standard*
- Key Performance Indicators *– Refer Section 8.1 of the Standard*
- Links to ADNOC Standards *– Refer Section 9 of the Standard*
- Appendices *– Refer Section 10 of the Standard*

Training Agenda

- HAZOP features
- HAZOP Team Members
- Where does HAZOP fit?
- HAZOP Terminology and Sequence
- How we do a HAZOP Study?
- Risk Rating
- Explained Complex Case Study
- Simple Case Study
- Fault Tree Analysis

TRAINING OBJECTIVES

On successful completion of this course you will :

- Learn how the HAZOP technique is applied at different stages of a project's lifecycle i.e.
- FEED (Front End Engineering Design), detailed design, operations, revalidation and decommissioning, and for different types
- of process operations
- Prepare for a HAZOP workshop, determine the skills and actions necessary for a HAZOP,
- generate a HAZOP report, review HAZOP worksheets and recommendations.

CONTENTS

- Introduction, background and need for HAZOP
- Overview of the HAZOP process
- The HAZOP process in detail
- HAZOP team members and competencies
- HAZOP typical examples and applications
- Typical HAZOP failings, limitations and shortcomings
- HAZOP results, record-keeping and report writing
- HAZOP Practical exercises

INTRODUCTION

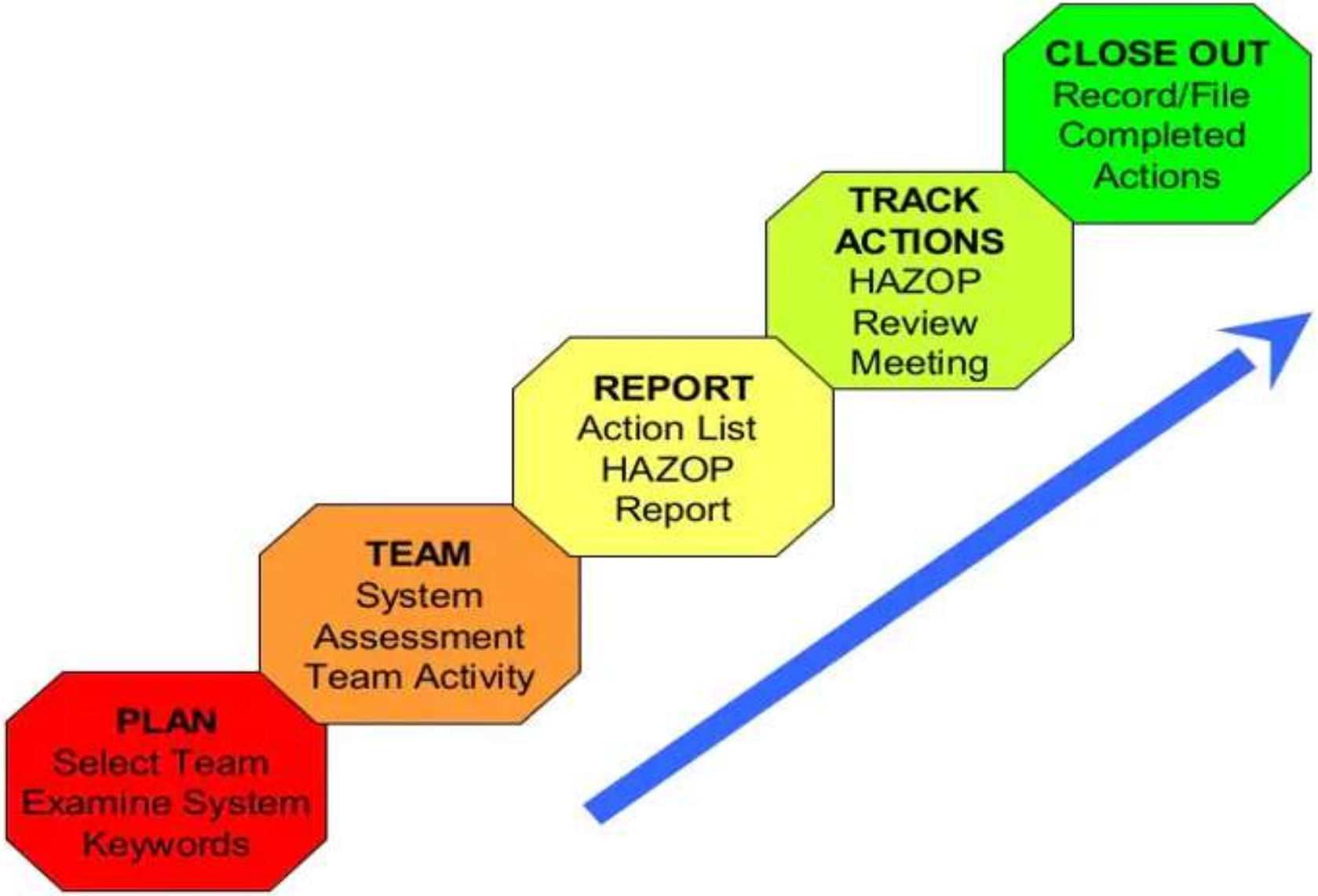
What Is HAZOP Study ?

- Systematic technique to IDENTIFY potential HAZard and OPerating problems
- Involves a multi-disciplinary team methodically “brainstorming” the plant design
- A qualitative technique based on “guide-words” to help provoke thoughts about the way deviations from
- the intended operating conditions can lead to hazardous situations or operability problems

Abbreviations and Terms

DG – Dangerous Goods.
Facility – any building or structure at which materials are present.
FMEA / FMECA – Failure mode and effects analysis /
Failure mode and effects criticality analysis.
FTA – Fault Tree analysis.
HAZID – Hazard Identification.
HAZOP – Hazard and operability study.
LOC – Loss of Containment.
LOPA – layers of Protection analysis.
MHF – Major Hazard facility.
MA – Major accident.
PFD – Process Flow Diagram.
P&ID – Piping and instrumentation diagram.
PSV – Pressure safety valve.
SMS – safety management system.\
FEED – Front-End Engineering Design
SAFOP – Safety and Operability.
RPN – Risk Priority Number
SIL – safety Integrity Level

HAZOP Planning and Execution



When to perform a HAZOP ?

HAZOP studies may also be used more extensively, including:

- At the initial concept stage when design drawings are available
- When the final piping and instrumentation diagrams (P&ID) are available
- During construction and installation to ensure that recommendations are implemented
- During commissioning
- During operation to ensure that plant emergency and operating procedures are regularly reviewed and updated as required

TYPE OF HAZOP

Process HAZOP

✦ The HAZOP technique was originally developed to assess plants and process systems

Human HAZOP

✦ A “family” of specialized HAZOPs. More focused on human errors than technical failures

Procedure HAZOP

✦ Review of procedures or operational sequences

Sometimes denoted SAFOP - SAFety Operation Study

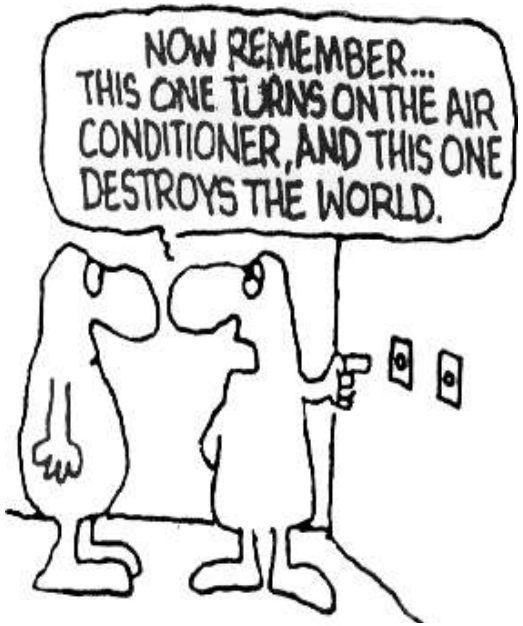
Software HAZOP

✦ Identification of possible errors in the development of software

PURPOSE OF A HAZOP

The purpose of a HAZOP study is to:

- Identify the causes of potential safety and environmental hazards and major operability problems.
- Consider the consequences of these hazards and major operability problems.
- Identify the safeguards provided as hazard prevention or mitigation.
- Propose recommendations, as needed, to prevent, control, or mitigate hazards.
- Provide assistance to facility management in their efforts to manage risks.
- It is important to remember the “Op” bit in Hazop



PURPOSE OF A HAZOP

HAZOP **is** for

- Identifying hazards and operability problems
  - is it safe?
  - will it work?
  - can it be maintained?
- Recommending where additional study is required

HAZOP **is not** a means to

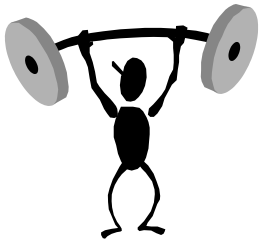
- Complete the design by group
- Evaluate engineering / procedural solutions for hazards
- Debate differences over codes & standards

HAZOP to be done in line with Hazop Study Procedure of the company

HAZOP features

Strength and Weakness.
Advantages.
Success Factors.
Pitfalls and objections.

HAZOP FEATURES



Strengths

Leverages skills / experience of multi-disciplinary team

Structured process

Operations input

Preferred technique with new or revised P&IDs

Weaknesses

- Lower quality study may result from:
  - Incomplete information
  - Lack of team & management commitment
  - Inappropriate selection of team members
  - Poor leadership

Advantages

- Systematic examination
- Multidisciplinary study
- Utilizes operational experience
- Covers safety as well as operational aspects
- Solutions to the problems identified may be indicated
- Considers operational procedures
- Covers human errors
- Study led by independent person
- Results are recorded

Success factors

- Accuracy of drawings and data used as a basis for the study
- Experience and skills of the HAZOP team leader
- Technical skills and insights of the team
- Ability of the team to use the HAZOP approach as an aid to identify deviations, causes, and consequences
- Ability of the team to maintain a sense of proportion, especially when assessing the severity of the potential consequences.

Pitfalls and objections

- Time consuming
- Focusing too much on solutions
- Team members allowed to divert into endless discussions of details
- A few of the team members dominate the discussion
- “This is my design/procedure”
- - Defending a design/procedure
- - HAZOP is not an audit
- No Problem
- “Wasted time”

HAZOP Team Members

Team Members Responsibilities
Team Members composition

ADNOC ROLES AND RESPONSIBILITIES

- *HAZOP Chairman*: responsible for ensuring that the HAZOP method is systematically applied in accordance with the requirements of the Standard.

- *HAZOP Secretary*: responsible for recording the HAZOP and aid the HAZOP Chairman in collation of documents and other administrative tasks.

- *HAZOP Team Members*: be knowledgeable in their respective discipline. It is preferable that HAZOP members have previously attended HAZOP and are familiar with the HAZOP technique.

HAZOP STUDY TEAM

- The personnel who form the core of the HAZOP Study team are:
  - HAZOP Team Chairman – minimum 10 years of relevant experience
  - HAZOP Secretary
  - HAZOP Team Members
- Further information on the responsibilities of the Chairman and Secretary are provided in the Standard
- HAZOP Team Members in the adjacent figure, as applicable for the study are required to be present.

DISCIPLINE	AREA OF EXPERTISE
Operations	Knowledge of DCS/Process control
Process Engineering	Peaks and troughs in throughput, historical data, changes to the process
Control & Instrumentation Engineer	Cause and effect diagrams, ESD, Interlocks, F&G systems
Instrument Maintenance	Operating and maintenance data for instruments
Technical HSE Representative	HSE hazards and effects associated with the system being studied including specialist HSE and risk input
Asset & Operating Integrity	Integrity risks associated with plants, pipeline, wells, vis-à-vis process conditions, etc. Past incidents involving corrosion. Lines handling known corrosive materials
Rotating Equipment	Operating and maintenance data for Turbines, Compressors and Pumps
Static Equipment	Operating and maintenance data for coolers, heat exchangers and fired heaters. Equipment data sheets.
Piping & Pipeline	Pressure/Temperature differentials, known forces and failures of piping/pipeline and supports. Stress analysis.
Maintenance	Pipe and flange alignments, Valves locked open/shut, electrical equipment modes of failure, electrical system design and compliance with codes, switchgear operation etc.

Section 7.5.11 in the Standard shall be referred for Risk Reduction Measures

Team member responsibilities

- HAZOP team leader

  Responsibilities:

  - Define the scope for the analysis
  - Select HAZOP team members
  - Plan and prepare the study Chair the HAZOP meetings

  - Trigger the discussion using guide-words and parameters
  - Follow up progress according to schedule/agenda
  - Ensure completeness of the analysis

The team leader should be independent (i.e., no responsibility for the process and/or the performance of operations)

Team member responsibilities

- HAZOP secretary

  Responsibilities:

  - Prepare HAZOP work-sheets
  - Record the discussion in the HAZOP meetings
  - Prepare draft report(s)

Team members

- HAZOP team members

  The basic team for a process plant may be:

  - Project engineer
  - Commissioning manager engineer
  - Process engineer
  - Instrument/electrical engineer Safety

Depending on the actual process the team may be enhanced by:

- Operating team leader
- Maintenance engineer
- Suppliers representative
- Other specialists as appropriate

RULES OF A HAZOP

Multi-disciplinary team

- 5-7 team members optimum
- Leader and scribe
- Team members may wear multiple hats

Shall have present: engineering and operating experience with

- Process/facility design
- Equipment, design limits, materials of construction, and condition of equipment being reviewed.
- Operations

May have present:

- Instrument or controls - control and shutdown hardware and logic.
- Corrosion and materials.
- Maintenance - instrumentation and/or mechanical.
- Mechanical.
- Inspection.

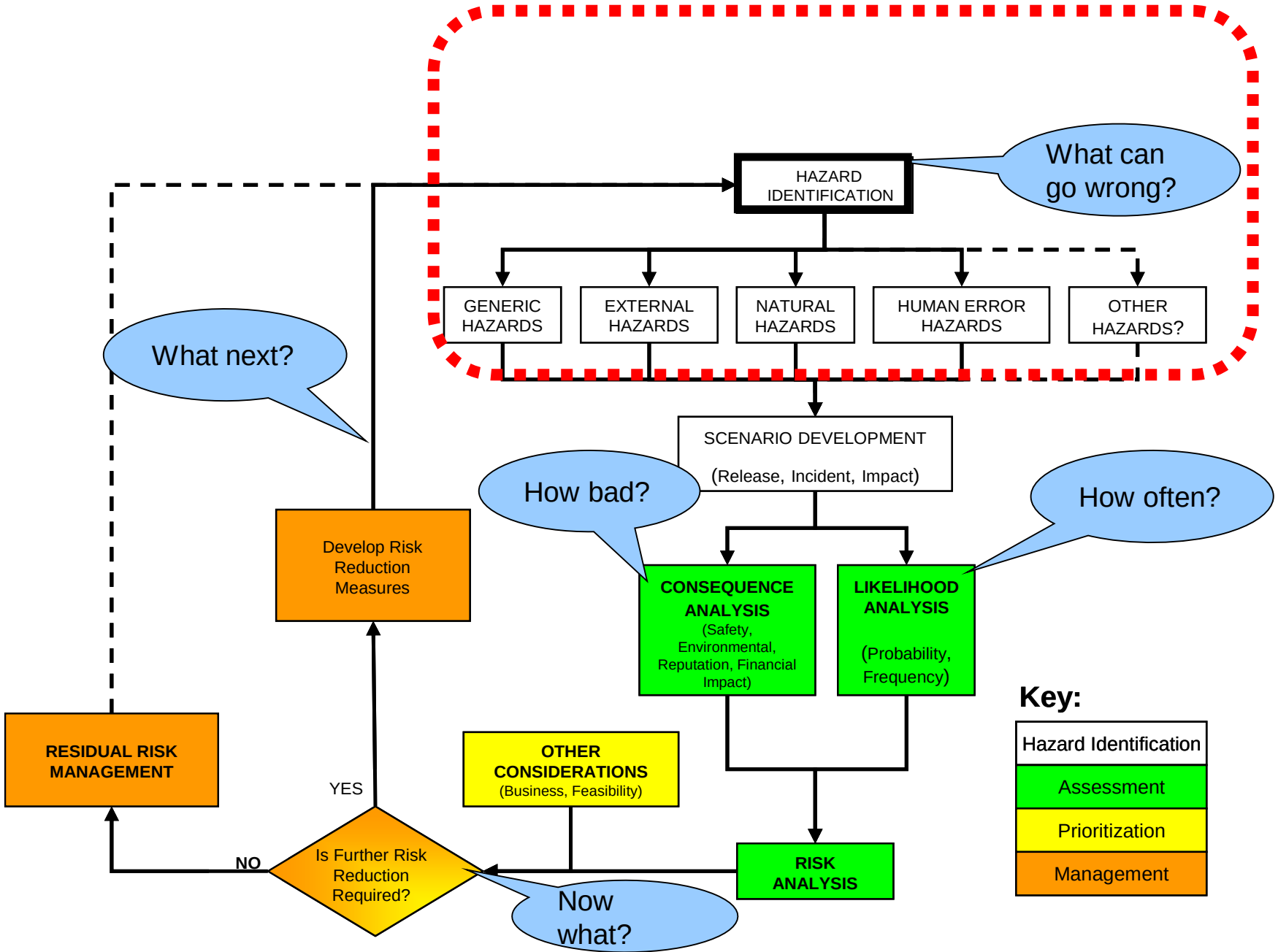
How to be a good HAZOP participant

- Be active! Everybody's contribution is important
- Be to the point. Avoid endless discussion of details
- Be critical in a positive way – not negative, but constructive
- Be responsible. Shee who knows should let the others know

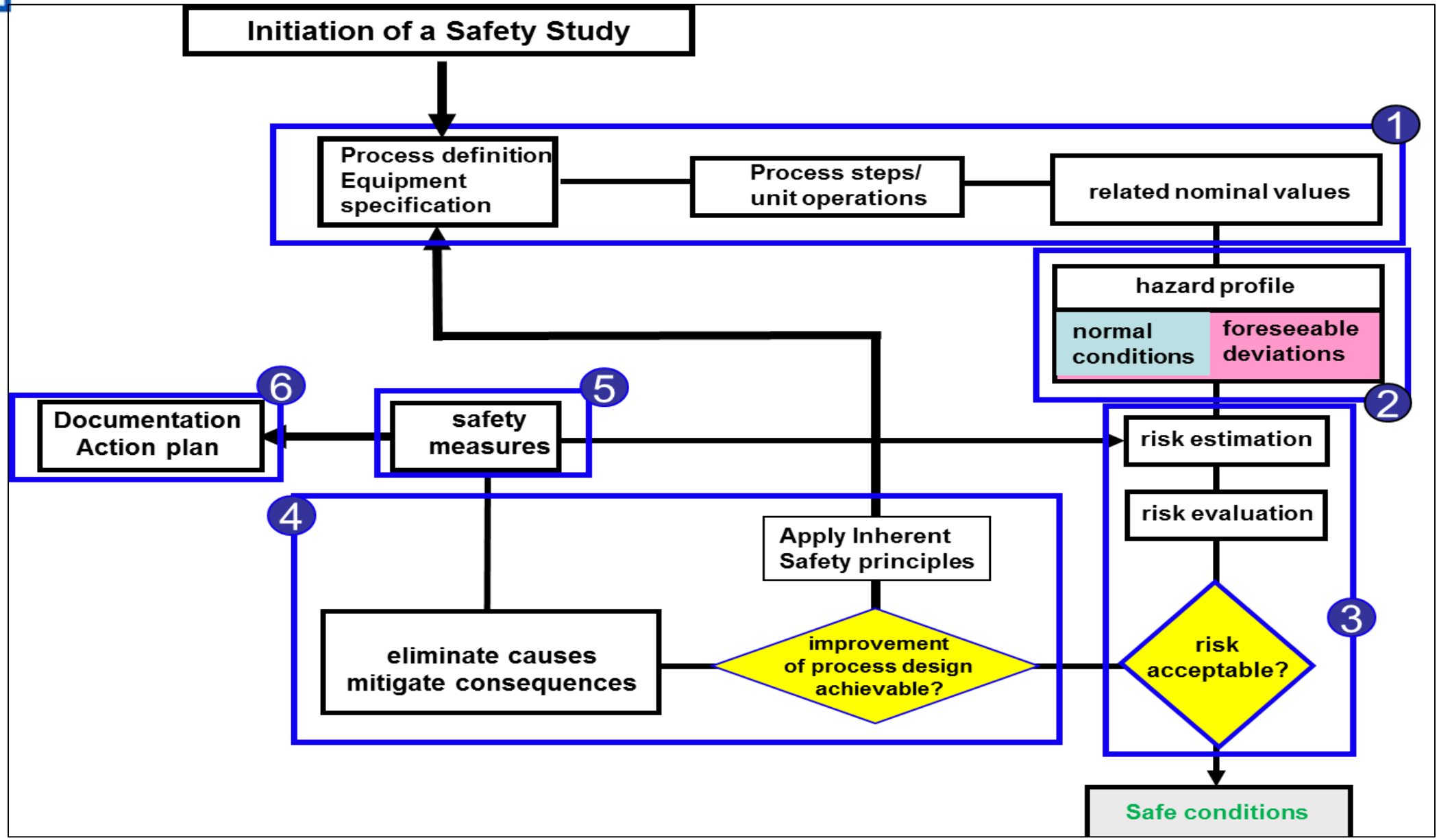
Where does HAZOP fit?

- Process Risk Analysis.
- Adequate Protection and the BOW-TIE.
- Sequential level of Control and Recovery.
- LOPA – Layer Of Protection Analysis.

WHERE DOES HAZOP FIT?



Process Risk Analysis Flow Diagram

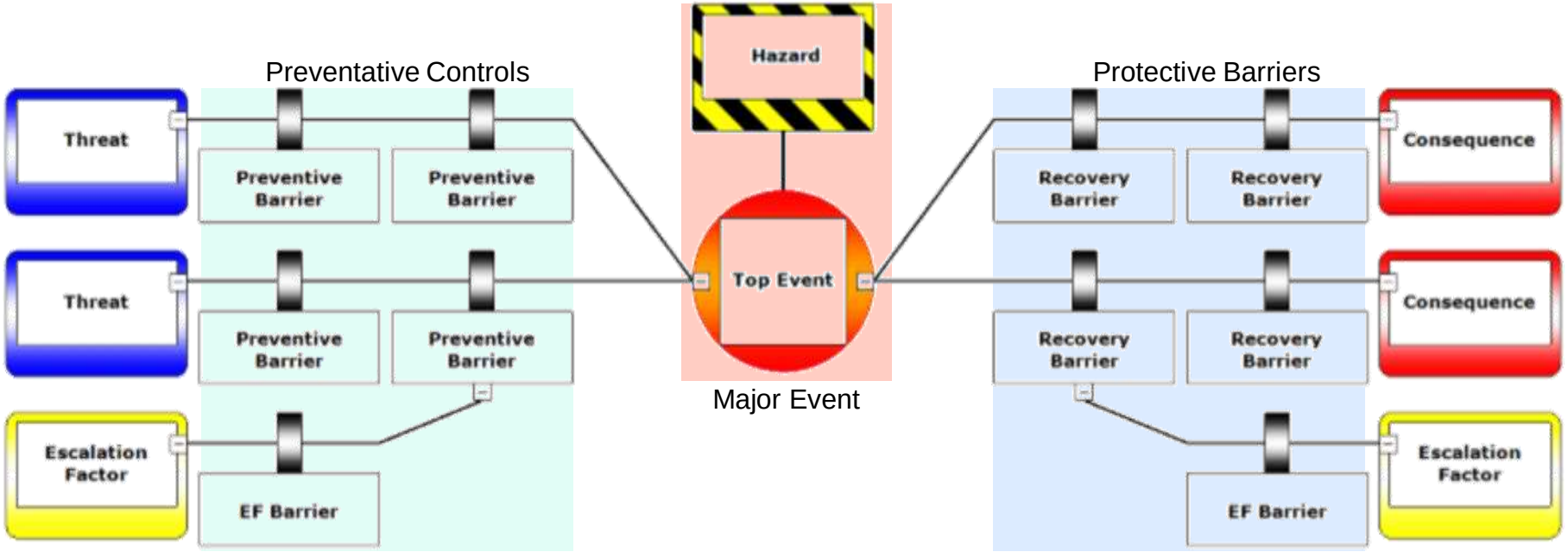


HAZARD AND OPERABILITY (HAZOP) STUDY

Adequate Protection

The Hazard Identification, Threat Recognition, Risk Assessment and Risk Mitigation processes aim to identify what could go wrong and how can we prevent it from happening or protect against it causing significant harm; what protection is needed.

This is normally achieved using a '**Bow-Tie**' analysis for each **Major Accident Hazard [MAH]** (Top Event), defining Preventative Barriers (Controls) and Protective Barriers (Recovery).



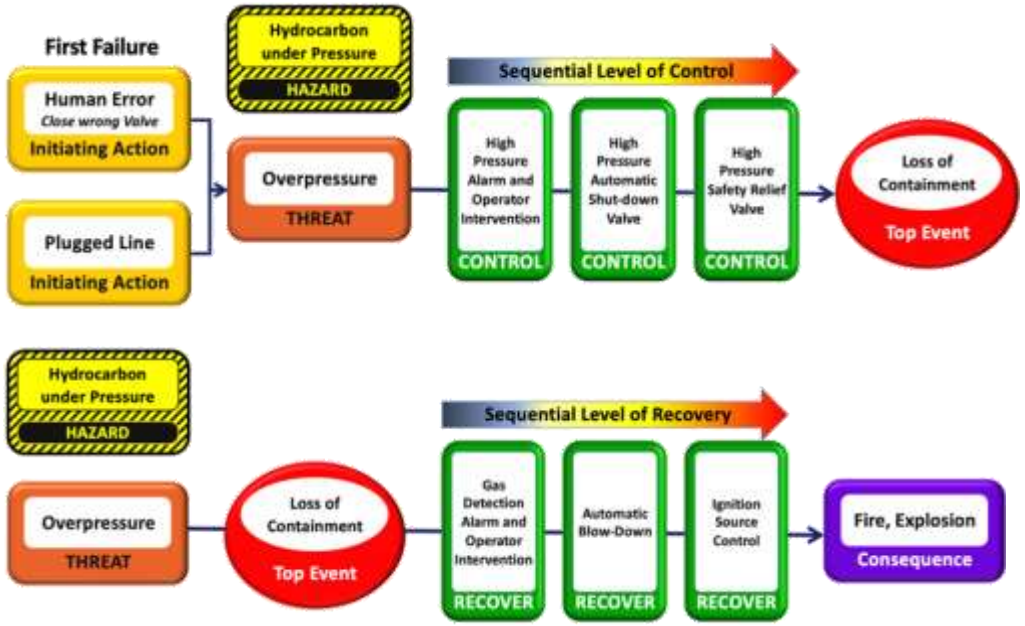
HAZARD AND OPERABILITY (HAZOP) STUDY

Adequate Protection

The Hazard Identification, Threat Recognition, Risk Assessment and Risk Mitigation processes aim to identify what could go wrong and how can we prevent it from happening or protect against it causing significant harm; what protection is needed.

The objective is to ensure that the design intent of the facility has Adeqaute Protection against conceivable, feasible, realistic top event scenarios.

“Do we have enough safeguarding Controls, Barriers and Recovery measures?”



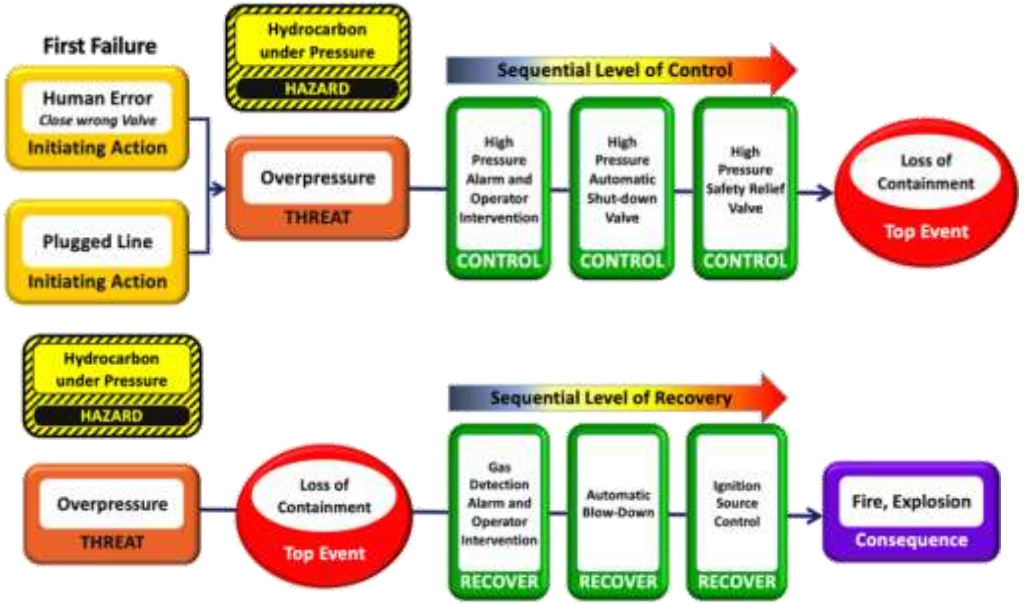
HAZARD AND OPERABILITY (HAZOP) STUDY

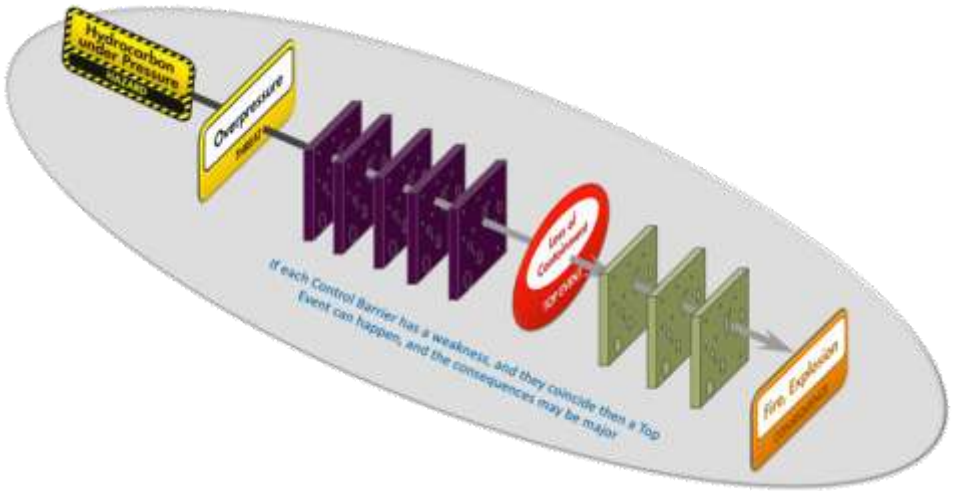
Adequate Protection

HAZID, HIRA and **HAZOP** are qualitative studies, looking for Hazards-Threats, potential Deviations from Design Intent, and Safeguards to prevent an Incident or Accidenbt.

If there is concern that existing Safeguards, plus HAZOP Recommendations, may not meet **ALARP** mitigation, then a **Layer of Protection Analysis [LOPA]** study can be implemented.

LOPA is semi-quantitative analysis that sequentially looks at the effectivenesss of the combination of Controls and Barriers and the Risks of multiple barrier failure.





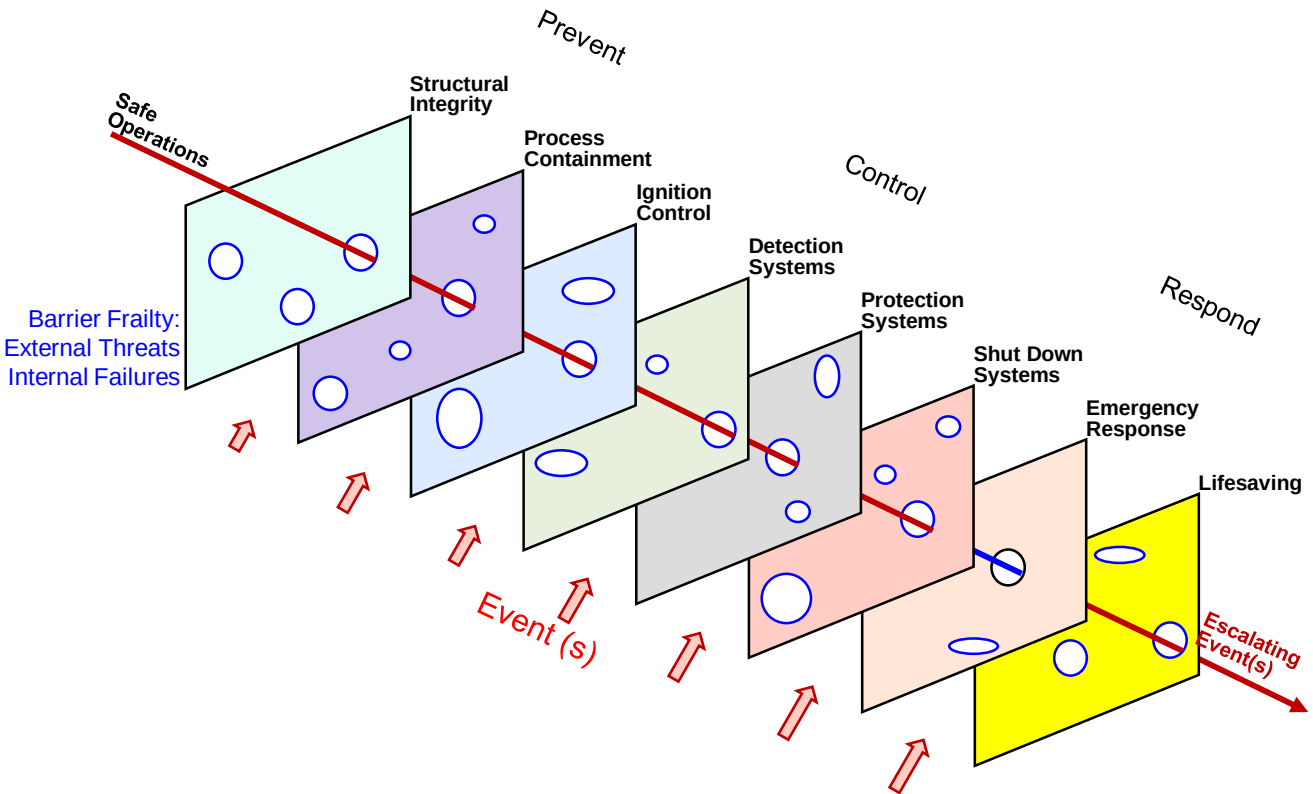
HAZARD AND OPERABILITY (HAZOP) STUDY

Adequate Protection

- **Barrier Protection**

LOPA looks at each of the layers of protection afforded by the various mitigation controls and barriers, evaluating each's potential to protect against other barrier faliures.

Each barrier layer may be comprised of one or more **Safety Critcal Elements [SCE]**



Note: It is not necessary for all 8 barrier systems to fail for a major accident to happen
e.g. the loss of Process Containment and Ignition Control barriers could lead to a fire or explosion

HAZARD AND OPERABILITY (HAZOP) STUDY

- **Barrier Protection**

  e.g. Vessel Structure Integrity and Stability

- Process Containment

  e.g. Tank Integrity, Piping and Joint Integrity, Valve Integrity

- Detection Systems

  e.g. Gas, Heat, Smoke, Fire Detection

- Ignition Control

  e.g. EEx/IEx equipment, Earth Bonding, Hot Surface Insulation

- Protection Systems

  e.g. Segregation,Explosion Walls, Fire Suppression

- Shut Down Systems

  e.g. ESDVs, EDP, Electrical Isolation, Product Segregation

- Emergency Response

  e.g. Clear Evacuation Routes with Emergency Lighting

- Life Saving

  e.g. Escape Systems

HAZOP Terminology and Sequence

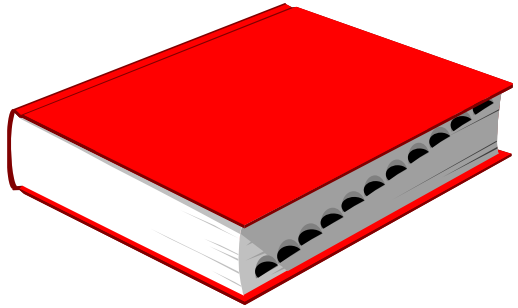
- Terminology.
- HAZOP Sequence.
- HAZOP flow diagram.
- HAZOP Procedures, and Parameters first approach.

TERMINOLOGY

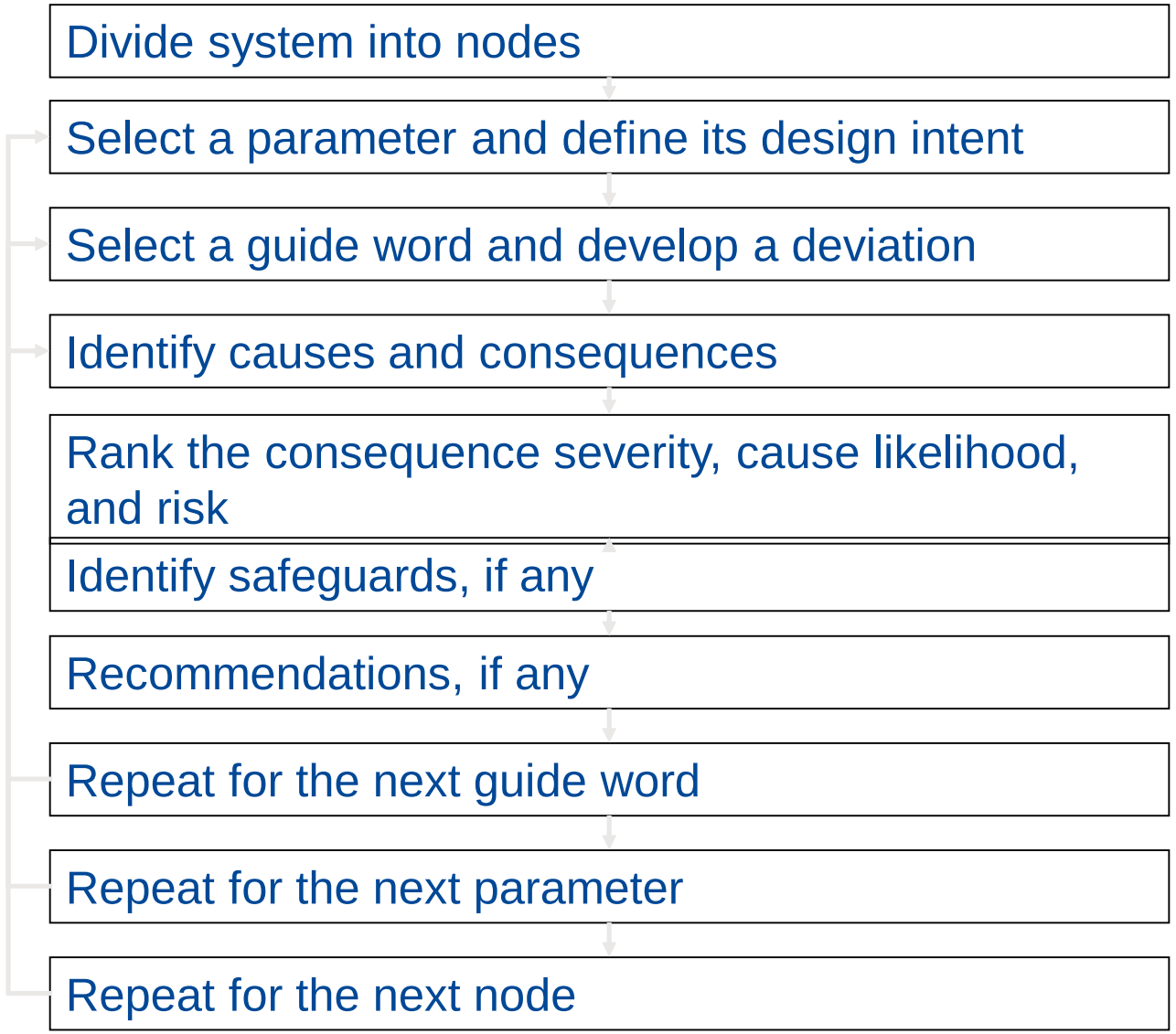
Nodes Parameters Intention

Guide words Deviations Causes

Consequences Safeguards Recommendations

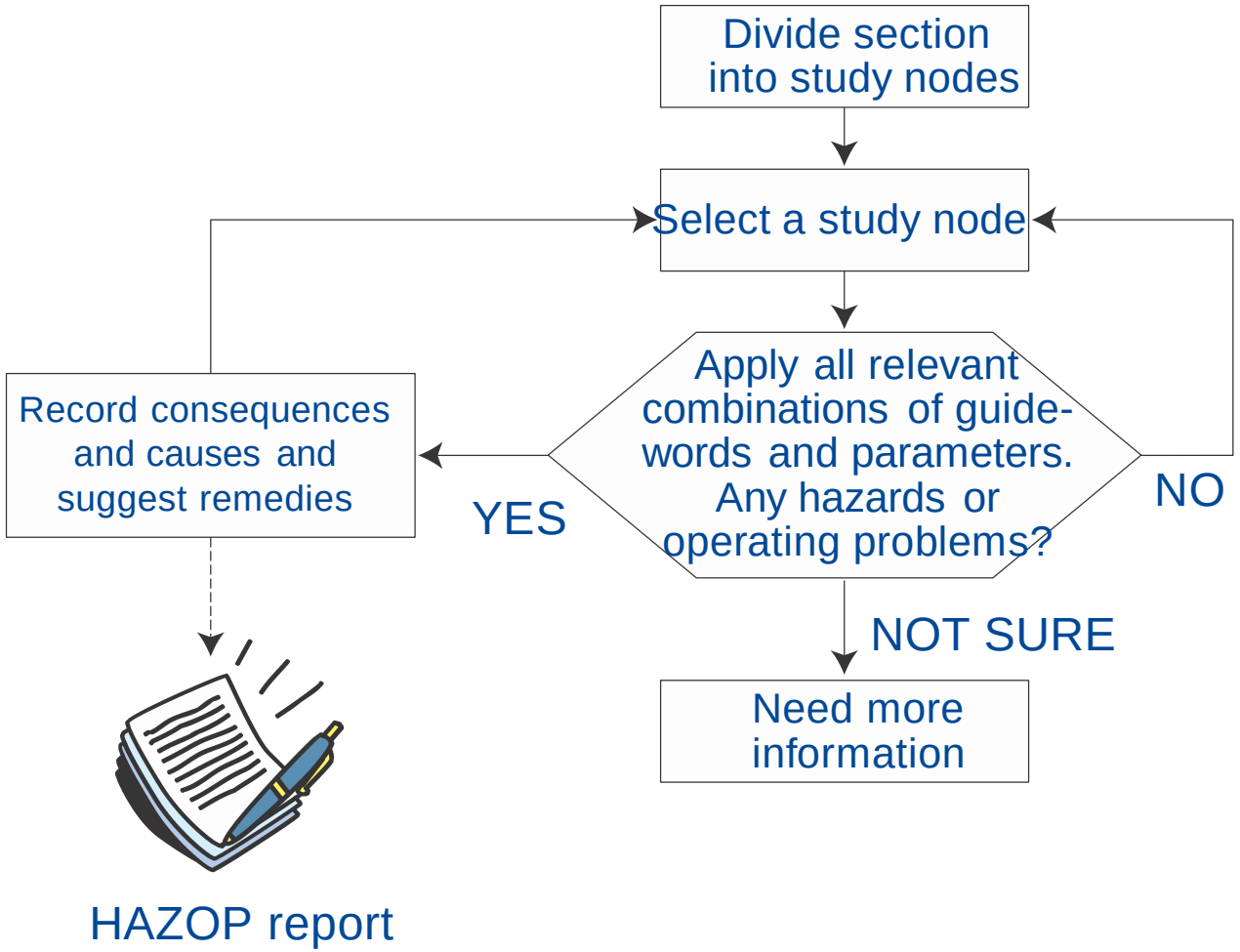


HAZOP SEQUENCE



HAZOP procedure

The HAZOP procedure may be illustrated as follows:



HAZOP METHODOLOGY

The study requires a full description of the process which includes a PFD, P&ID, C&E diagram, operation and control philosophies etc.

Nodes

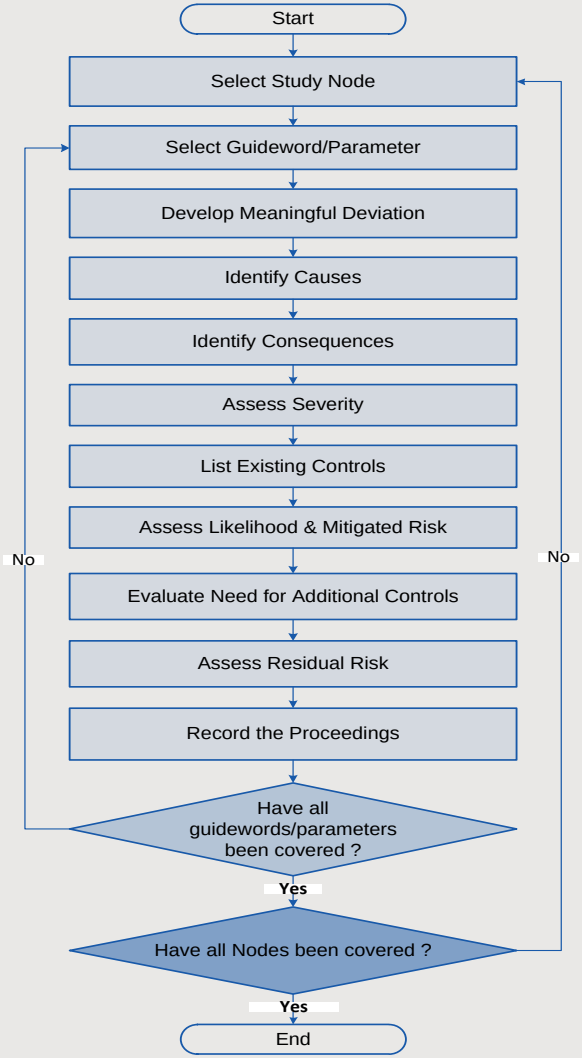
- HAZOP study progresses through the facility node by node.
- Following guidance should be referred for node selection:
  1. Major equipment (e.g. Vessel, distillation column etc.);
  2. Change in process fluid state (e.g. from liquid to vapor); and
  3. Change in design and operating parameters.

Design Intent and Parameters

- Design operating conditions of each applicable parameter (e.g. flow, pressure, temperature, level etc.) and normal operating conditions in the node shall be established.
- Design intent must be explained to HAZOP team (typically by the Process Engineer) along with the normal operating procedure.

Guidewords and Deviations

As provided in *Appendix 5* of the Standard



Section 7.5 in the Standard shall be referred for HAZOP Methodology

HAZOP METHODOLOGY

Causes

- All the potential causes of the deviation should be identified by the team brainstorming.
- “Double jeopardy” events shall not be considered in HAZOP study.

Note: Causes identified for the deviation must be within the node being studied e.g. equipment failure should be considered within the node. The exception is the battery limit or border node. If the node starts from a battery limit, causes from upstream and downstream must also be considered.

Consequences

- Having identified the credible causes of the deviation, the team members shall analyze and assess the significance of the consequences

Note: Consequences of the deviation identified in the node being studied can be within the node or outside the node being studied.

Safeguard (Controls)

- Identify all the existing safeguards that are available

Note: Safeguard (Controls) for the scenarios can be within the node or outside the node being studied.

Section 7.5 in the Standard shall be referred for HAZOP Methodology

HAZOP METHODOLOGY

Risk Assessment

- As per ADNOC Corporate Risk Assessment Matrix provided in *Appendix 1* of the Standard

Recommendations

- Includes Closed (Simple) Actions, Open (Complex) Actions, Conditional Recommendations

Linkage with LOPA

- Identified hazards (i.e. deviations) in the HAZOP Study with the estimated severity level of 4 or above ('Major', 'Catastrophic' or 'Disastrous') shall be further analyzed using Layer of Protection Analysis

Use of Documentation during the Study

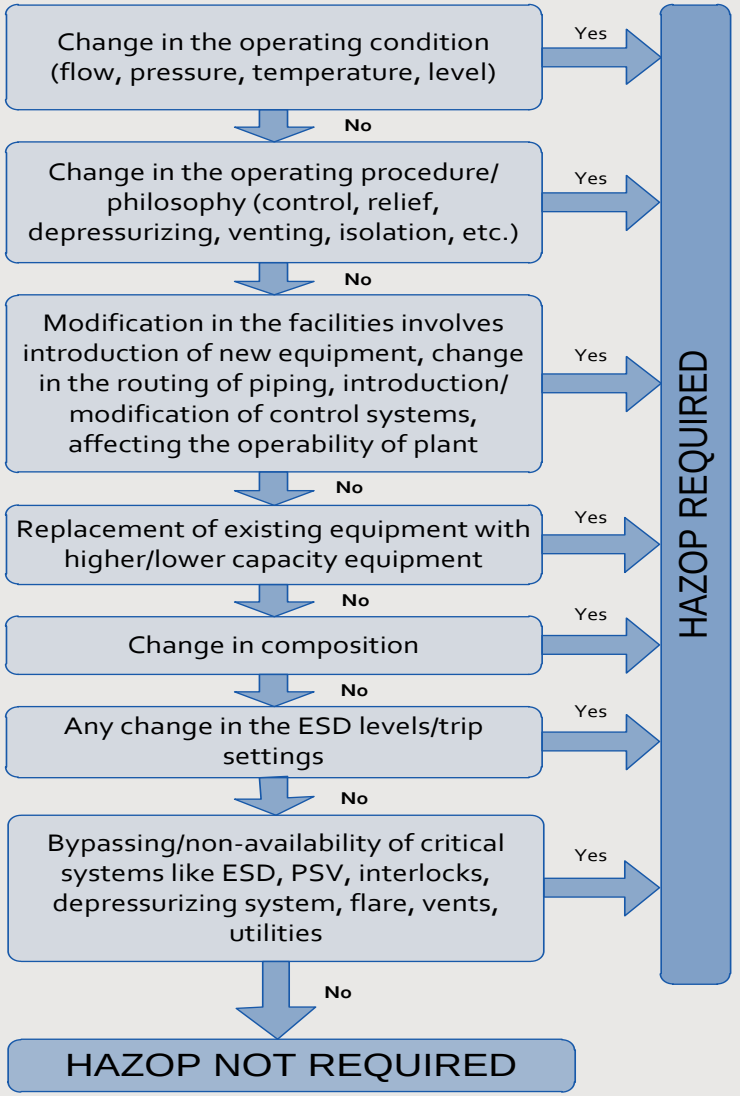
- Examples PFD, P&IDs, Layouts, C&E, SDS, HMB etc.

Section 7.5 in the Standard shall be referred for HAZOP Methodology

HAZOP THROUGH PROJECT/FACILITY LIFECYCLE

- The type of HAZOP required during the Asset Development Phase includes:
  - FEED Stage HAZOP
  - Detailed Engineering Stage (EPC) HAZOP
- The type of HAZOP required during the Asset Operating Phase include:
  - Management of change (MOC) HAZOP – screening as per adjacent figure
  - Revalidation HAZOP

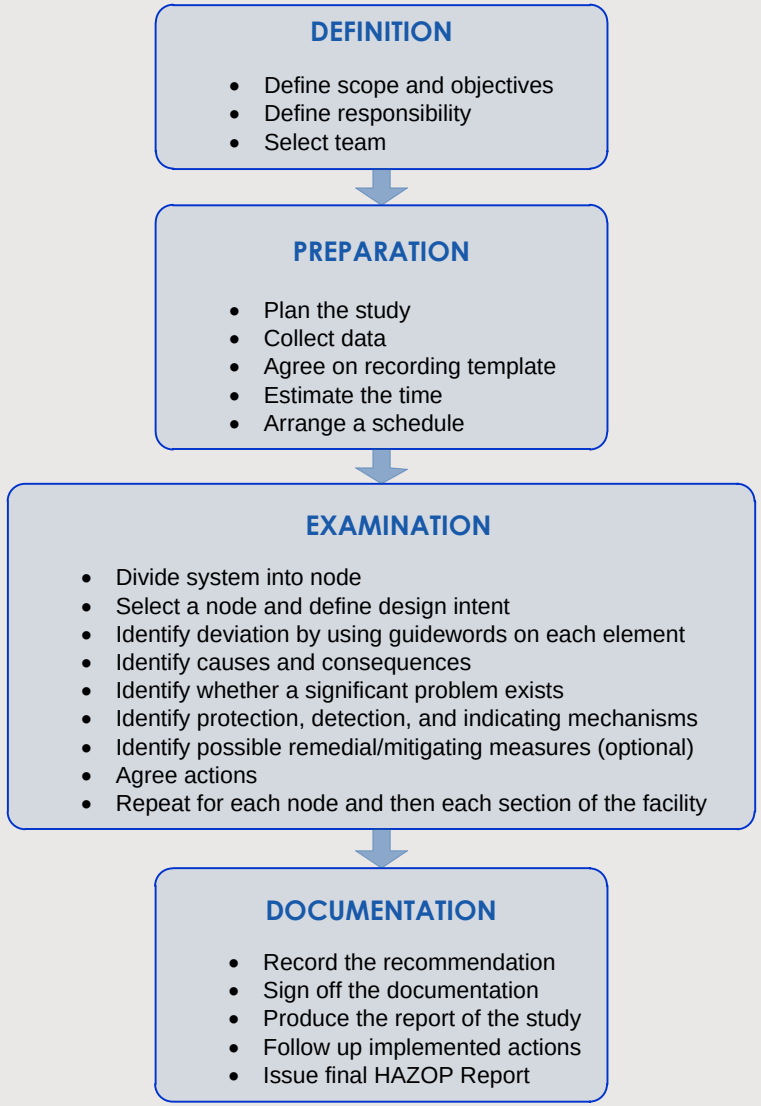
***Note**: If preliminary P&IDs are available, a HAZOP study could also be conducted at Concept Stage of the project.*



Section 7.1 in the Standard shall be referred for HAZOP Through Project/Facility Lifecycle

OVERVIEW OF HAZOP PROCESS

- The HAZOP process is executed in four phases
  - Definition Phase – identifies selection of Subject Matter Expert (SMEs) from various disciplines with appropriate skills and experience.
  - Preparation Phase – includes Project Management Preparation, Consensus on guidewords to b used, facilities like meeting room, projector, refreshment etc., Terms of Reference (ToR)
  - Examination Phase – includes identification of all parameters of the system or process
  - Documentation Phase



Section 7.4 in the Standard shall be referred for Overview of HAZOP Process

Sequence for conducting a HAZOP study

NODES

Nodes are sequential divisions of the facility into appropriately sized sections containing process lines
and/or equipment. HAZOP study progresses through the facility node by node. The selection of the node
size and the route through the plant is made prior to the study by the HAZOP Chairman.

Following guidance should be referred for node selection:

(a) Major equipment (e.g. Vessel, distillation column etc.);
(b) Change in process fluid state (e.g. from liquid to vapor); and
(c) Change in design and operating parameters.

Sequence for conducting a HAZOP study

DESIGN INTENT AND PARAMETERS

- The design intent defines design limits for a component or system.
- The design operating conditions of each applicable parameter (e.g. flow, pressure, temperature, level etc.) and normal operating conditions in the node must be established.
- HAZOP study will examine or identify potential causes that would result in deviations to the design intent, leading to hazardous consequences and operability issues.

Sequence for conducting a HAZOP study

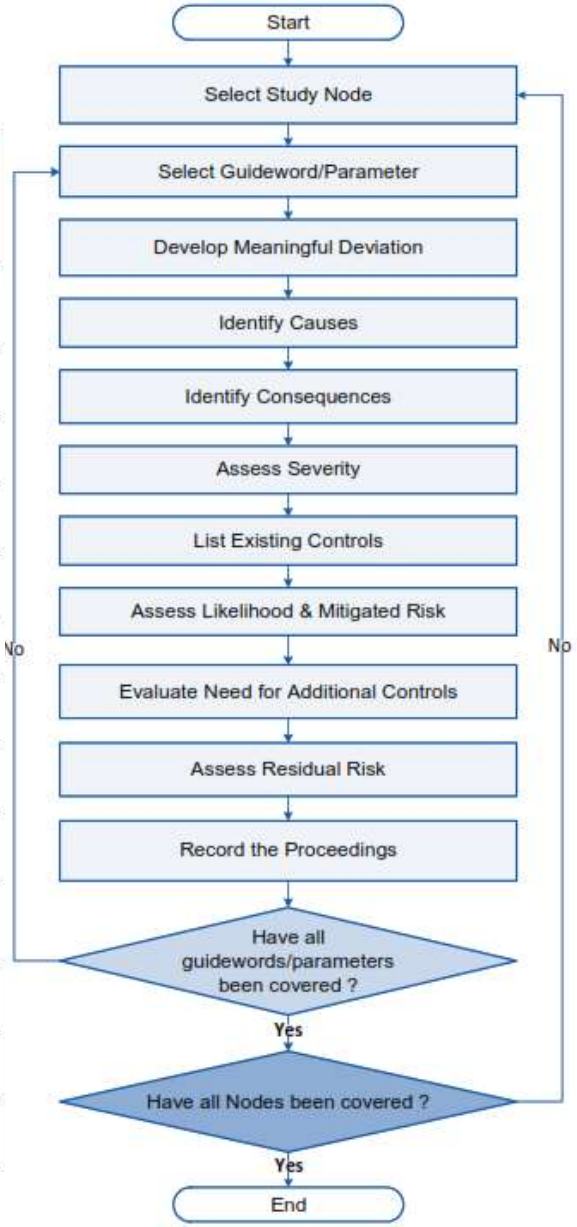
GUIDEWORDS AND DEVIATIONS

Guidewords are simple words or phrases used to qualify or quantify the design intent and associated parameters in order to develop meaningful deviations. 'No', 'less', 'more', 'reverse', 'part of', 'as well as' and 'other than' are the guidewords for HAZOP study.

Sequence for conducting a HAZOP study

GUIDEWORDS AND DEVIATIONS

Parameters	None	Less	More	Reverse	Part of	As well as	Other than
Flow	No flow	Low flow	High flow	Back flow	Wrong concentration	Other Phase	Misdirected flow
Pressure	No confinement	Low pressure	High pressure	Vacuum	Wrong source	External source	Air failure
Temperature	Heat source failure	Low temperature	High temperature			Fire/Explosion	
Level	Empty tank	Low level	High level	Salvage	Wrong tank	Foam/ swell	
Reaction	No reaction	Low reaction	High/runaway reaction	Reverse reaction		Side reaction	Wrong reaction
Concentration	No additive	Low Concentration	High concentration	Reversed ratio	Wrong additive	High/Low Density	Contaminants
Viscosity		Low viscosity	More viscosity				
pH		More pH	Less pH				
Composition		Less Composition	More Composition				
Other	No mixing	Low mixing/reaction	High mixing/reaction			Static build-up	Relief/leak rupture
	Utility Failure	Sampling	Testing	Maintenance	Start-up	Shutdown	Human Factors
						Sequence	
						Separation	



Sequence for conducting a HAZOP study

CAUSES

There may be many causes identified for each deviation, and all potential causes should be discussed as the consequences and recommendations for action may be different. All the potential causes of the deviation should be identified by the team brainstorming. The HAZOP Secretary will record each separate cause as it is identified by creating new rows on the worksheet. Generally, causes will fall into one of these three categories:

(a) Human error

(b) Equipment failure

(c) External events

Sequence for conducting a HAZOP study

CONSEQUENCES

- Having identified the credible causes of the deviation, the team members shall analyse and assess the

significance of the consequences.

- For e.g. guideword 'No Flow' due to the 'Cause' of manual isolation valve closure at the discharge of centrifugal pump would result in a 'Consequence' of over-pressurization
- leading to leakage from pipeline gaskets, causing fire, explosion, environmental impact.

Sequence for conducting a HAZOP study

SAFEGUARD (CONTROLS)

- The team must identify all the existing safeguards that are available.
- The team shall discuss and agree on the effectiveness of the safeguard in preventing the consequences from occurring.
- Safeguard (Controls) for the scenarios can be within the node or outside the node being studied.

Sequence for conducting a HAZOP study

RISK ASSESSMENT

- Risk Assessment shall primarily focus on 'Inherent safe design concept' by ensuring that the existing/proposed engineering controls effectively function properly on demand.
- Risk ranking must be assigned based on severity of consequence considering failures of all safeguards.

- If the estimated severity level of consequence is 4 or above ('Major', 'Catastrophic' or 'Disastrous') no further risk ranking in HAZOP is required and that specific hazard (deviation) must be further assessed using LOPA technique for mitigated and residual risk ranking.

Sequence for conducting a HAZOP study

USE OF DOCUMENTATION DURING HAZOP STUDY

a- The following information/documentation should be available:
(i) Process flow diagrams (PFD)
(ii) Piping and instrumentation diagrams (P&IDs) including detailed vendor PIDs, piping
classifications, material of construction, design parameters
(iii) Layouts, plot-plans and site visit reports
(iv) Safety Data Sheets (SDS)
(v) Operating & Control philosophy
(vi) Fire & Gas Detection and Protection Philosophy
(vii) Heat and Material Balances (HMB)
(viii) Equipment data sheets
(ix) Basic Process control systems, ESD systems and C&E diagrams which includes alarm, trip
and interlock information
(x) HAZID/ENVID report and other applicable safety study reports
(xi) Pressure relief, vent and depressurization information

Sequence for conducting a HAZOP study

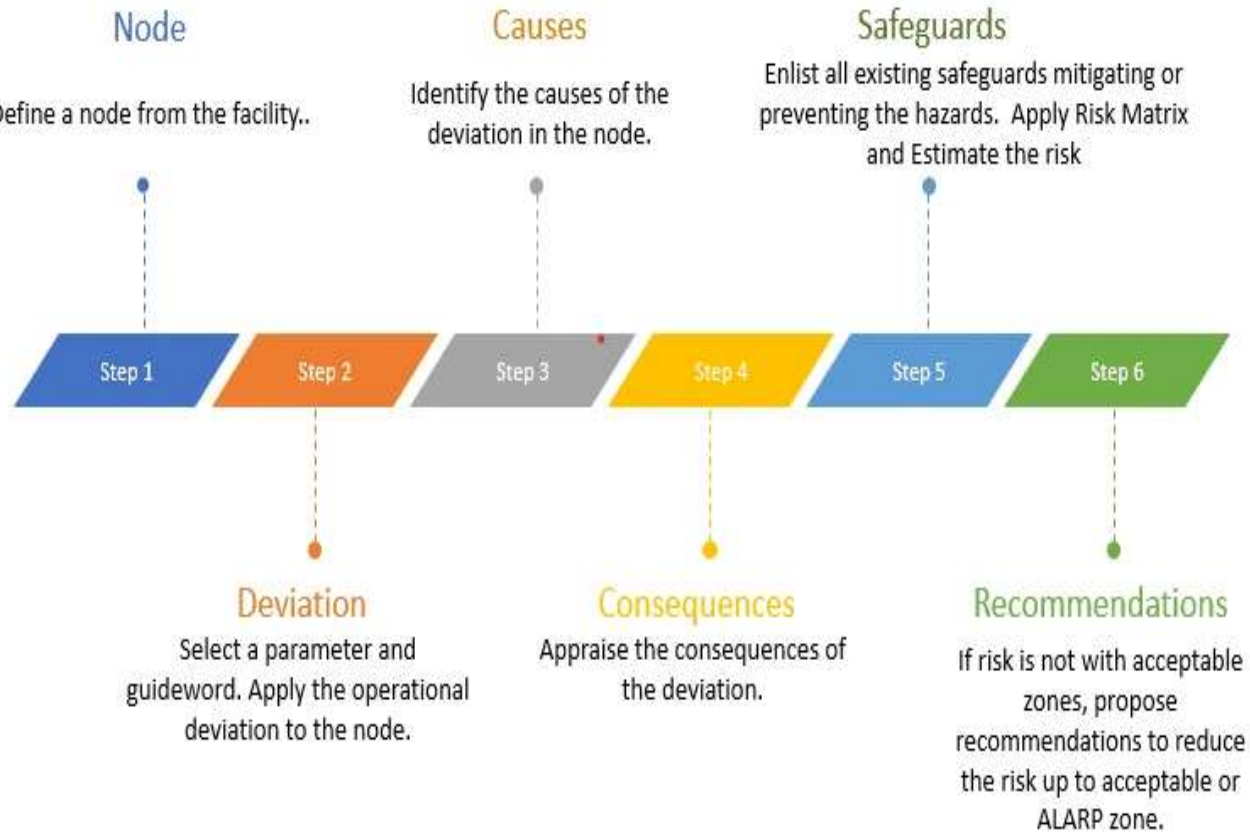
USE OF DOCUMENTATION DURING HAZOP STUDY

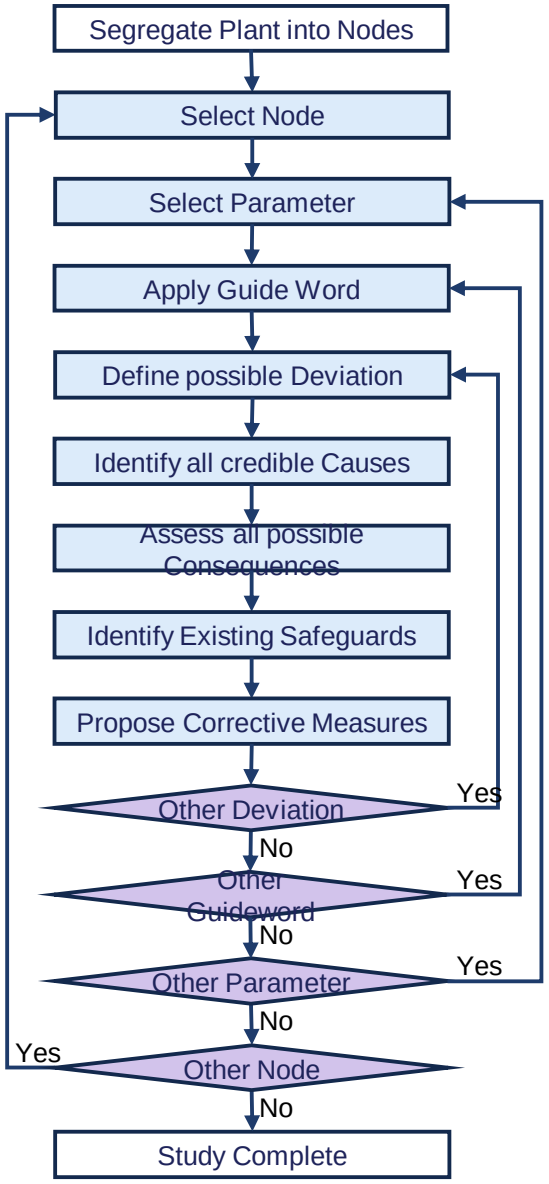
b - Additional applicable documentation from list below should also be available:
(i) Corrosion control specification
(ii) Pump and Compressor operating curves
(iii) Instrument data sheets
(iv) Valve capacities – particularly important during gas breakthrough
(v) HSE Philosophies
(vi) Inspection and test records, maintenance history
(vii) General arrangement (GA) and elevation drawings
(viii) Commissioning and Maintenance procedures
(ix) HVAC design
(x) Electrical load and loop diagrams
(xi) Design codes and standards used

HAZARD AND OPERABILITY (HAZOP) STUDY

HAZOP Process Summary

The HAZOP study is essentially a six (6) step process to logically identify potential hazards and operability problems and ensure that preventative mitigations measures are implemented.





How we do a HAZOP Study?

- Prerequisites.
- Hazop Terminology – Guide words and parameters.
- Hazop Terminology – Nodes.
- Deviation – Causes and consequences.
- Consequence Development – the Cheese Model

HOW DO WE DO A HAZOP?

- We split the plant up into sections (normally stopping at a valve or change in design specification (e.g. pressure) – these are called nodes.

- We ask the design engineer to give a brief description of the node – how it works, what are design aspects etc.

- As a team, we look at the node and ask general questions until we understand how it works (in general)

- We then apply Parameter keywords, one at a time, to the design and for each keyword there are a list of guidewords. (A combination of a parameter and a guideword give us the deviation)

- Once we have done Flow (which takes a long time as it can cover most of the other keywords as well) we move onto Pressure, Level, Temperature, Reaction etc.

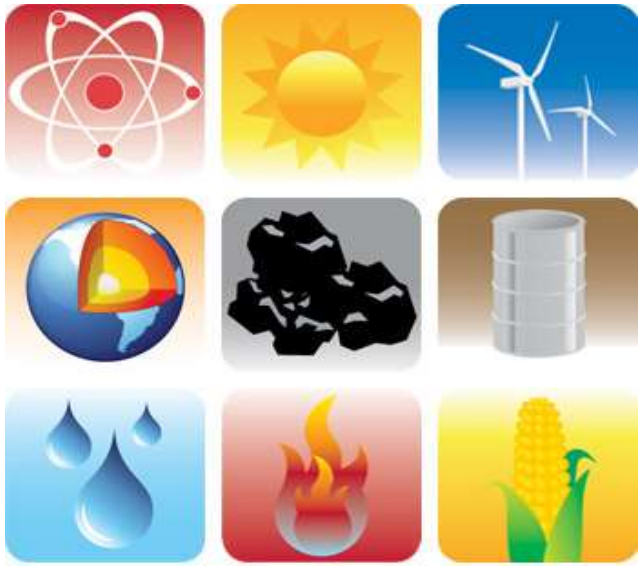
Prerequisites

As a basis for the HAZOP study the following information should be available:

- Process flow diagrams (PFD)
- Piping and instrumentation diagrams (P&IDs)
- Layout diagrams
- Material safety data sheets
- Provisional operating instructions
- Heat and material balances
- Equipment data sheets Start-up and emergency shut-down procedures

HAZOP TERMINOLOGY

Parameter	Guideword
Flow	
Pressure	• More / Less / No / Reverse / Misdirected /
Temperature	• Contamination / Ratio / As Well As
Level / Elevation	• High / Low / Vacuum
Reaction	• High / Low
Spillage / Chemical Leaks	• High / Low / No
Sampling	• High Rate / Low Rate / No Reaction / Effect on
Service Failure	• Gaskets, Packing etc / Effect on Other
Maintenance	• Chemicals
Environment	
Human Factors	
Contamination / Composition / QA	
Corrosion / Erosion	
Vibration	
Start Up and Shutdown	
Manual Operations Utilities	



HAZOP TERMINOLOGY

Node : section of process unit, used to organize the study. The locations (on P&IDs) at which the process parameters are investigated for the deviations

- Usually a pipe, vessel, or equipment group
- Selection
- Follow process flow
- Size (big enough to save time, small enough to document)

Intention : design operating conditions for a particular parameter

Parameter : conditions used to define a process

- Examples: flow, temperature, pressure, level, PH, state, viscosity

HAZOP TERMINOLOGY (CONTINUED)

Guide words : adjective describing the parameter

Guidewords for continuous process

GUIDEWORDS	MEANING
No, Not, None	Negation of intent
More, Higher, Greater	Quantitative increase
Less, Lower	Quantitative decrease
As well as	Quantitative increase
Part of	Quantitative decrease
Reverse	Opposite of
Other than	Substitution

Guidewords

The basic HAZOP guide-words are:

Guide-word	Meaning	Example
No (not, none)	None of the design intent is achieved	No flow when production is expected
More (more of, higher)	Quantitative increase in a parameter	Higher temperature than designed
Less (lessof, lower)	Quantitative decrease in a parameter	Lower pressure than normal
As well as (more than)	An additional activity occurs	Other valves closed at the same time (logic fault or human error)
Part of	Only some of the design intention is achieved	Only part of the system is shut down
Reverse	Logical opposite of the design intention occurs	Back-flow when the system shuts down
Other than (other)	Complete substitution - another activity takes place	Liquids in the gas piping

Additional guidewords

Guide-word	Meaning
Early / late	The timing is different from the intention
Before / after	The step (or part of it) is effected out of sequence
Faster / slower	The step is done/not done with the right timing
Where else	Applicable for flows, transfer, sources and destinations

Guidewords

Guide-word	Meaning
No (not, none)	None of the design intent is achieved
More (more of, higher)	Quantitative increase in a parameter
Less (lessof, lower)	Quantitative decrease in a parameter
As well as (more than)	An additional activity occurs
Part of	Only some of the design intention is achieved
Reverse	Logical opposite of the design intention occurs
Other than (other)	Complete substitution - another activity takes place

Alternative guidewords - 1

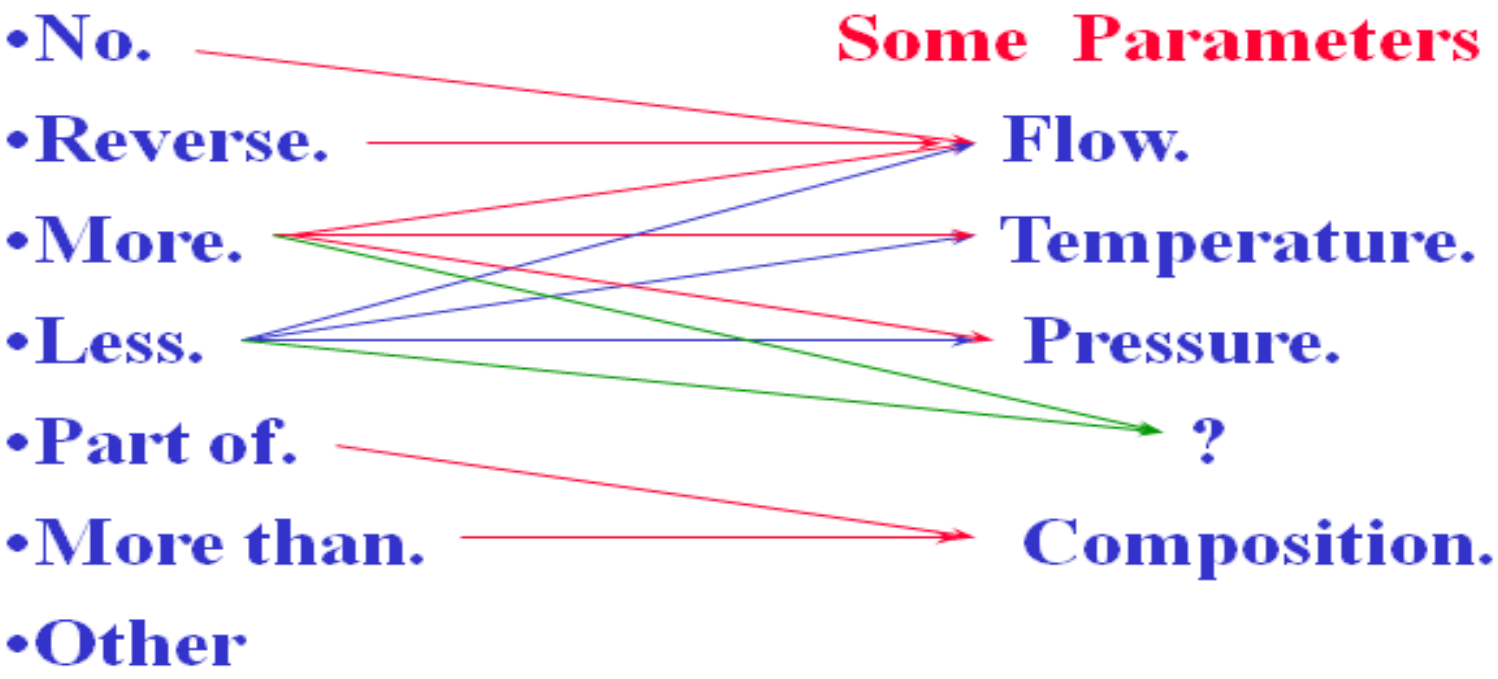
Guide-word	Meaning
Unclear	Procedure written in confusing and ambiguous fashion
Step in wrong place	Procedure will lead to actions out of correct sequence or recovery failure
Wrong action	Procedure action specified is incorrect
Incorrect information	Information being checked prior to action is incorrectly specified
Step omitted	Missin step, or steps too large, requiring too much of the operator
Step unsuccessful	Step likely to be unsuccessful due to demands on operator
Interference effects from others	Procedure-following performance likely to be affected by other personnel carrying out simultaneous tasks (usually when co-located)

Alternative guidewords - 2

Parameter	Guide-word / deviation
Time	Too early, too late
Sequence	Wrong sequence, omissions, wrong action
Procedure	Not available, not applicable, not followed
Measurement	Instrument failure, observation error
Organization	Unclear responsibilities, not fitted for purpose
Communication	Failed equipment, insufficient/incorrect information
Personnel	Lack of competence, too few, too many
Position	Wrong position, movement exceeding tolerences
Power	Complete loss, partly lost
Weather	Above limitations - causing delayed operation

HAZOP TERMINOLOGY

HAZOP Guidewords and Parameters



HAZOP TERMINOLOGY

Deviation : departure from the design intent

- Guideword + Parameter
- Low temperature, high pressure, flow in direction other than intended

Different guideword/parameter deviations may be used for non-process

Additional guidewords are used in the case of a batch process

Parameters	Guideword						
	More	Less	No	Reverse	Part of	As well as	Other than
Flow							
Pressure							
Temperature							
Level							
Reaction							

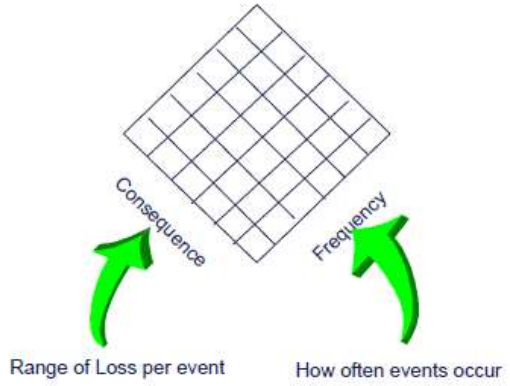
HAZOP TERMINOLOGY (CONTINUED)

Causes : These are reasons why deviations might occurs.

- The cause can be hardware failures, human errors, unanticipated process state or external disruptions (e.g. loss of power)

Consequences : Direct, undesirable result of an accident sequence usually involving a fire, explosion, or release of toxic material. Consequence descriptions may be qualitative or quantitative estimates of the effects of an accident in terms of factors such as health impacts, economic loss, and environmental damage

- There are the direct results of the deviations
  - Loss of containment
  - Major operating upset



CAUSES AND CONSEQUENCES

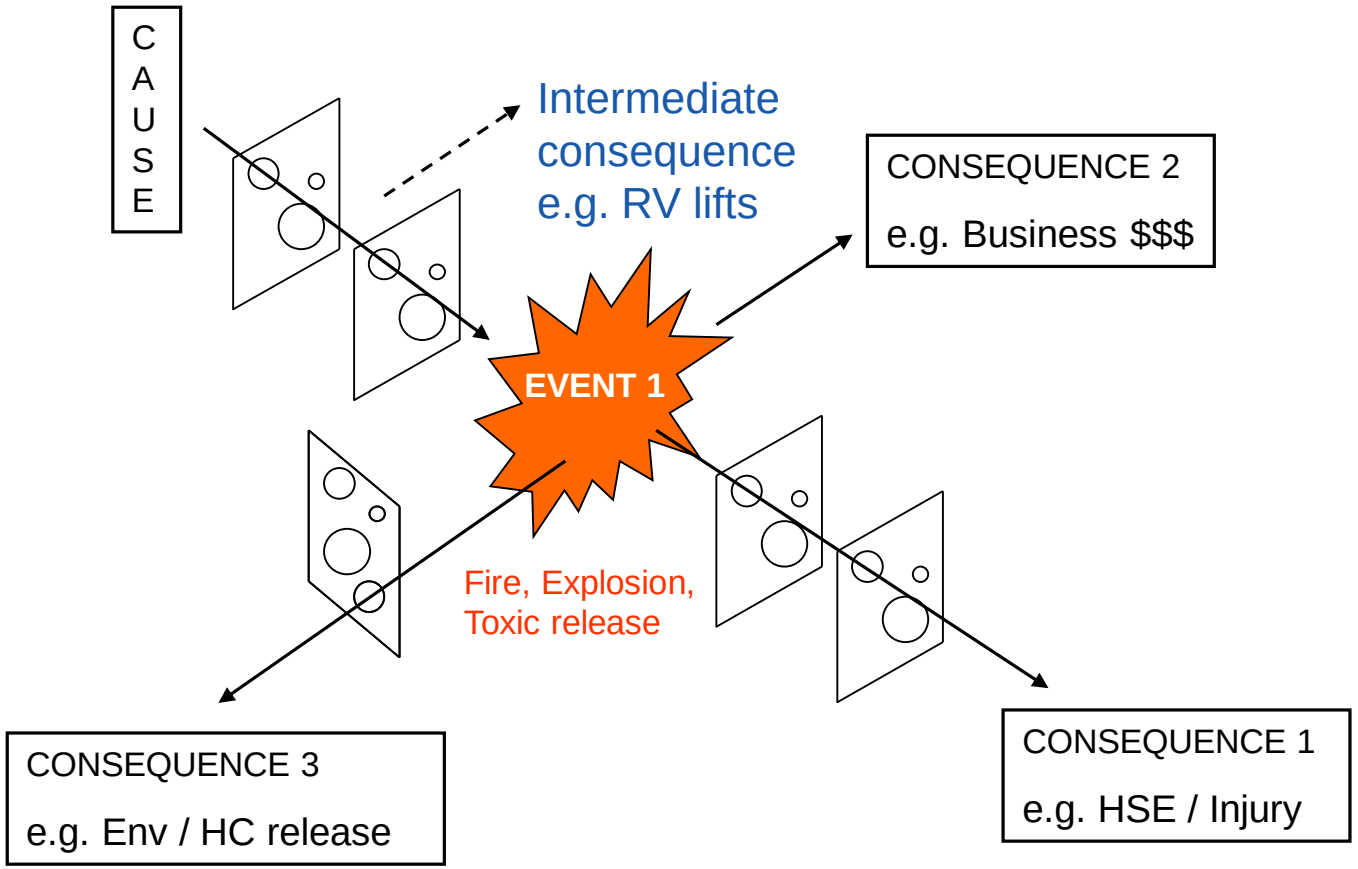
First identify all causes

- Systematic e.g. move left to right through P&ID
- Be aware of causes not shown on the drawings e.g. layout, slope, location, elevation etc.
- Refer to experience / incidents / lessons learned
- Brainstorm

Cause within the node

- Consequence globally i.e. develop through to other areas a cause in the node we are looking at may have a large effect on something outside of the node – record the cause and consequence in the node that is causing the problem.
- At scope (battery) limit include up / downstream
- Do think about significant issues across nodes
- What do YOU know about the area or links to the plant that are not on the drawings? We need your experience and knowledge to make this successful.

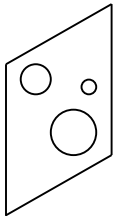
CONSEQUENCE DEVELOPMENT
THE CHEESE MODEL



Consequences without safeguards

Likelihood with safeguards

Where the holes in the cheese lines up, then an event can occur



Safeguard / Barriers

Risk Rating

- Risk Matrix.
- Safeguard examples.
- Process HAZOP work-sheet.
- HAZOP Worksheet Template.
- HAZOP Information Requirements.

RISK RATING

- The Risk Rating of the Cause and Consequence will be completed by the Hazop team.
- It is based on the team's experience in the operational field.
- The potential / reasonable outcome of the plant deviation from an incident point of view and likely frequency is chosen by the team.
- Using the matrix (next slide) a severity can be applied to the Risk.
- The Consequence Severity is to be chosen without any of the safeguards in place.
- The Likelihood is to be chosen with all of the installed safeguards in place.
- The Outcomes can have a effect on Safety (injury / fatality), Environment or Cost (production and reputation) – or a mixture of any or all of the three.

25/06/18

ADNOC Corporate Risk Matrix

Term	Rare	Unlikely	Possible	Likely	Very Likely	Almost Certain
ERM Criteria	Hasn't happened in the industry in the last 50 years	Could be incurred in the next 20-30 years	Could be incurred within a 5 -10 year time frame	Could be incurred within the 5 year Strategic Planning period	Could be incurred over the next 1-2 year budget period	Could be incurred once or more during the next year
HSE Frequency	$10^{-6} \leq - < 10^{-5}$	$10^{-5} \leq - < 10^{-4}$	$10^{-4} \leq - < 10^{-3}$	$10^{-3} \leq - < 10^{-2}$	$10^{-2} \leq - < 10^{-1}$	$10^{-1} \leq - < 1$
HSE Likelihood	Has not occurred in world-wide industry	Has occurred in world-wide industry but not in ADNOC	Has occurred at least once in the Group Company	Has occurred at least once in Group Company but not on the site	Has occurred more than once in Group Company or once on the site	Has occurred more than once on the site

Severity	Health & Safety	Environment	Reputation	*/**/***Financial		Legal	#	A	B	C	D	E	F
				Direct Financial Impact (DFI)	Production Loss (PL)								
Disastrous	Multiple public (more than 1) / workers (more than 10) fatalities or permanent total disabilities	Disastrous effect (severe and permanent impacts, consistently exceeding limits)	Prolonged international impact and public attention. Effect will last for years and can spread internationally and affect other industry players	>=$1Billion in a year	>=$1Billion in a year	Inability to comply with laws, regulations or contracts resulting in substantially material losses. Disastrous regulatory sanction, prosecution or prolonged multiple litigations. Potential jail terms for executives	6	6A	6B	6C	6D	6E	6F
Catastrophic	Multiple worker fatalities (upto 10) / permanent total disabilities, or single public fatality	Catastrophic effect (serious impacts on many attributes of environment in larger area)	Serious international impact and public attention - extensive adverse coverage in the international media with potentially severe impact on licenses	>=$100 million - <$1 Billion in a year	>=$100 million - <$1 Billion in a year	Significantly constrained ability to comply with laws, regulations or contracts resulting in material financial losses. Very serious litigation, including class actions	5	5A	5B	5C	5D	5E	5F
Major	Single worker fatality / permanent total disability or serious injury to public	Major effect (negative impacts on surrounding environment and repeated non compliances)	Significant national impact and public concern - extensive adverse attention in the national media. Effect could last a few months and likely to spread to close industry partners	>=$10M - <$100M in a year	>=$10M - <$100M in a year	Major breach of law, contract or regulation. External investigation(s), significant regulatory sanction or major litigation	4	4A	4B	4C	4D	4E	4F
Serious	Serious injuries or health effects (permanent partial disability)	Local effect (reversible impacts but frequent non compliances)	Considerable impact - adverse attention in local media / local government / action groups	>=$1M - <$10M in a year	>=$1M - <$10M in a year	Serious breach of law, contract or regulation - moderate fines / litigation and / or requires reporting to regulator(s)	3	3A	3B	3C	3D	3E	3F
Minor	Minor injuries or health effects (reversible effects - weeks to months)	Minor effect (impacts limited organizational surroundings)	Limited impact - some local media / political attention. Effect will last a few days only	>=$100K - <$1M in a year	>=$100K - <$1M in a year	Minor breach of law, contract or regulation where mild regulatory sanction or minor litigation	2	2A	2B	2C	2D	2E	2F
Notable	Slight injuries or health effects (short term effects)	Slight effect (impacts within fence area)	Slight impact - no public concern	<$100K in a year	<$100K in a year	Low-level legal or business ethics issue; litigation or regulatory sanction unlikely	1	1A	1B	1C	1D	1E	1F

Risk Level	Minimum Required Action	Management Signoff Authority
HIGH / CATAGORY 1	Report immediately upon identification. Must be reduced as soon as possible to As Low As Reasonably Practicable (ALARP) / Management satisfied the costs to reduce the risk exceed the benefits of doing so. Include in Risk Register for tracking. Consider advanced risk methodologies for further investigation. Quantification of **Financial impact, Maximum Foreseeable Loss (MFL) and Risk Control Effectiveness (RCE) shall be calculated.	Signoff by Director or GC CEO
HIGH-MEDIUM / CATAGORY 2	Should be reduced as soon as possible to ALARP / Management satisfied the costs to reduce the risk exceed the benefits of doing so. Include in Risk Register for tracking. Consider advanced risk methodologies for further investigation. Quantification of **Financial impact, Maximum Foreseeable Loss (MFL) and Risk Control Effectiveness (RCE) shall be calculated.	Signoff by Unit Manager / SVP
MEDIUM / CATAGORY 3	Medium priority, monitor and improve effectiveness of current controls. Include in Risk Register for tracking. Quantification of **Financial impact, Maximum Foreseeable Loss (MFL) and Risk Control Effectiveness (RCE) should be calculated.	Signoff by Dept. Manager / VP
LOW / CATAGORY 4	Low priority, monitor and improve effectiveness of current controls.	Signoff by Line Manager

*Financial criteria for Operating Companies shall be specified by ADNOC Corporate / for upward reporting Operating Companies shall report against the ADNOC Corporate & Operating Company Financial Consequence levels.

**Financial Impact is the combination of Direct and Indirect costs.

*** For Investments, "Financial" refers to NPV impact.

HAZOP TERMINOLOGY

Safeguard : device, system, or action that would likely interrupt the chain of events following an initiating cause or that would mitigate loss event impacts

- Existing safeguards only

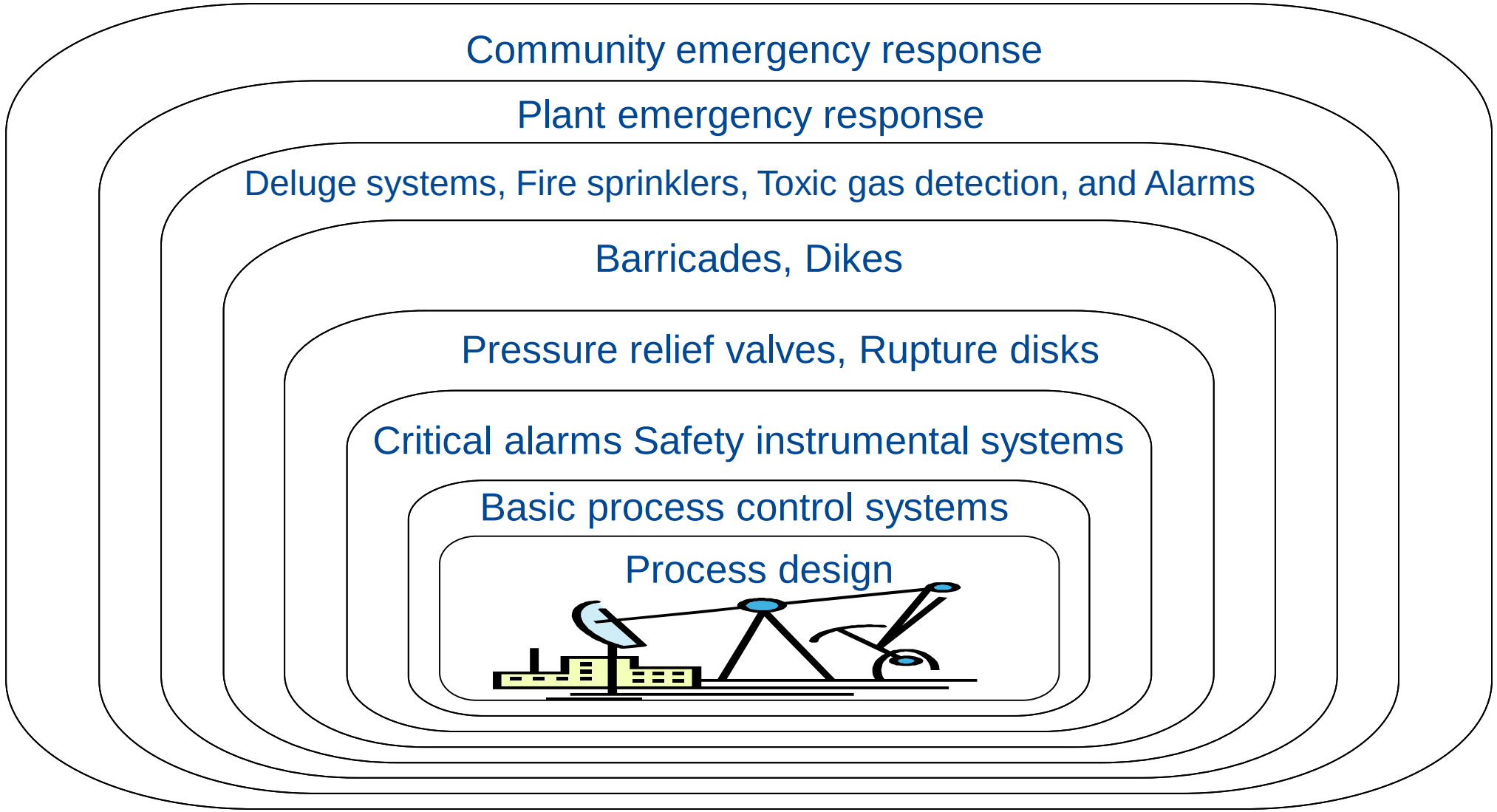
Recommendation : course of action, NOT engineered solution

Important: Document all issues!

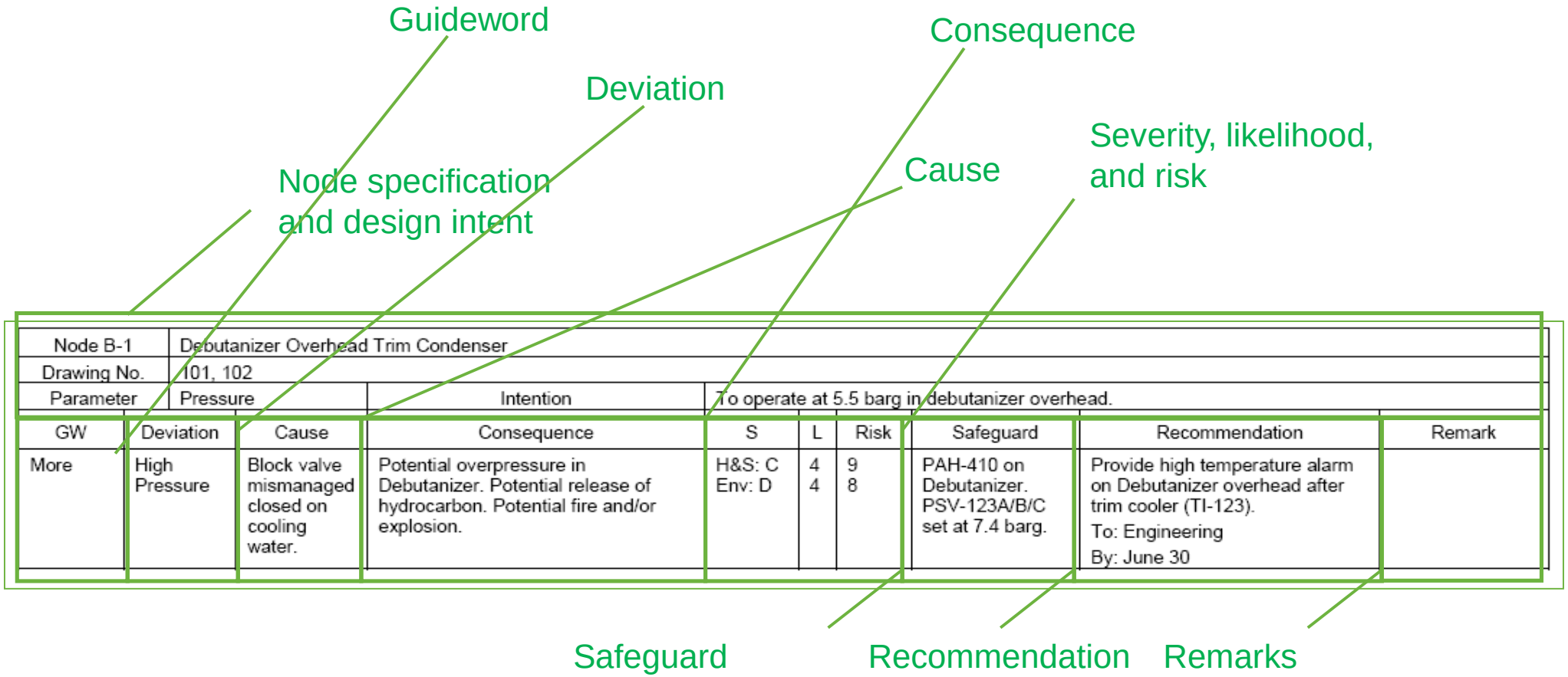
Use phrases like “no credible causes” or “no adverse consequences”

Rather than leaving a section blank!

SAFEGUARD EXAMPLES



EXAMPLE HAZOP WORKSHEET



Node B-1	Debutanizer Overhead Trim Condenser								
Drawing No.	101, 102								
Parameter	Pressure		Intention	To operate at 5.5 barg in debutanizer overhead.					
GW	Deviation	Cause	Consequence	S	L	Risk	Safeguard	Recommendation	Remark
More	High Pressure	Block valve mismanaged closed on cooling water.	Potential overpressure in Debutanizer. Potential release of hydrocarbon. Potential fire and/or explosion.	H&S: C Env: D	4 4	9 8	PAH-410 on Debutanizer. PSV-123A/B/C set at 7.4 barg.	Provide high temperature alarm on Debutanizer overhead after trim cooler (TI-123). To: Engineering By: June 30	

Notice level of details required in the text… PAH-410, PSV-123A/B/C or TI-123

Need to be traceable

ADNOC HAZOP work sheet

Site:	Plant:	Unit
Team members (including roles):		
Design intent:		
Node: Node Description:		
P&ID number:	Associated Dwg./Doc:	

Deviation	Cause	Consequence	Severity (assuming no safeguards)				Overall Severity (S)	Current Safeguards	Likelihood (L) (considering current safeguards)	Overall Mitigated Risk (R)	Recommendations	Likelihood (L) (considering recommend-dations)	Overall Residual Risk (R)
			Health & Safety	Environment	Financial	Reputation							

HAZOP INFORMATION REQUIREMENTS

Process flow diagram (PFD)

- Heat and mass balance
- Inventory
- Safe upper and lower operating limits, operating envelopes

Piping & Instrumentation Diagram (P&IDs)

- Instrumentation
- Piping class specification

and materials of construction

Previous HAZID, What-if, HAZOP, or LOPA reports

MOCs since last HAZOP, if any

Control, alarm and trip information

Pressure relief, flare, vent, and depressuring information

Operating procedure

Previous process safety accident/incident/near miss reports

Process description and process chemistry

Facility layout and unit layout drawing

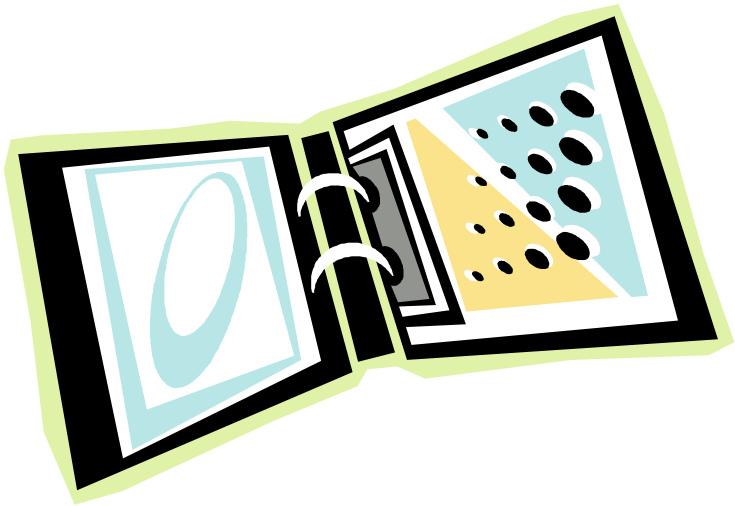
HAZOP REPORT & FOLLOW-UP

Recommendations are addressed in a timely manner and tracked until closure

HAZOP report includes:

- HAZOP scope
- Process description & design intent
- Methodology including guidewords
- Team members & roles
- Recommendations
- HAZOP Worksheets
- Color-coded P&IDs showing nodes

All HAZOP reports and action item tracking documentation shall be retained for the life of the facility.



DAY 3

HAZOP Recording and Reporting

HAZOP RECORDING AND REPORTING

- The HAZOP Study shall be recorded in full.
- The use of professional HAZOP software should be considered as it supports efficient recording and reporting.
- The HAZOP report structure as follows:
  - Introduction
  - HAZOP Chairman's Feedback on the HAZOP study
  - Areas of potential weakness
  - Comments applicable to the whole plant
  - Major and priority findings
  - Further studies required
  - Highlight areas for next HAZOP
  - Reports/comments for other safety meetings/studies
  - Appendices

Section 7.6 in the Standard shall be referred for HAZOP Recording & Reporting

HAZOP RECORDING AND REPORTING

RECORDING RESULTS FOR THE MEETINGS

- The HAZOP study shall be recorded in full.
- The full recording includes documentation of the nodes'
- description, parameters intention, deviation, cause, consequence, safeguards, risk ranking,
- recommendations, and all relevant hazards identified by the team.
- If a deviation is reviewed but there is no consequence of concern, then it should be recorded in the HAZOP worksheet as "no hazardous consequences".
- Full recording also allows persons reviewing the study to identify that the deviation was considered.

HAZOP RECORDING AND REPORTING

RECORDING RESULTS FOR THE MEETINGS

(a) Minutes

- It is the HAZOP Secretary's role to record the minutes of the HAZOP study meetings.
- The Chairman may provide support and guidance to ensure that full concise minutes are produced.

- The main requirement is that someone not at the meeting should be able to read the minutes and fully understand all the potential hazards discussed by the team (including those where the protection is adequate) and especially the concerns and recommendations of the team.

HAZOP RECORDING AND REPORTING

RECORDING RESULTS FOR THE MEETINGS

(b) Worksheet

- The structure of the worksheet follows the sequence of the HAZOP brainstorming and analysis technique.
- A typical HAZOP worksheet is shown in Appendix 2.

(c) Recording

- The use of professional HAZOP software should be considered as it supports efficient recording and reporting of HAZOP studies.
- Any software to be used for recording the HAZOP study shall be ADNOC Group CHSE approved. HAZOP worksheet in MS Word or Excel can also be used for recording.

HAZOP RECORDING AND REPORTING

HAZOP REPORTING

- The HAZOP report is a document describing the objectives and success of the whole study.
- The report should form the basis of a reviewer's understanding of the completeness of the study and the confidence that can be put in the results. In general, the HAZOP report should contain the following sections:

HAZOP RECORDING AND REPORTING

HAZOP REPORTING

(a) Introduction

The introduction to the HAZOP report should contain short descriptions of the following:

(i) The background to the project and the scope of the HAZOP;

(ii) The purpose and achievements of the meeting should be described;

(iii) The terms of reference given prior to the HAZOP or HAZOP minutes used for reference;

(iv) Timing the schedule of the meeting;

(v) The composition and affiliation of the team including the attendance of part-time members at each session;

(vi) Study method, including any variations on normal HAZOP practice adopted for the study; and

(vii) Sections of the facility not covered because they were outside the scope of the study or documentation or key personnel were not available.

HAZOP RECORDING AND REPORTING

HAZOP REPORTING

(b) HAZOP Chairman's Feedback on the HAZOP study

- It is important that the quality of the meeting should be assessed in terms of the composition and experience of the team and their performance.
- The HAZOP Report should include a section, prepared by the HAZOP Chairman on the quality of the study.

(c) Areas of potential weakness

- Areas of potential weakness such as a lack of specialist knowledge or incomplete drawings should be noted.

HAZOP RECORDING AND REPORTING

HAZOP REPORTING

(d) Comments applicable to the whole plant

- The general issues discovered should be listed and introduced, together with their significance for the progress of the project.

(e) Major and priority findings

- HAZOP study for a major project/facility may produce very large numbers of action items.
- Obviously, all of them cannot be addressed at the same time and the project/operations may have to progress whilst they are being dealt with.
- The main study findings should be discussed in the report. A list of the significant or high-risk actions items should be included in the main report.

HAZOP RECORDING AND REPORTING

HAZOP REPORTING

(f) Further studies required

- If the team recommends that QRA or other studies (e.g. LOPA, Fire and Explosion Risk Assessment (FERA), etc.) are required then those should be listed for easy reference and priority action.

(g) Highlight areas for next HAZOP

- Identification of areas that are unresolved should be made for subsequent HAZOP studies.

(h) Reports/comments for other safety meetings/studies.

- The HAZOP report should give details of issues or action points that in the opinion of the team have a direct relevance to other project safety meetings.

HAZOP RECORDING AND REPORTING

HAZOP REPORTING

(i) Appendices

- The appendices should contain the following information:

  (i) Terms of reference;

  (ii) List of guidewords used;

  (iii) Node list;

  (iv) Worksheets;

  (v) Drawings (master set of marked-up P&IDs);

  (vi) List of background reference documents;

  (vii) Individual action sheet; and

  (viii) All communications to and from HAZOP team to subject matter experts, vendors and third parties.

HAZOP RECORDING AND REPORTING

HAZOP REPORTING

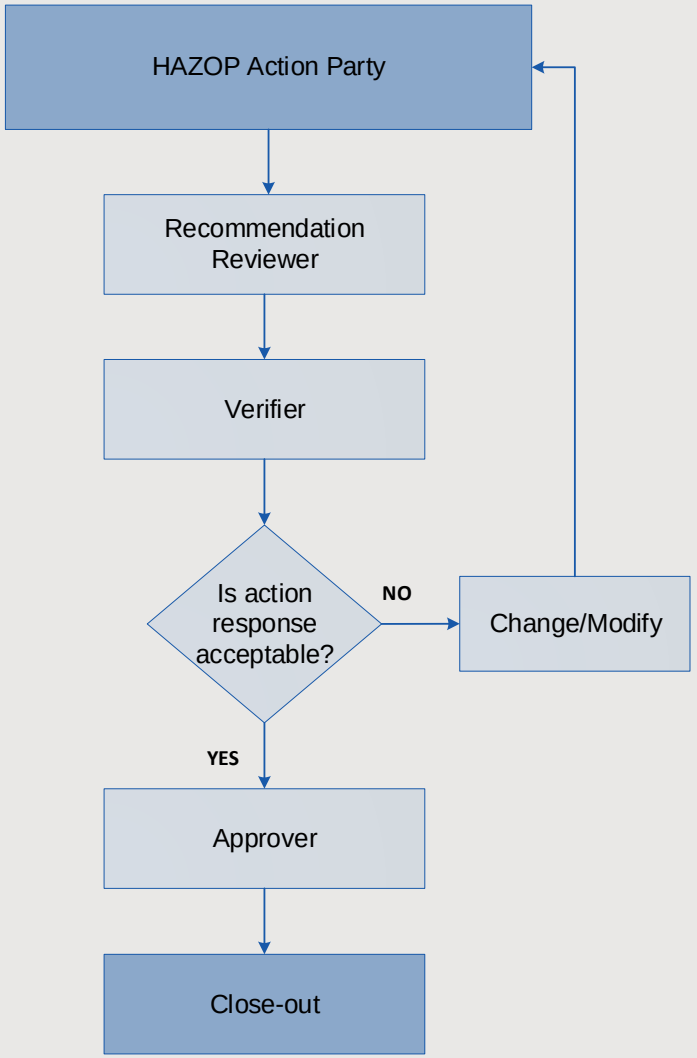
(j) Report Distribution

- The draft HAZOP Report should be issued to all team members for review, to ensure it is an accurate record of the meeting.
- During the review of the draft report, if ADNOC Group CHSE determines that minutes of the workshop or risk ranking is required to be changed based on technical judgement, this shall be incorporated by the HAZOP Chairman.

- The final HAZOP Report shall be issued to the Project Manager/Facility Manager for review and approval.

HAZOP ACTION TRACKING AND FOLLOW-UP

- Be resolved with an auditable, fully documented record of all actions taken, decisions and alternative solutions.
- All HAZOP study recommendations must be adequately addressed and resolved.
- Recommendations may be modified, referred for further consideration, or rejected due to updated information obtained during the deliberations of actions to be taken.
- A formal system of review and authorisation should be adopted for the close-out of HAZOP action recommendations.
- The Action Close-out and Approval process is provided in the adjacent figure



Section 7.7 in the Standard shall be referred for HAZOP Action Tracking & Follow-up

HAZOP ACTION TRACKING AND FOLLOW-UP

IMPLEMENTATION/REJECTION

- Responsibility for follow-up of HAZOP actions should be assigned to a focal point in the project/facility.
- HAZOP recommendations must be resolved with an auditable, fully documented record of all actions taken, decisions and alternative solutions. All accepted actions shall be tracked and ensured that all actions are implemented by the project/facility.
- As follow-up may continue quite some time after the study and may also involve parties not involved in the study, it is imperative that the HAZOP records, adequately describe issues.

- All HAZOP study recommendations must be adequately addressed, resolved and closed.
- If the recommendation is modified or rejected, it should be referred back to the team that carried out the respective HAZOP for its review with technical justification to ensure that the intent of recommendation is not compromised.

HAZOP ACTION TRACKING AND FOLLOW-UP

ACTION RESPONSES

- The responding person should always explain completely the reasoning and justification for his decision.
- Completion statements should be specific and unambiguous. For example, for a HAZOP action of 'confirm the size of the relief valve (RV-123) for the maximum operating case of 10,000 bbl/day', an appropriate response would be 'relief valve RV-123 confirmed for maximum flow rate as quoted, each action response sheets shall be supported with the evidence (e.g. Updated P&ID, Data sheet, procedure, O&M Manual etc.)'.

HAZOP ACTION TRACKING AND FOLLOW-UP

OVERLAPPING ACTIONS

- It is possible that some recommendations on the same or separate nodes will overlap with others.
- The implementation of these issues should be handled carefully and may need to be resubmitted to the next HAZOP meeting.

RESPONSE CONFIRMATION

- It is important to get formal acceptance of the response from the responsible parties. In the case of a design Contractor on a major project it is usual for a number of specified signatures to be required.

ACTION RESPONSE FORMS

- All HAZOP action recommendations/rejection should be copied onto individual action response forms.
- An example of an action response sheet is provided in the following Table 7.7.1.

HAZOP ACTION TRACKING AND FOLLOW-UP

Action Response Form

HAZOP Title and Document Number:	
Recommendation No.:	Node No.:
Drawing numbers:	
Node Description:	
Parameter/Guideword:	
Deviation:	
Cause:	
Consequence:	
Safeguards:	
Responder:	Due Date:
Recommendation:	

HAZOP ACTION TRACKING AND FOLLOW-UP

Action Response Form Continued

Action Response:		
	Name	Signature
	Designation	Date
Reviewed By:		
	Name	Signature
	Designation	Date
Verified By:		
	Name	Signature
	Designation	Date
Action Acceptable:	☐ Yes	☐ No
Approved By:		
	Name	Signature
	Designation	Date

ACTION CLOSE-OUT AND APPROVAL

ACTION CLOSE-OUT AND APPROVAL

- It is important that all HAZOP recommendations are reviewed, approved and followed-up to close-out at each of the stages of the project and operating facility. The response to the action should be returned within the specified timeframe as agreed.

- A formal system of review and authorization should be adopted for the close-out of HAZOP action recommendations.
- This response shall be provided on the HAZOP action sheet. HAZOP action sheets shall be accompanied by supporting documentation (e.g. P&ID and related document mark-up), detailing the specific action implemented to close the action.

ACTION CLOSE-OUT AND APPROVAL

Following is the typical review and approval process for HAZOP actions:

HAZOP Action Party

- Person assigned to complete the action must prepare the response to the action along with the supporting documentation and submit it to the reviewer.

Reviewer

- Reviewer is typically the action party's supervisor/Contractor Project Manager. The reviewer must ensure that the response meets the intent of the action and that quality checks have been performed and sign the action response sheet accordingly.

Verifier

- Verifier is typically the technical authority in ADNOC or respective ADNOC Group.
- Verifier must ensure that the response meets the intent and is in compliance with ADNOC standards and procedures and subsequently sign the action response sheet.
- If the recommendations of HAZOP team is modified or rejected, then the verifier should consult the team that had carried out the respective HAZOP before signing off the action response.

ACTION CLOSE-OUT AND APPROVAL

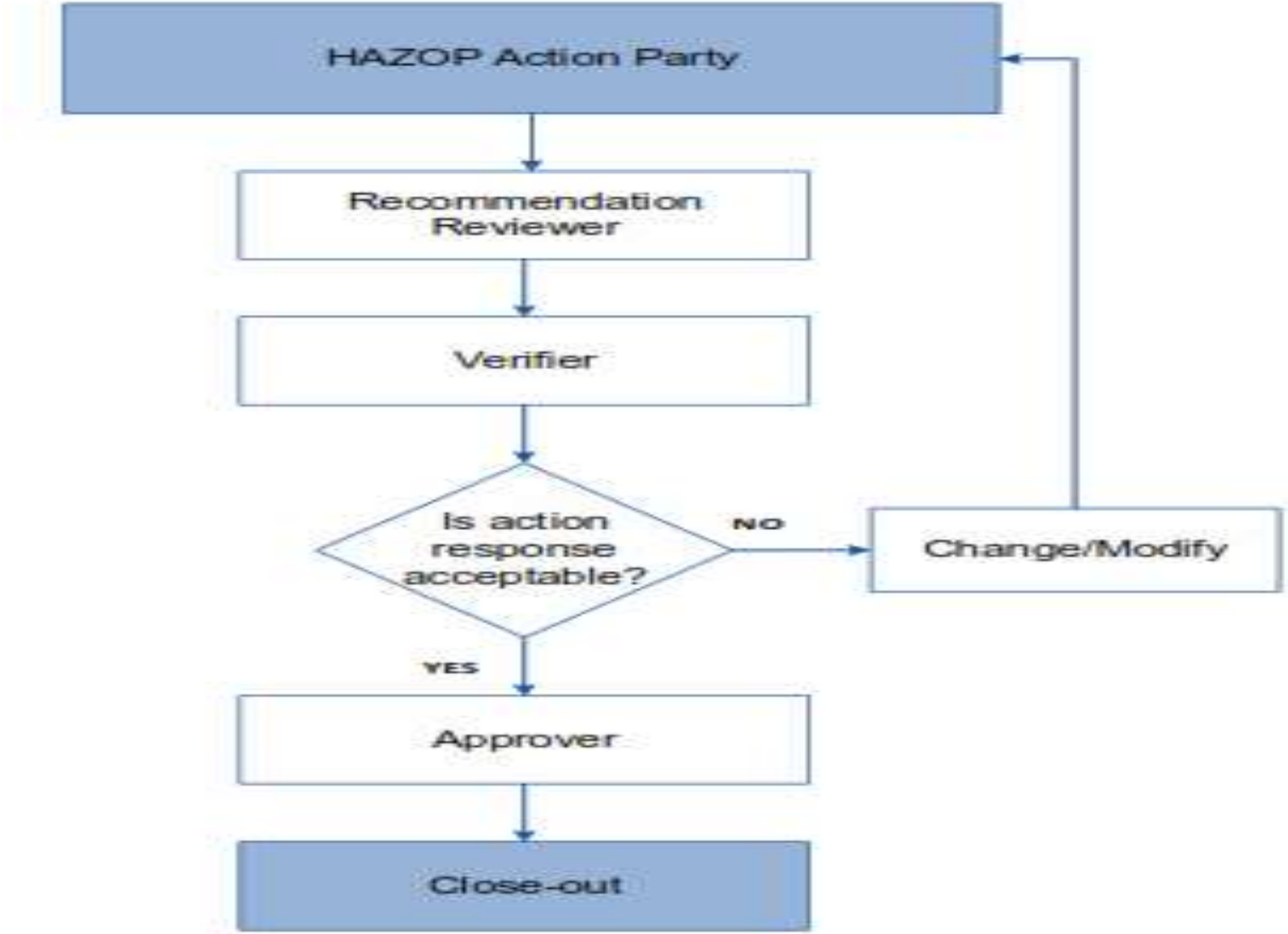
Approver

- Approver is typically the person in charge of a project or an operating facility from ADNOC Group.
- Approver must ensure that the responses for the action have been reviewed and verified by relevant technical authorities and signs off the action as complete.
- During the asset development stage, the CONTRACTOR shall issue the action response for ADNOC Group review and approval.
- Based on the nature of the recommendation, the respective technical authority from the Company shall approve all the recommendations.

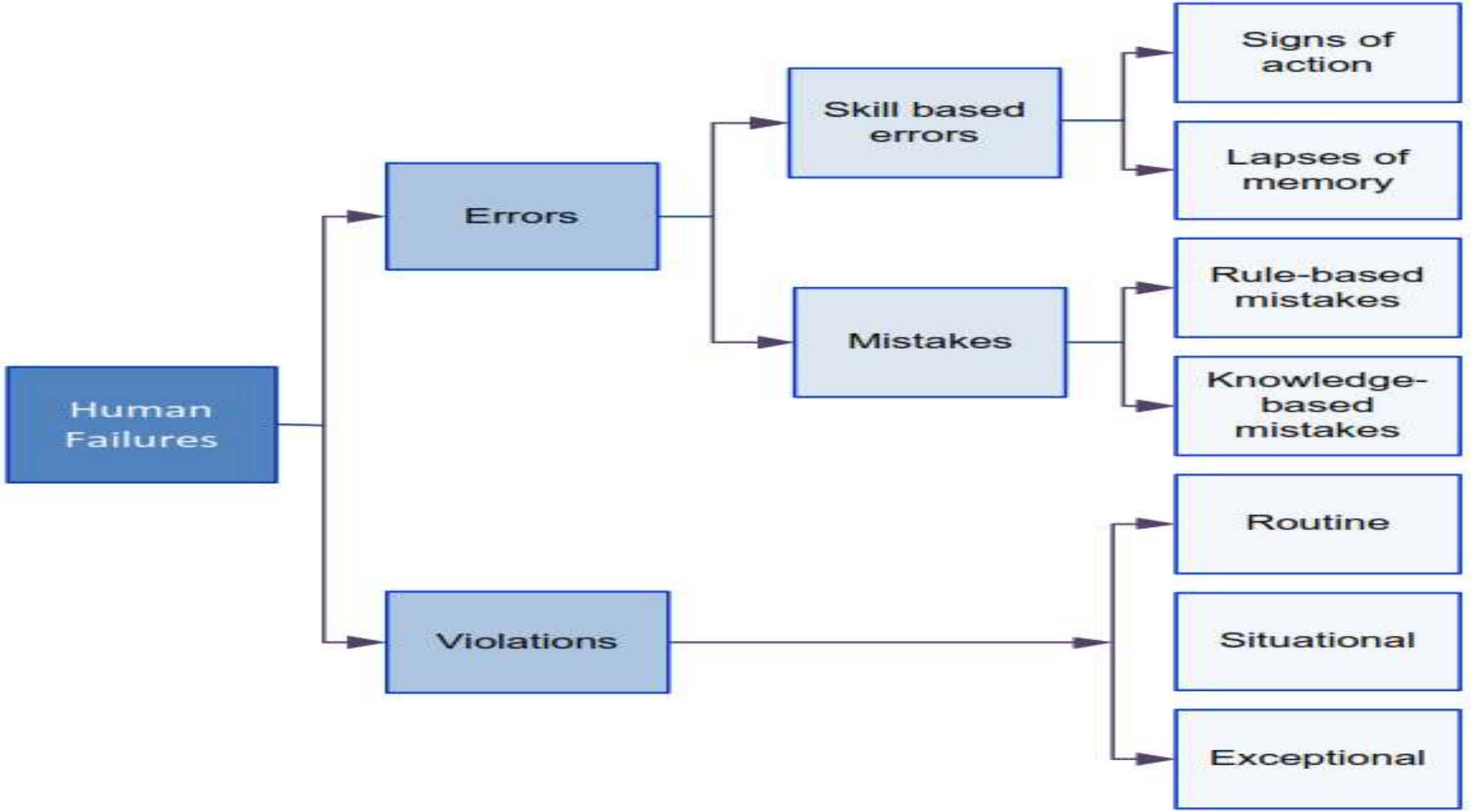
CLOSE-OUT REPORT

- Once all actions response sheets are complete and signed off, a close-out report comprising of the summary of actions, action response sheets, supporting documentation, copies of communications must be issued.

ACTION CLOSE-OUT AND APPROVAL



Integrating Human Errors (Failure) into the HAZOP (Informative)



KEY PERFORMANCE INDICATORS

Key Performance Indicators (KPIs) for the Standard shall include as a minimum the following

KPI	Target
HAZOP conducted as per requirements of this Standard	100% compliance with requirements of this Standard.
HAZOP Actions - Identified & Tracked	100% compliance with requirements of this Standard.
HAZOP Revalidation conducted as per requirements of this Standard	100% compliance with requirements of this Standard.

APPENDICES

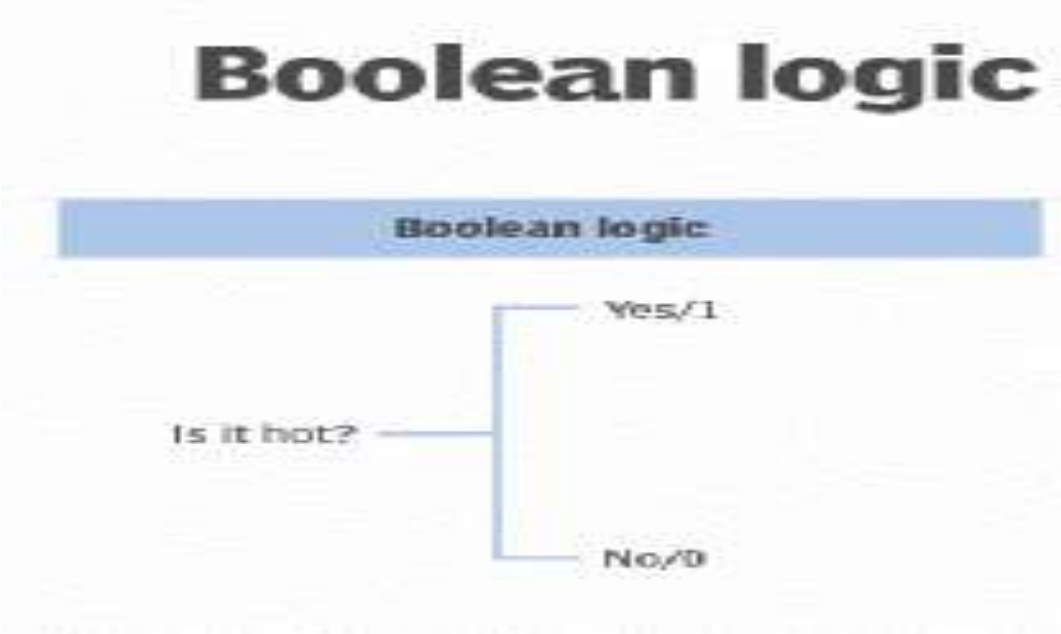
1. ADNOC Corporate Risk Matrix
2. HAZOP Worksheet
3. Information Pack Contents (Informative)
4. Integrating Human Errors (Failure) into the HAZOP (Informative)
5. List of Guidewords with Example Causes (Informative)
6. Specific Considerations in HAZOP (Informative)

Section 10 in the Standard shall be referred for Appendices

Fault Tree Analysis

What is Fault Tree Analysis

- Fault Tree Analysis (FTA) is a graphical tool used to explore the causes of system-level failures.
- It uses Boolean logic to combine a series of lower-level events.
- It is basically a top-down approach to identify the component-level failures (basic events) that cause the system-level failures (top events).
- Fault tree analysis consists of “events” and “logic gates,” which connect the events to identify the cause of the top undesired event.



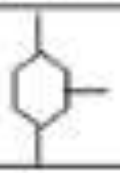
Fault-tree analysis FTA Symbols

Event Symbols in FTA:

S.No	Event Symbol	Description
1		Primary or basic failure event. It is a random event and sufficient data is available
2		State of system, subsystem or component event
3		Secondary failure or under developed event, can be explored further
4		Conditional event and is associated with the occurrence of some other event
5		House event representing either occurrence or non-occurrence of an event
6		Transfer in and transfer out symbols used to replicate a branch or sub-tree of the FTA

Fault-tree analysis FTA Symbols

Gate Symbols in FTA:

S.No	Gate Symbol	Description
1	 AND Gate	The output event occurs when all the input events occur
2	 OR Gate	The output event occurs when at least one of the input events occur
3	Priority AND Gate 	The output event occurs when all the input events occur in the order from left to right
4	 Exclusive OR gate	The output event occurs if either of the two input events occur but not both
5	 Inhibit gate	The output event occurs when the input event occurs and the attached condition is satisfied

When Would You Use FTA

- Fault Tree Analysis can be used to perform all types of system-level risk assessment processes. The purpose of FTA is to effectively identify the cause(s) of system failure and mitigate the risks before it occurs.

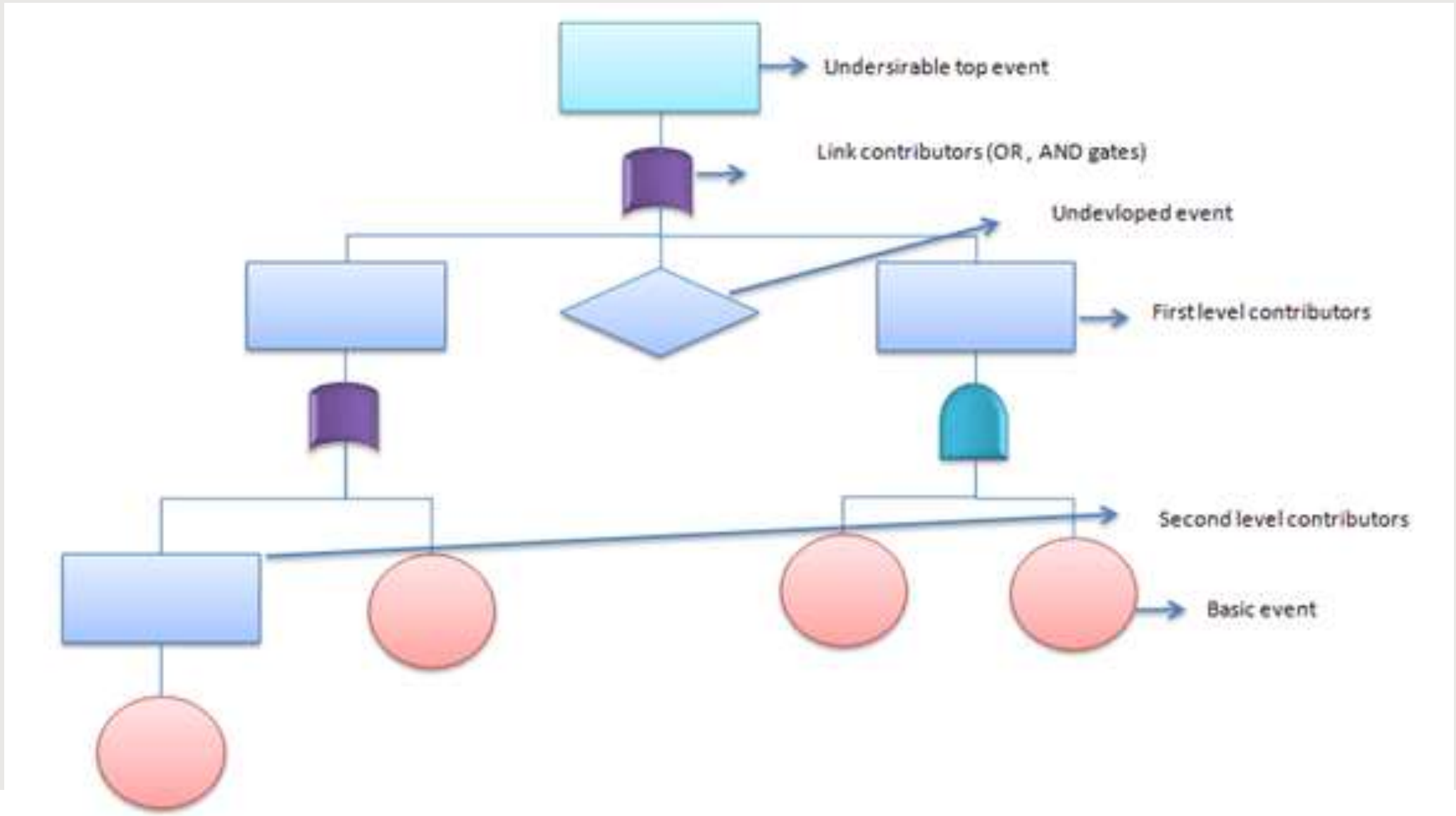
- This is an invaluable tool for complex systems that visually display the logical identification of the problem. Moreover, system efficiency can be attained by this analysis.

- It can be implemented alone or complement Failure Mode and Effects Analysis (FMEA).

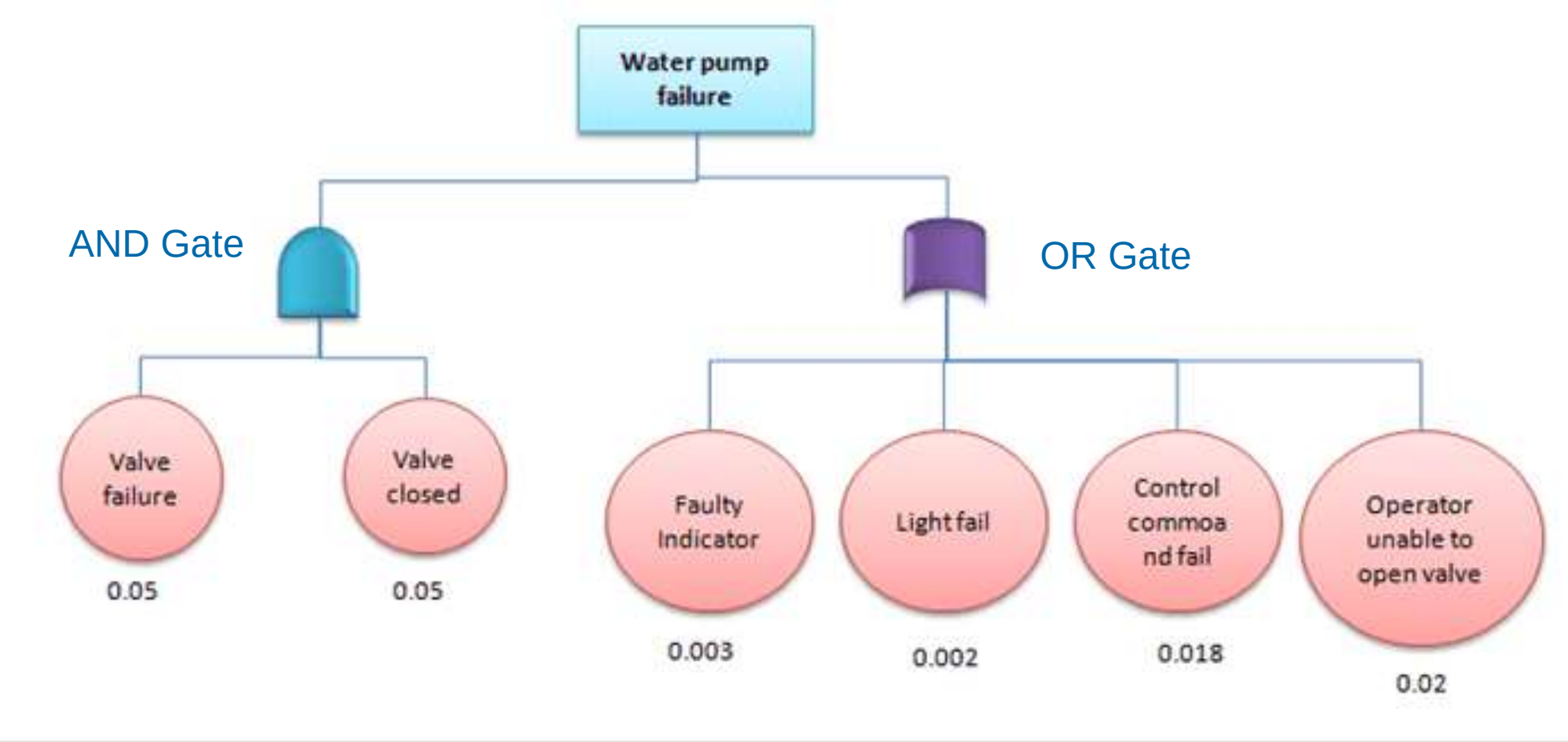
How do you do Fault Tree Analysis

- Define the primary failure to be analyzed. In other words, identify the undesirable top event.
- Identify first-level contributors who are just below the top level using the available technical information.
- Link these contributors to the top-level event using logical gates (AND, OR gates), and also see the relationship to help identify the appropriate logical gate.
- Identify the second-level contributors and link to the top by using logical gates.
- Identify the minimal cut set.
- Repeat the same steps till the basic causes,
- Finally, complete and evaluate the FTA.
- Calculate the probability of the lowest level element occurrence and also measure the probabilities from the bottom up.

Fault Tree Analysis flow Diagram



Example:
Find the probability of water pump failure from the below example.



The water pump will fail because of value failure and value closed or fault indicator or light failure control command failure or operator unable to open the valve, since OR gates add and AND gates multiply the probability of pump failure.

$$\mu_{\text{pump fail}} = 1 - [(1 - (0.05 * 0.05)) * (1 - 0.003) * (1 - 0.002) * (1 - 0.018) * (1 - 0.02)] = 0.0448$$

Hence, the probability of water pump failure = 4.48%

Advantages of Fault Tree Analysis

- The fault tree visually depicts the analysis that will help the team to work on the cause of an event in a logical way that leads to failure.
- Highlights the critical components related to system failure.
- Provides an efficient method to analyze the system.
- Unlike other analysis methods, human errors are also included in the analysis.
- It helps to prioritize the action items to solve the problem.
- Provides qualitative and quantitative analysis.

Disadvantages of Fault Tree Analysis

- Too many gates and events to be considered for large system analysis.
- The basic disadvantage is that it examines only one top event.
- Common cause failures are not always obvious.
- Difficult to capture time-related and other delay factors.
- Needs experienced individuals to understand the logical gates.

DAY 4

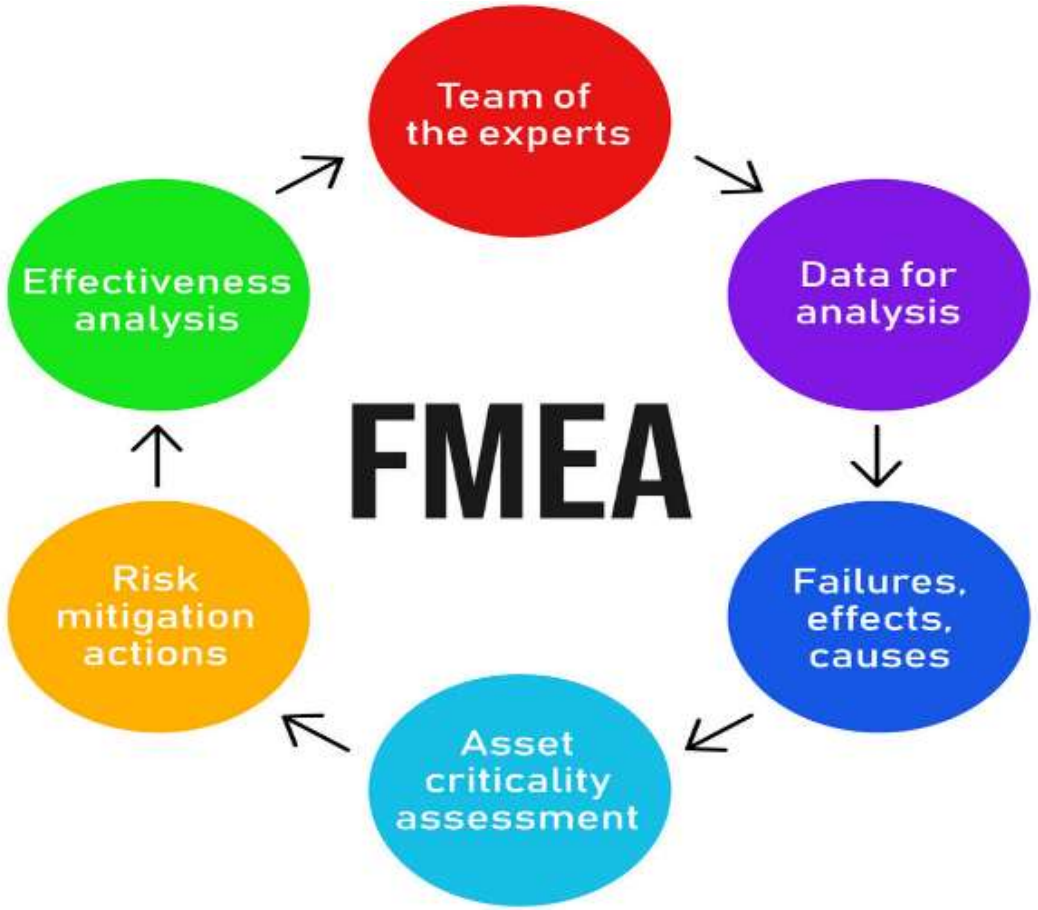
FMEA - LOPA

Failure Mode and Effects Analysis
Layers Of Protection Analysis

FMEA

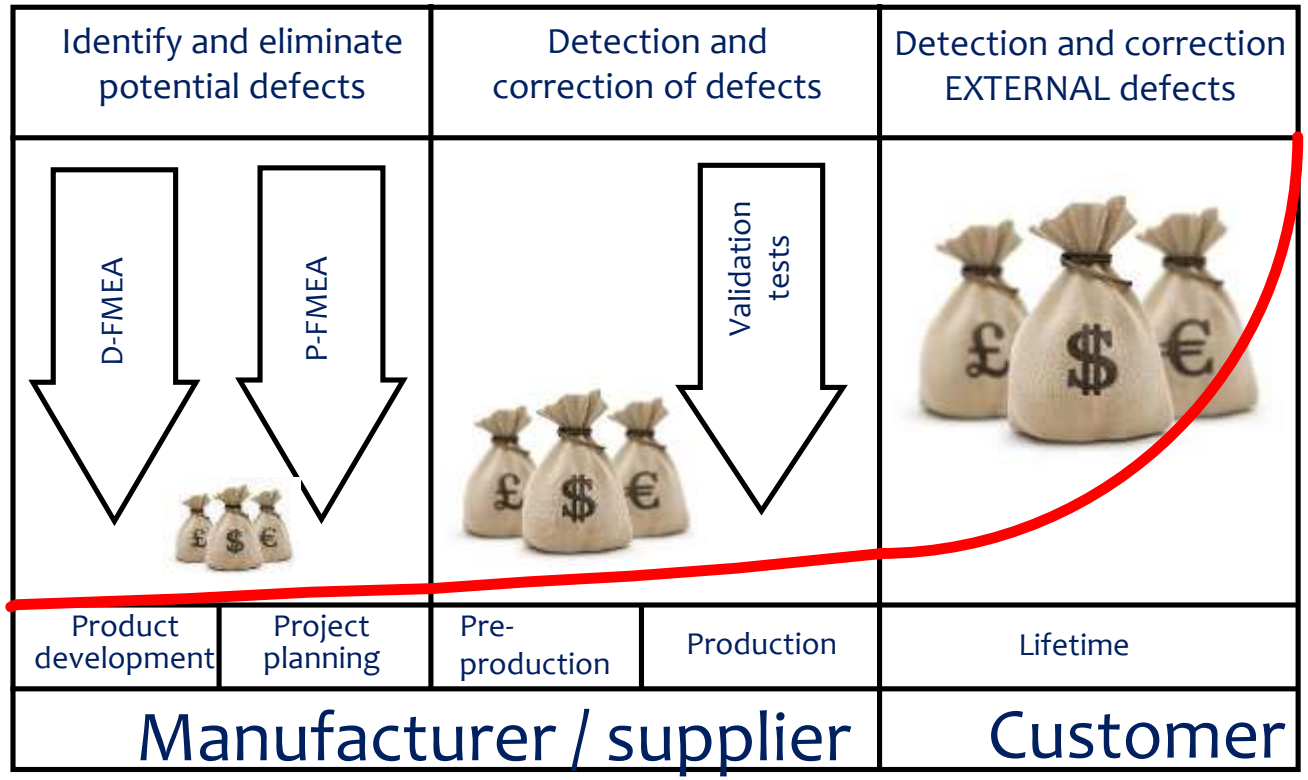
Failure Mode and Effects Analysis

FMEA : Failure mode and effects analysis



Purpose of the FMEA

Preventive costs | Cost of validation | Warranty costs



Preventive costs to identify potential defects by FMEA's are relatively low compared to in-house detection and correction of defects and even much lower than recovery costs in case defects are found by our Customers.

Purpose of the FMEA

Purpose of the FMEA:

- Methodology that facilitates process improvement
- Identifies and eliminates concerns early in the development of a process or design
- Improve internal and external customer satisfaction
- Risk Management tool, focuses on prevention
- FMEA may be a customer requirement (likely contractual, Level 3 PPAP, ISO 9001)

LEARNING FMEA, TRAINING OBJECTIVES

Training Objectives:

- To understand the use of Failure Modes and Effect Analysis(FMEA)
- To learn the steps to developing FMEAs
- To summarize the different types of FMEAs
- To learn how to link the FMEA to other Process tools

FMEA, SUMMARY

FMEA, a mathematical way to identify:

- failure modes, the ways in which a product or process can fail
- the Effects and Severity of a failure mode
- Potential causes of the failure mode
- the Occurrence of a failure mode
- the Detection of a failure mode
- the level of risk (Risk Priority Number)
- actions that should be taken to reduce the RPN

RPN = Severity X Occurrence X Detection

BENEFITS FMEA INPUTS

Inputs might include other tools such as:

D-FMEA (Part and Assembly level) Defines VOC

- Customer requirements
- CTQ (Critical to Quality) Flow down analysis
- Quality Function Deployment (House Of Quality)
- Risk assessments

P-FMEA (Process level) Delivers VOC (Volatile Organic Compounds)

- Process flowchart
- Sequence Of Events
- Process Tooling
- Poka-Yoke list

FMEA, APPLICATION EXAMPLES

There are several situations where an FMEA is the optimal tool to identify risk:

Process-FMEA:

- Introducing a new process
- Reviewing existing processes after modifications
- Introduce new Part Numbers on an existing Production Line

•Design-FMEA:

- Introducing a new Design, Part, Sub Assembly or Assembly
- Use an existing Design for another application
- Reviewing existing Designs after modifications

WHAT IS A FAILURE MODE?

A **Failure Mode** is:

- The way in which the component, subassembly, product or process could fail to perform its intended function
- Failure modes may be the result of previous operations or may cause next operations to fail
- Things that could go wrong INTERNALLY:
  - Warehouse
  - Production Process
- Things that could go wrong EXTERNALLY:
  - Supplier Location
  - Final Customer

WHEN TO CONDUCT AN FMEA

When to Conduct an FMEA?

- Early in the New Product Introduction (A-Build) complete for B build.
- When new systems, products, and processes are being designed
- When existing designs or processes are being changed, FMEA’s to be updated
- When process improvements are made due to Corrective Action Requests

HISTORY OF FMEA

History of FMEA:

- First used in the 1960's in the Aerospace industry during the Apollo missions
- In 1974, the Navy developed *MIL-STD-1629* regarding the use of FMEA
- In the late 1970's, the automotive industry was driven by liability costs to use FMEA
- Later, the automotive industry saw the advantages of using this tool to reduce risks related to poor quality (QS-9000, VDA and ISO-TS 16949 standard)

Case Study, what could have been avoided using FMEA

AubieSat-1 was the first ever, 4-inch **Cube**

Satellite to be accepted by NASA for launch.

It was launched into space 28 th October 2011

from Vandenberg Air Force Base in California on

a NASA-sponsored Delta II rocket.

HISTORY OF FMEA, CASE STUDY

What was the failure mode?

Once the satellite was deployed:

- the team had problems making contact with the satellite
- One of the 2 antennae failed to deploy
- The signal transmitter at the control center did not have enough power to communicate with the satellite

How was it solved?

- The team used another signal transmitter from an earlier flight which had enough power to enable communication

Lessons learned:

- Plan for errors!

The use of an FMEA most likely had avoided the malfunction involving people from the earlier flight

- Teamwork!

The collaboration relationship between teams enabled the team to use the alternative equipment. Without it, the mission could have failed.

Why Do I Care?

First Time Right, Calculated Risk, Rights Team will safe resources!

TYPES OF FMEAS

Design FMEA

- Analyzes product design before release to production, with a focus on product function
- Analyzes systems and subsystems in early concept and design stages

Process FMEA

- Used to analyze manufacturing and assembly processes before they are implemented

FMEA: A TEAM TOOL

•A team approach is necessary, see example **AubieSat-1**

communication problems could have been avoided by involving a practical experienced team!

•Team should be led by the **Right** person, Design, Manufacturing or Quality Engineer, etc…familiar with FMEA

•The following Team members should be considered:

- Design Engineers
- Process Engineers
- Supply Chain Engineers
- Line Design Engineers
- Suppliers
- Operators
- Practical Experts

THE FMEA FORM

Process/Product
Failure Modes and Effects Analysis Form
(FMEA)

Processor Product Name:	
Responsible:	

Prepared by:	Page ____ of ____
FMEA Date (Orig) _____ (Rev) _____	

Process Step / Input	Potential Failure Mode	Potential Failure Effects	SEVERITY	Potential Causes	OCCURRENCE	Current Controls	DETECTION	RPN	Actions Recommended	Resp.	Actions Taken	SEVERITY	OCCURRENCE	DETECTION	RPN
What is the process step and Input under investigation?	In what ways does the Key Input go wrong?	What is the impact on the Key Output Variables (Customer Requirements)?		What causes the Key Input to go wrong?		What are the existing controls and procedures (inspection and test) that prevent either the cause or the Failure Mode?			What are the actions for reducing the occurrence of the cause, or improving detection?		What are the completed actions taken with the recalculated RPN?				
								0							0
								0							0
								0							0
								0							0
								0							0

Identify failure modes and their effects

Identify causes of the failure modes and controls

Prioritize

Determine and assess actions

FMEA PROCEDURE

1. For each process input determine the ways in which the input can go wrong (failure mode)

2. For each failure mode, determine effects

   Select a Severity level for each effect

3. Identify potential causes of each failure mode

   Select an Occurrence level for each cause

4. List current controls for each cause

   Select a Detection level for each cause

RPN = Severity X Occurrence X Detection

FMEA PROCEDURE (CONT.)

5. Calculate the Risk Priority Number (RPN)

6. Develop recommended actions, assign responsible persons, and take actions

- Give priority to high RPNs
- MUST look at highest severity

7. Assign the predicted Severity, Occurrence, and Detection levels and compare RPNs (before and after risk reduction)

RATING SCALES

- Preferred Scales are1-10
- Adjust Occurrence scales to reality figures for your company

Severity:

1 = Not Severe, 10 = Very Severe

Occurrence:

1 = Not Likely, 10 = Very Likely

Detection:

1 = Easy to Detect, 10 = Not easy to Detect

Process/Product
Failure Modes and Effects Analysis Form
(FMEA)

Processor Product Name:	
Responsible:	

Prepared by:	Page____ of____
FMEA Date (Orig)_____ (Rev)_____	

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								0							0
								0							0
								0							0
								0							0
								0							0

Identify failure modes and their effects

Identify causes of the failure modes and controls

Prioritize

Determine and assess actions

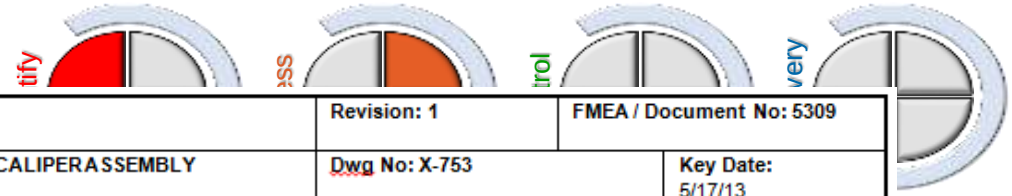
RPN scale
Focus on highest risk

FLUKE.

		RPN									
Severity	10	10	40	90	160	250	360	490	640	810	1000
	9	9	36	81	144	225	324	441	576	729	900
	8	8	32	72	128	200	288	392	512	648	800
	7	7	28	63	112	175	252	343	448	567	700
	6	6	24	54	96	150	216	294	384	486	600
	5	5	20	45	80	125	180	245	320	405	500
	4	4	16	36	64	100	144	196	256	324	400
	3	3	12	27	48	75	108	147	192	243	300
	2	2	8	18	32	50	72	98	128	162	200
	1	1	4	9	16	25	36	49	64	81	100
		1	2-4	5-9	10-16	17-25	26-36	37-49	50-64	65-81	82-100
		Occurance x Detection									

FMEA	
Priority Number (SxOxD)	Action
150-1000	Major - Risks that must be reduced
75-149	Medium - Investigate reducing risk in this area
1-75	Minor - Acceptable risks, no action required

Risk Assessment with FMEA



Customer: NMHG BEREA	**Customer Part No:** 8675309	**Revision:** 1	**FMEA / Document No:** 5309
Supplier: ACME WIDGETS	**Supplier Part No:** X-753 BRAKECALIPERASSEMBLY	**Dwg No:** X-753	**Key Date:** 5/17/13

Part Name: BRAKE CALIPER	**Process Responsibility:** M.E.	**Application Date:** 6/1/13	**Prepared By:** JENNY TONE	**Date:** 5/28/13
Core Team: JENNY TONE, JOHN DOE, JOHN SMITH, BILL CLINTON, SAMMY DAVIS		**Approved By:** DONALD TRUMP		**Date:** 6/27/13

Process Description / Process Purpose	Potential Failure Mode	Potential Effects(s) of Failure	SEV	Potential Cause(s) of Failure	OCC	Current Control	DET	RPN	Recommended Actions	Area/Individual Responsible & Completion Date	SEV	OCC	DET	RPN

1	Slight injury or health effect	Slight damage	Slight effect	Slight Impact
2	Minor injury or health effect	Minor damage	Minor effect	Minor Impact
3	Major injury or health effect	Moderate damage	Moderate effect	Moderate Impact
4	PTD or up to 3 fatalities	Major damage	Major effect	Major Impact
5	More than 3 fatalities	Massive damage	Massive effect	Massive Impact

BARRIERS

Risk Assessment with FMEA

Customer: NMHG BEREA	Customer Part No: 8675309	Revision: 1	FMEA / Document No: 5309
Supplier: ACME WIDGETS	Supplier Part No: X-753 BRAKECALIPERASSEMBLY	Dwg No: X-753	Key Date: 5/17/13
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Identify failure modes at each process step!

Identify consequences of that failure!

Determine Severity of failure mode!

Identify potential companyt causes of failure mode!

Document current process controls!

How capable are we of detecting the failure mode with our current controls?

Risk Priority Number (RPN).
Highest # equals Highest Risk!
Severity x Occurrence x Detectability = RPN
Use Like Pareto Chart to identify what items to address first.

Risk Assessment with FMEA

Severity

Effect	Rank	Effects on Process	Effects on Product
Extreme	10 9	No build condition Injury to process or assembly personnel	Effect on safety or noncompliance with codes and standards
High	7 8	Possible major disruption at downstream operations May cause major rework or repair Possible significant damage to equipment or tooling	Effects on major system. Not safety related. May require unscheduled maintenance
Moderate	4 5 6	Effects throughout process May cause unscheduled rework or repairs May cause minor damage to equipment or tooling	Customer will notice immediately upon receipt. Affects subsystem/product performance. May require additional maintenance
Low	3	Limited effect on local process. Limited effect to downstream process. May create minor rework	Slightly noticeable, no effect on system performance
Very Low	2	Limited effect to local process No downstream process impact	Not noticeable at the system level Limited effect on the product (subsystem or below)
Minor	1	Not noticeable in-house. No negative effect on any process. No negative effect on system performance	Not noticeable No effect on the product or end user

Occurrence

Frequency Ranking	Qualitative Condition	Quantitative Condition (Possible Failure Frequency Throughout Design Life)
1	Remote:Failure Unlikely	<=.005% (1/20000 Units)
2		.001% (1/10000 Units)
3	Low:Relatively Few	.05% (1/2000 Units)
4		.01% (1/1000 Units)
5	Moderate: Occasional	.2% (1/500 Units)
6		.5% (1/200 Units)
7		1% (1/100 Units)
8	High: Repeated Failures	2% (1/50 Units)
9		10% (1/10 Units)
10	Very high:Inevitable	>=10% (1/10 Units)

Detection

Detectability Rankings	Detectability	Condition
1	Very High	Probability of shipping <= .01% (1/10000)
2		.02% (1/5000)
3	High	.05% (1/2000)
4		.10% (1/1000)
5	Moderate	.2% (1/500)
6		.5% (1/200)
7	Low	1% (1/100)
8		2% (1/50)
9	Very Low	5% (1/20)
10		>=10% (1/10)

Risk Assessment with FMEA

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Supplier: ACME WIDGETS	Supplier Part No: X-753 BRAKE CALIPER ASSEMBLY	Dwg No: X-753	Key Date: 5/17/13
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CASTING ATTACH TORQUE	OVER TORQUE	CASTING FRACTURE	10	TORQUE WRENCH NOT CONTROLLED	4	DC TORQUE WRENCH USED / LINKED TO OMS	3	120	ADD TORQUE ALARM AND CALIBRATION AT START UP.	JENNY TONE	10	2	1	20
	UNDER TORQUE	CASTING SEPARATION	9	TORQUE WRENCH NOT USED/ CONTROLLED										
	CROSS THREAD	CASTING SEPARATION	9	NO LEAD IN ON BOLT THREAD										

Effect	Rank	Effects on Process	Effects on Product
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9	Very Low	5% (1/20)
10		>=10% (1/10)

RISK PRIORITY NUMBER (RPN)

RPN is the product of the severity, occurrence, and detection scores

FMEA, 10 STEPS CHECKLIST

10 Steps to Conduct a PFMEA

1. **Review the process**—Use a process flowchart to identify each process component
2. **Brainstorm potential failure modes**—Review existing documentation and data for clues
3. **List potential effects of failure**—There may be more than one for each failure
4. **Assign Severity rankings**—Based on the severity of the consequences of failure
5. **Assign Occurrence rankings**—Based on how frequently the cause of the failure is likely to occur
6. **Assign Detection rankings**—Based on the chances the failure will be detected prior to the customer finding it
7. **Calculate the RPN**—Severity X Occurrence X Detection
8. **Develop the action plan**—Define who will do what by when
9. **Take action**—Implement the improvements identified by your PFMEA team
10. **Calculate the resulting RPN**—Re-evaluate each of the potential failures once improvements

SUMMARY

HAZOP are fairly simple, but can be a bit on the tedious side and time consuming.

The Flow Keyword seems to go on for ever – once that one out of the way, the rest is normally quite quick – so don't get depressed if Flow takes many hours.

Time requirement depends on process complexity

- Typical refinery unit requires 2-4 weeks
- No more than 6 hours per day is recommended
- Additional team leader time required for planning & documentation

LOPA

Layers Of Protection Analysis

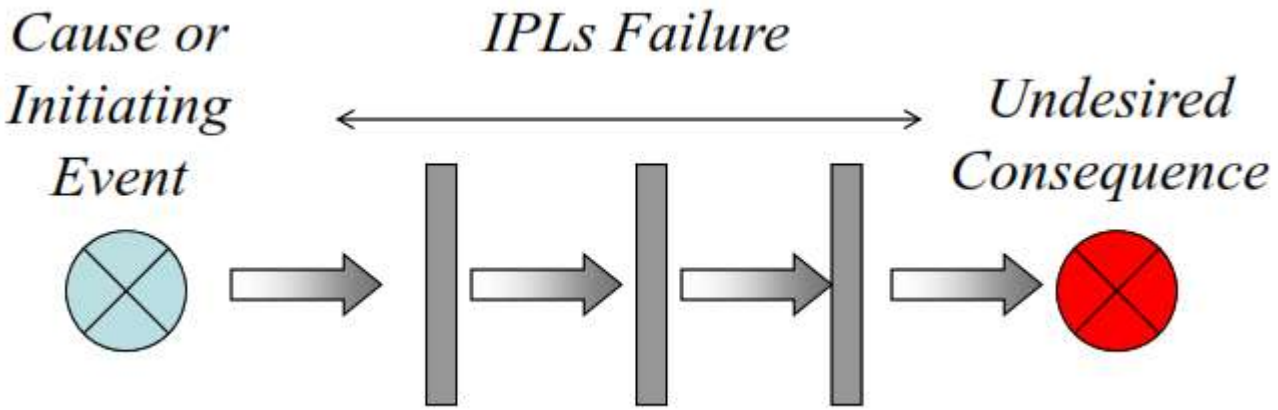
What is LOPA?

- Evaluate risks in ***orders of magnitude*** of selected accident ***scenarios***
- Builds on the information developed in ***qualitative hazard evaluation*** e.g. HAZOP

Main Questions

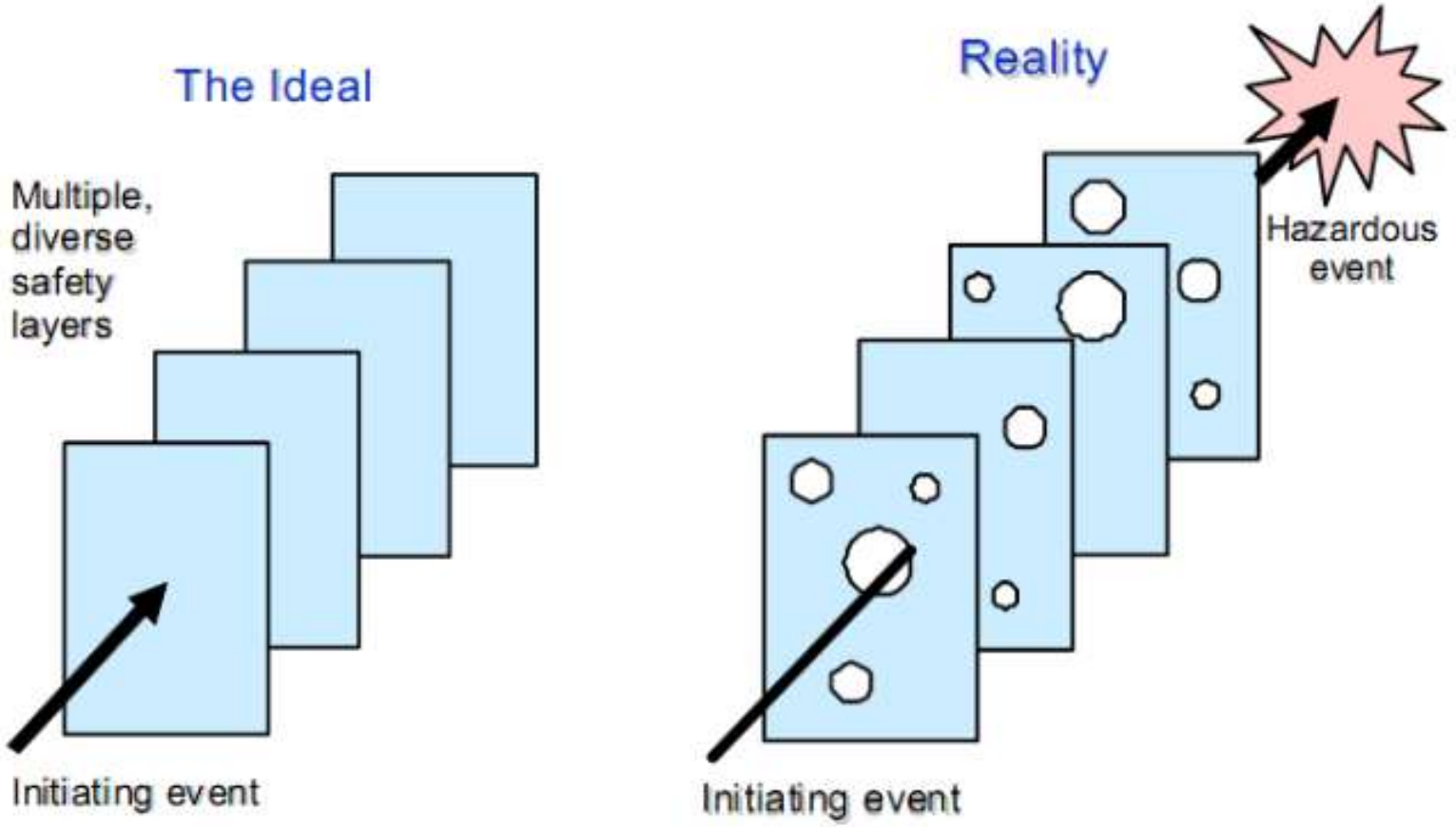
- LOPA helps to answer the following questions:
  - What's the ***likelihood*** of undesired events / scenarios?
  - What's the ***risk*** associated with the scenarios?
  - Are there ***sufficient risk mitigation measures?***

Basic Principle

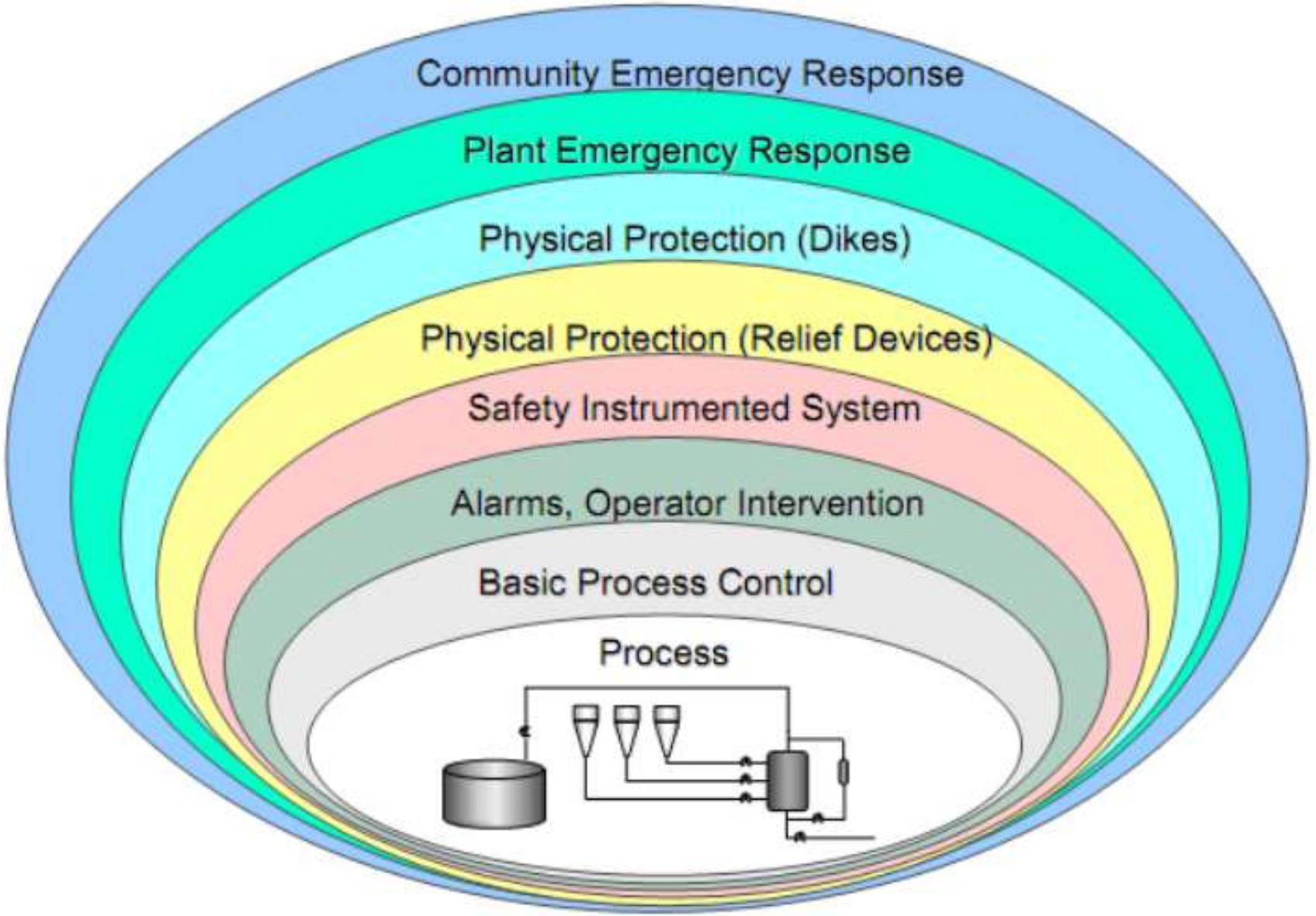


Independent Protection Layer (IPL)
Safeguard capable of preventing a scenario from proceeding to its undesired consequence.

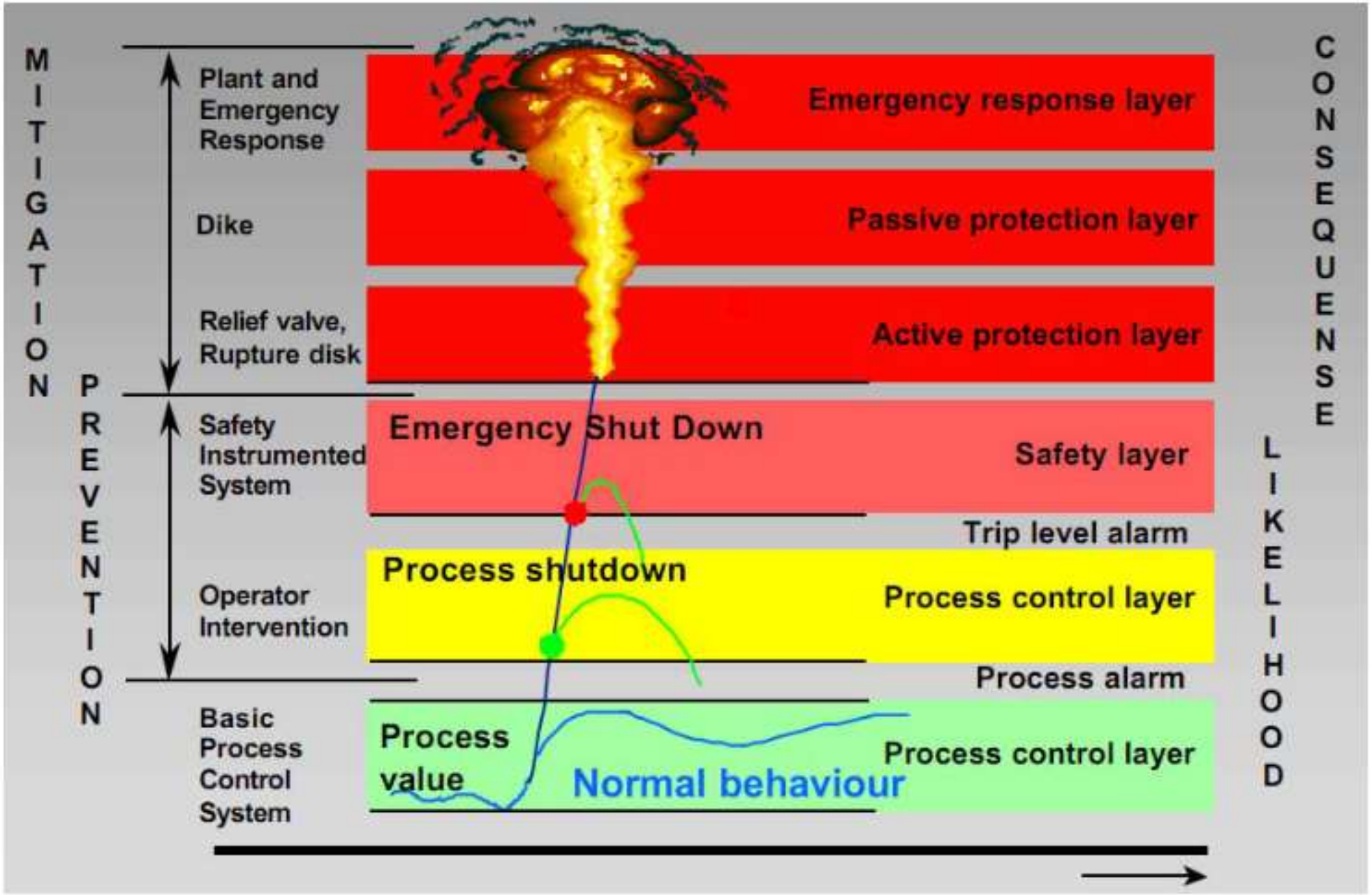
Protection Layers
The Ideal & Reality



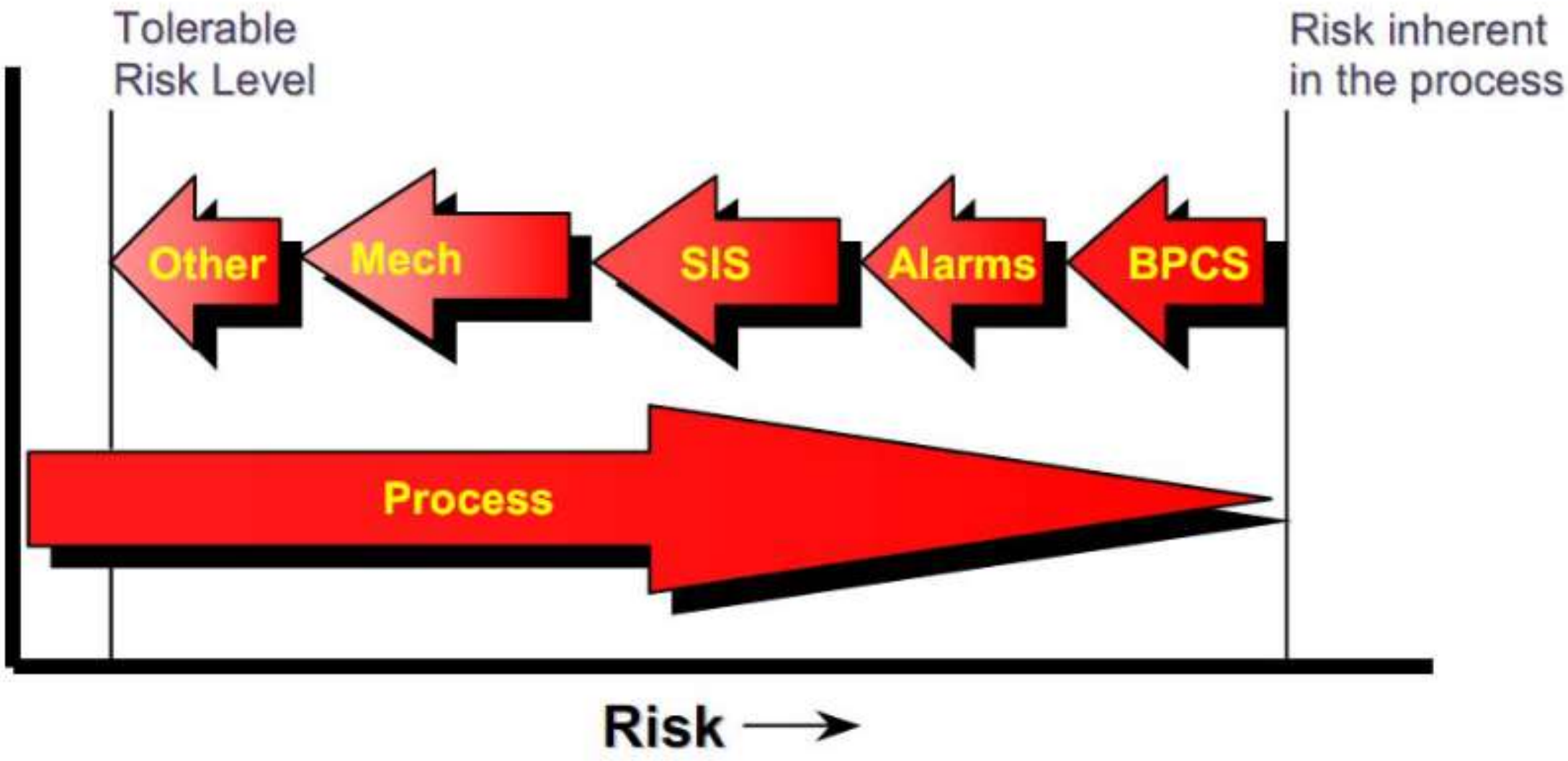
Concept of Layers of Protection



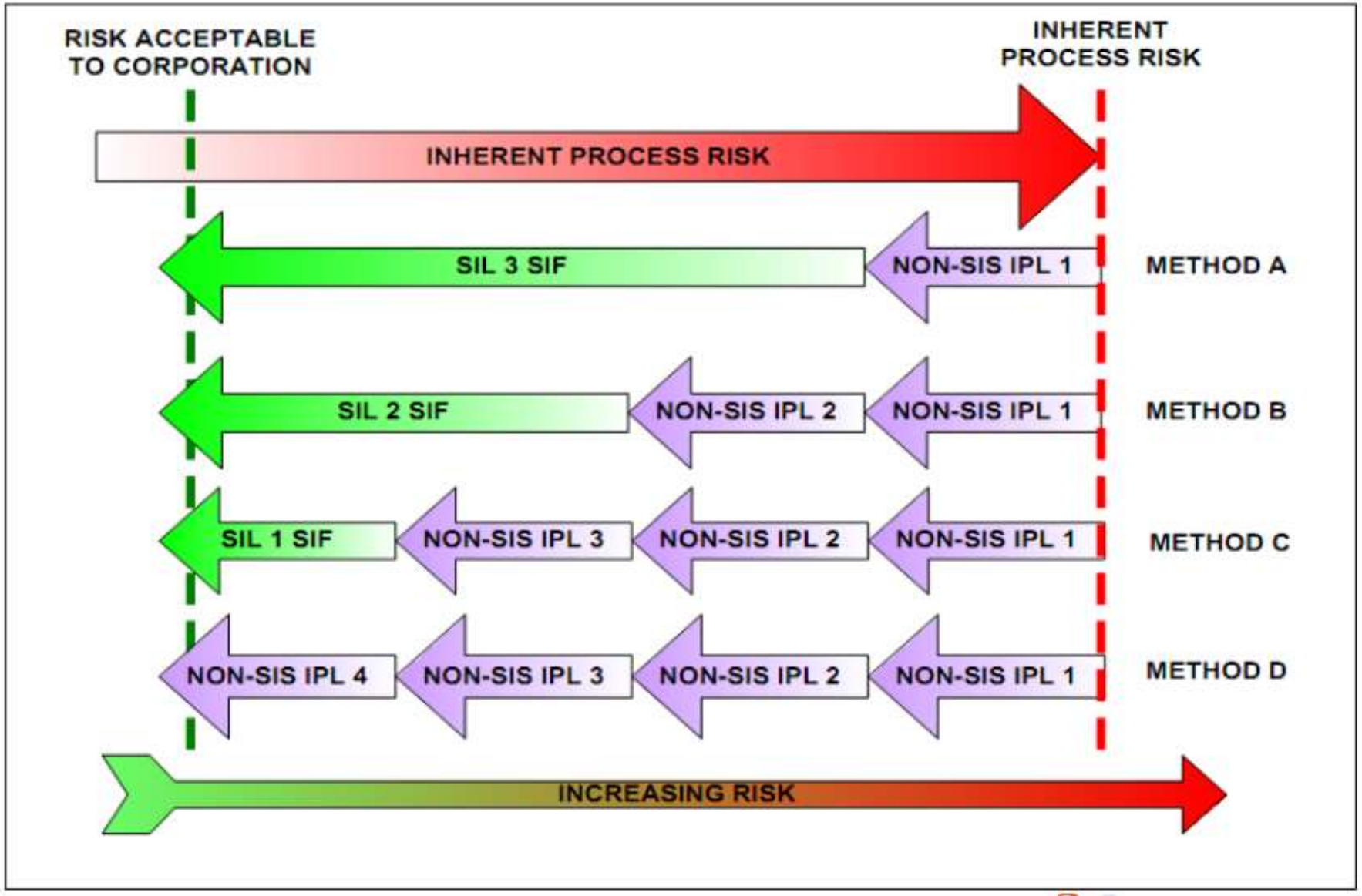
Concept of Layers of Protection



Reducing Risk with Multiple Protection Layers



Risk Reduction Using non-SIS (Safe Instrument Systems) IPLs (Independent Protection Layers) and SIFs (Safety Instrumented Functions)



What is ***scenario*** ?

Cause + ***Consequence*** = ***Scenario***

LOPA is limited to evaluating ***a single cause-consequence pair*** as a scenario

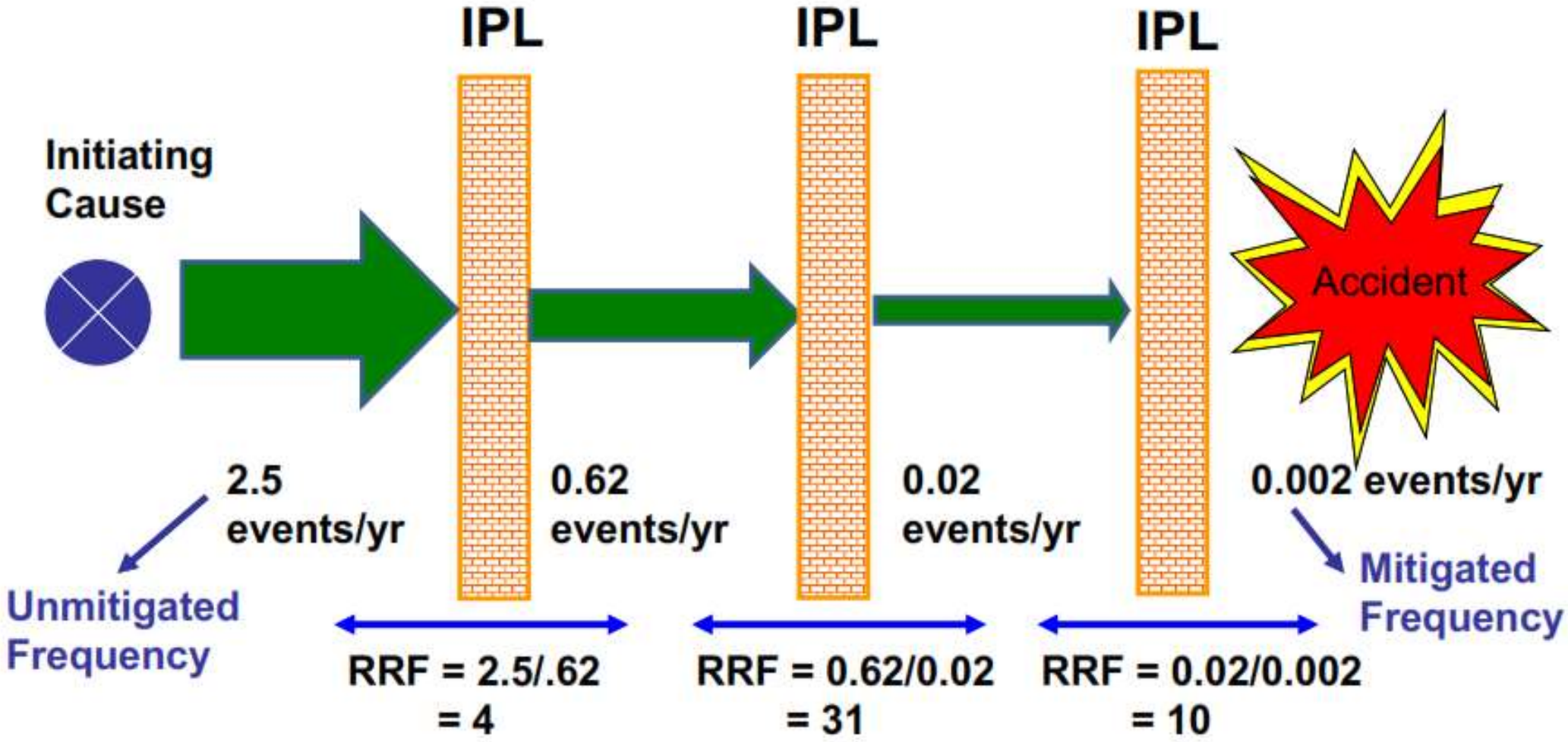
LOPA Five Basic Steps

1. Scenarios identification.
2. Identify the ***initiating event*** of the scenario and determine the initiating event frequency (events per year).
3. Identify the ***IPLs*** and estimate the ***probability of failure on demand*** of each IPL.
4. Estimate the risk of scenario.
5. Compare the calculated risk with the company's tolerable risk criteria

Independent Protection Layers

- All IPLs are safeguards, but not all safeguards are IPLs.
- An IPL has two main characteristics:
  - How effective the IPL in preventing the scenario from resulting to the undesired consequence?
  - Is the IPL independent of the initiating event and the other IPLs?

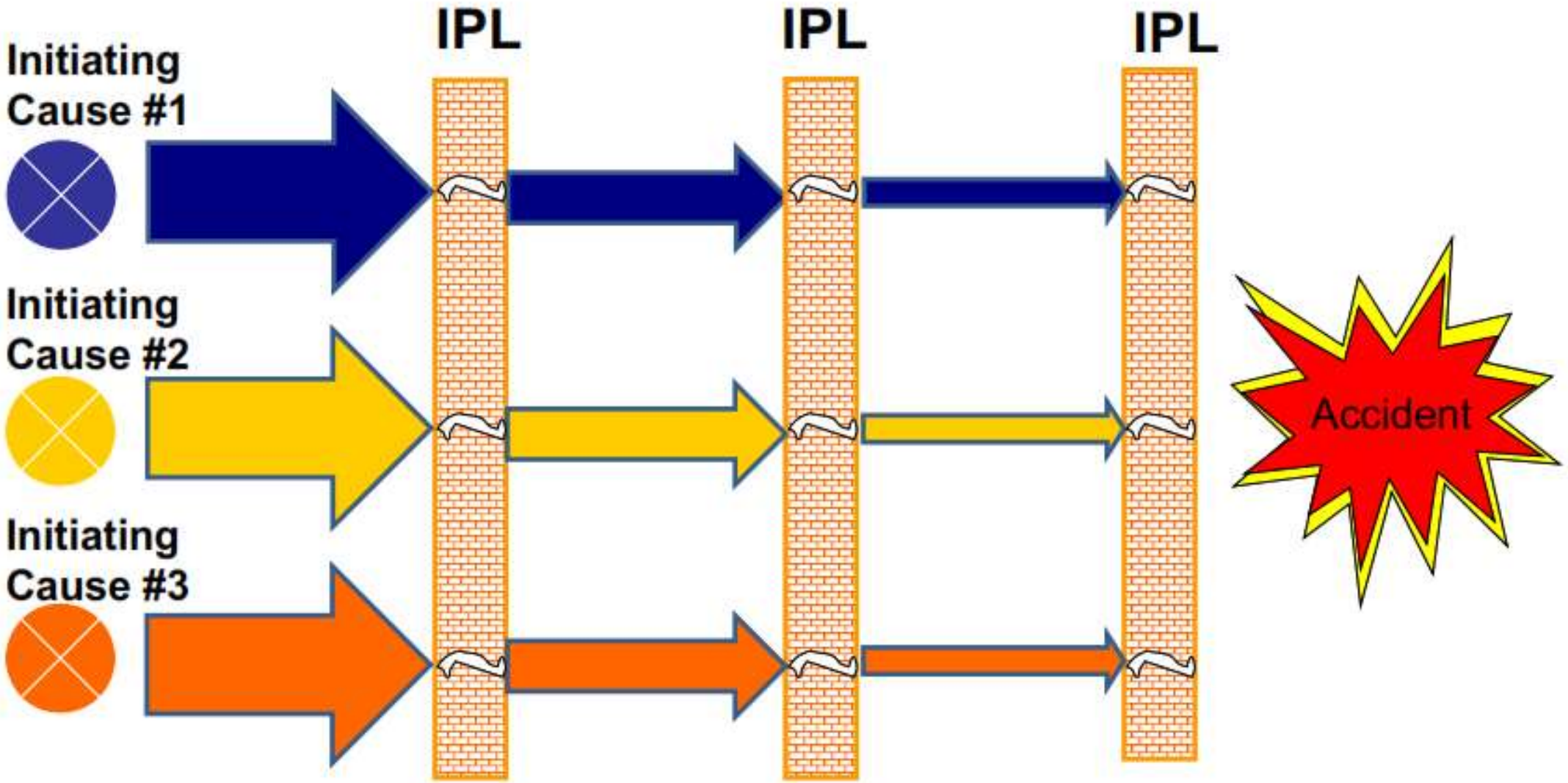
Basic Principle



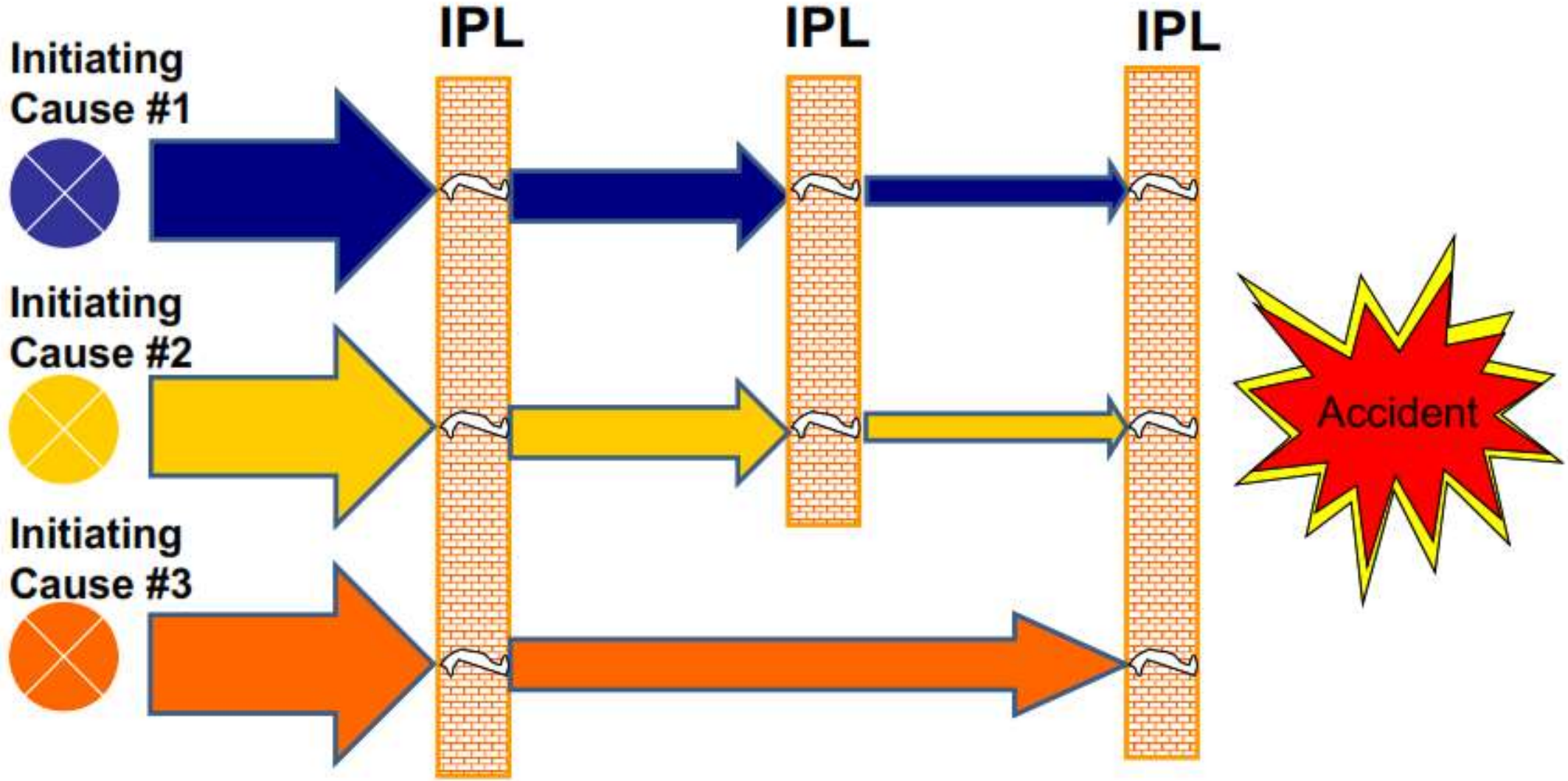
IPL - Independent Protection Layer

RRF - Risk Reduction Factor

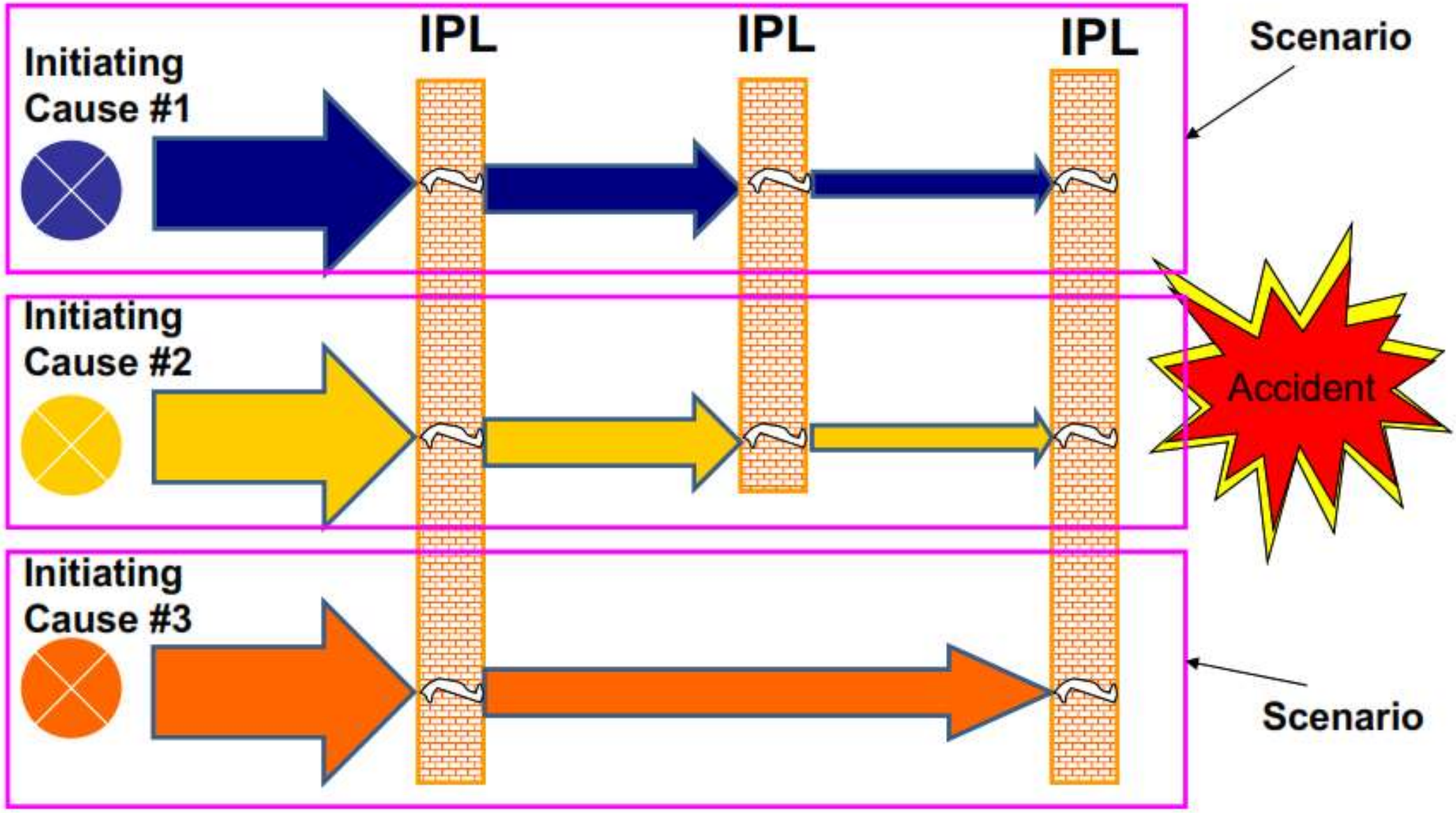
Basic Principle



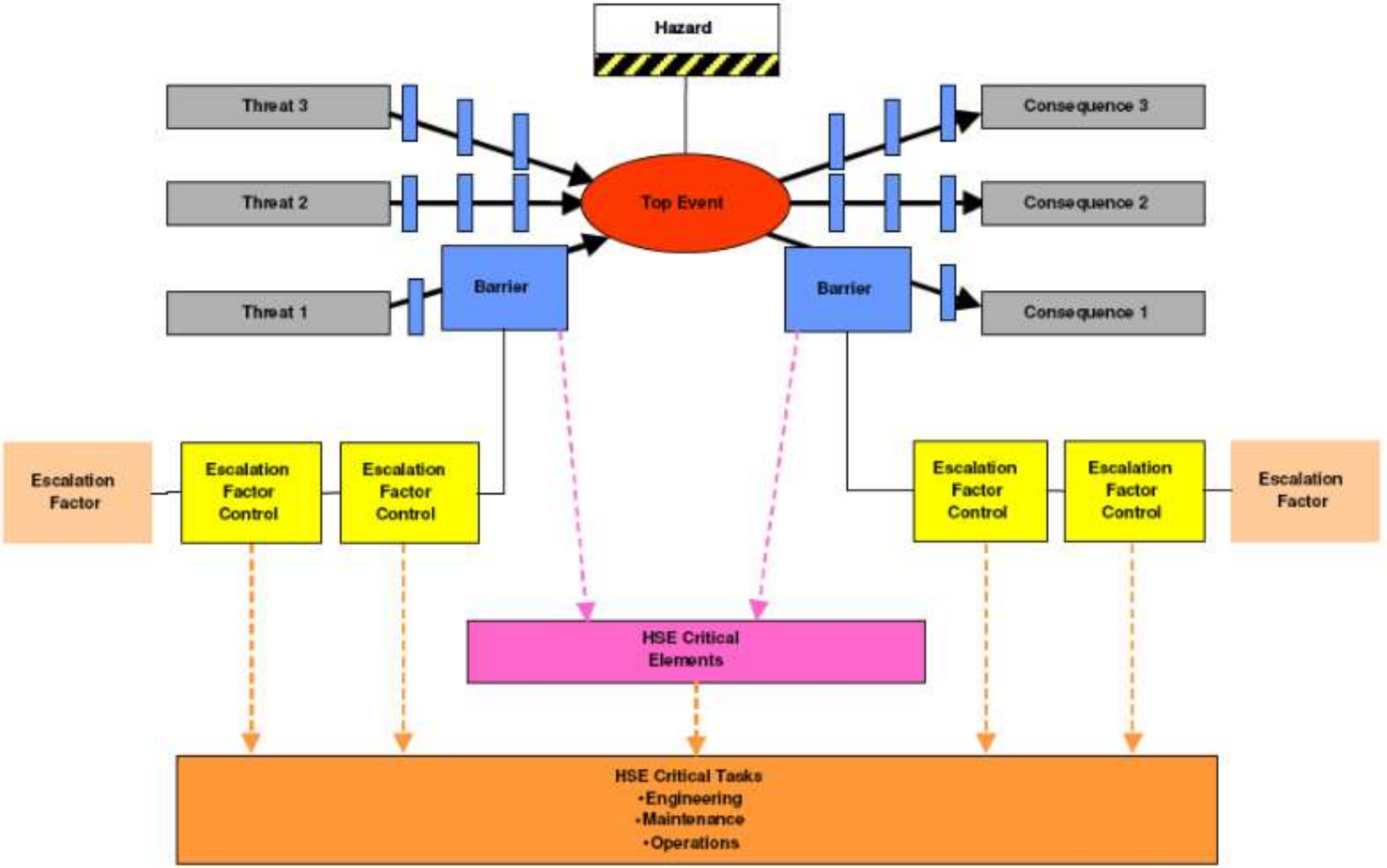
Basic Principle



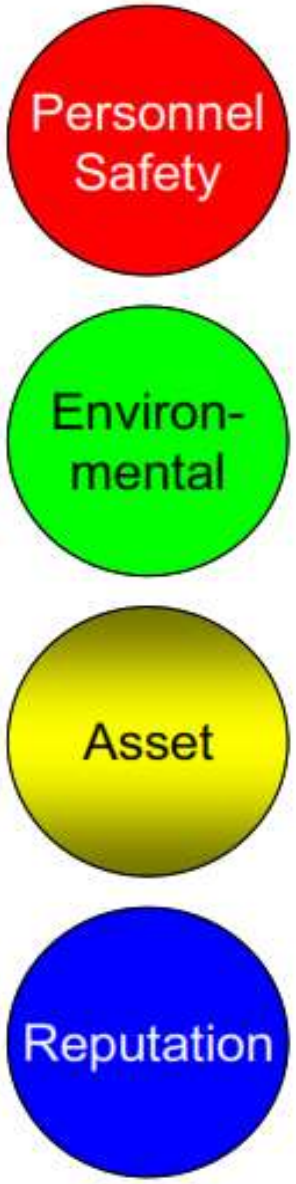
Basic Principle



Preventive & Mitigative Layers



No.	Initiating Event	Consequence			
		P	E	A	R
1	Flange leakage, HP Gas, High H2S, Manned Area	✓			
2	Major Crude Oil leakage from sub-sea pipeline		✓	✓	✓
3	Water carryover into HP Air Compressor leading to compressor damage			✓	
4	Over-pressurization & rupture of Gaseous Nitrogen Storage Vessel	✓		✓	
5	Over-pressurization & rupture of Two Phase Separator handling Hydrocarbons leading to fire.	✓		✓	
6	Loss of lube oil to HP Compressor bearings			✓	



Multiple Initiating Events

- Accidents often have multiple potential triggers that can propagate to an unwanted accident.

Example

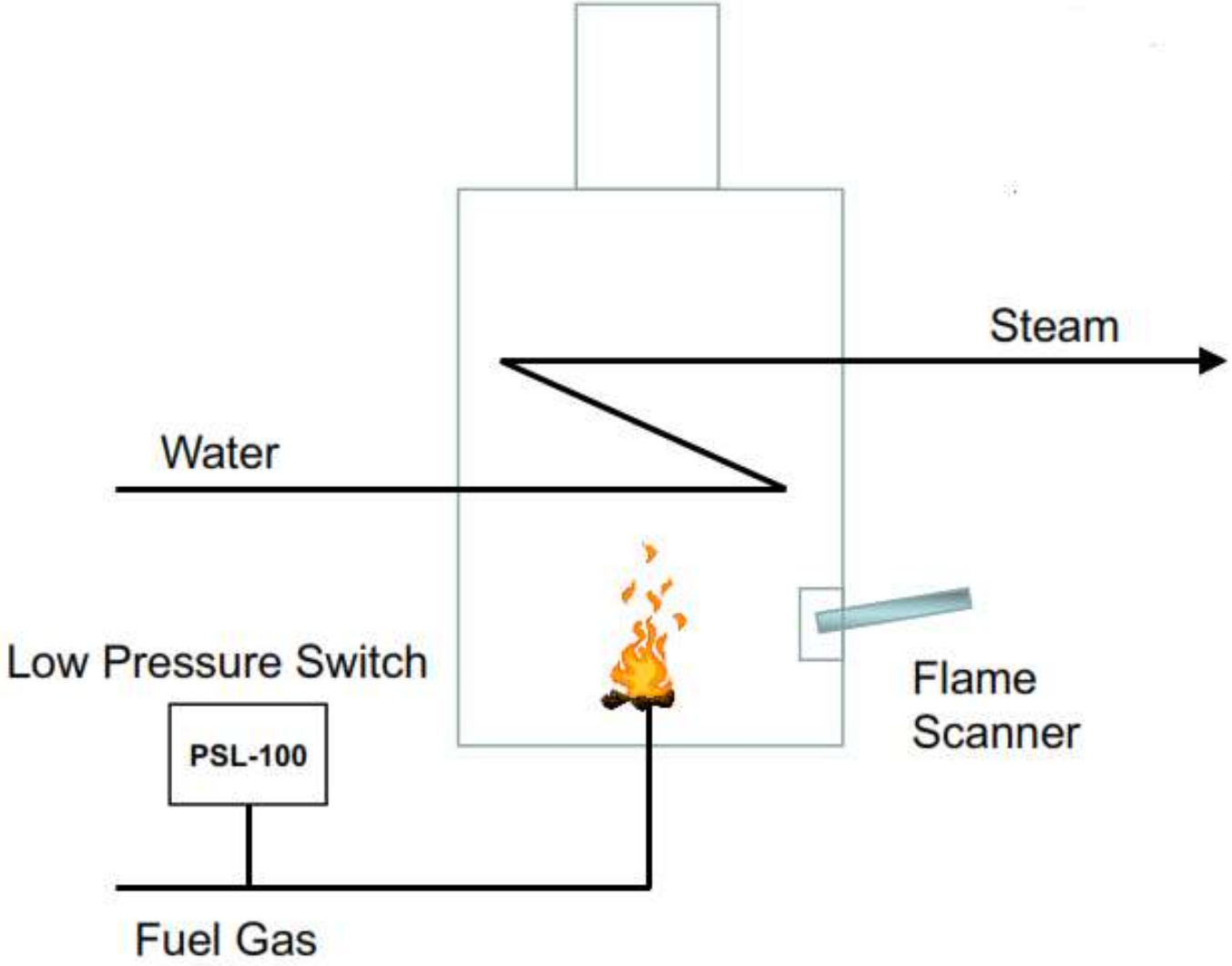
- Gas Fired boiler's loss of flame without isolating the fuel supply can result in vapour cloud explosion.

Initiating Events:

1. A momentary drop in fuel gas pressure
2. A momentary high pressure spike
3. A slug of condensate in the fuel line
4. Incorrect air fuel ratio

Multiple Initiating Events & IPLs

Example –Gas Fired Boiler



Gas Fired boiler's loss of flame without isolating the fuel supply can result in vapour cloud explosion.

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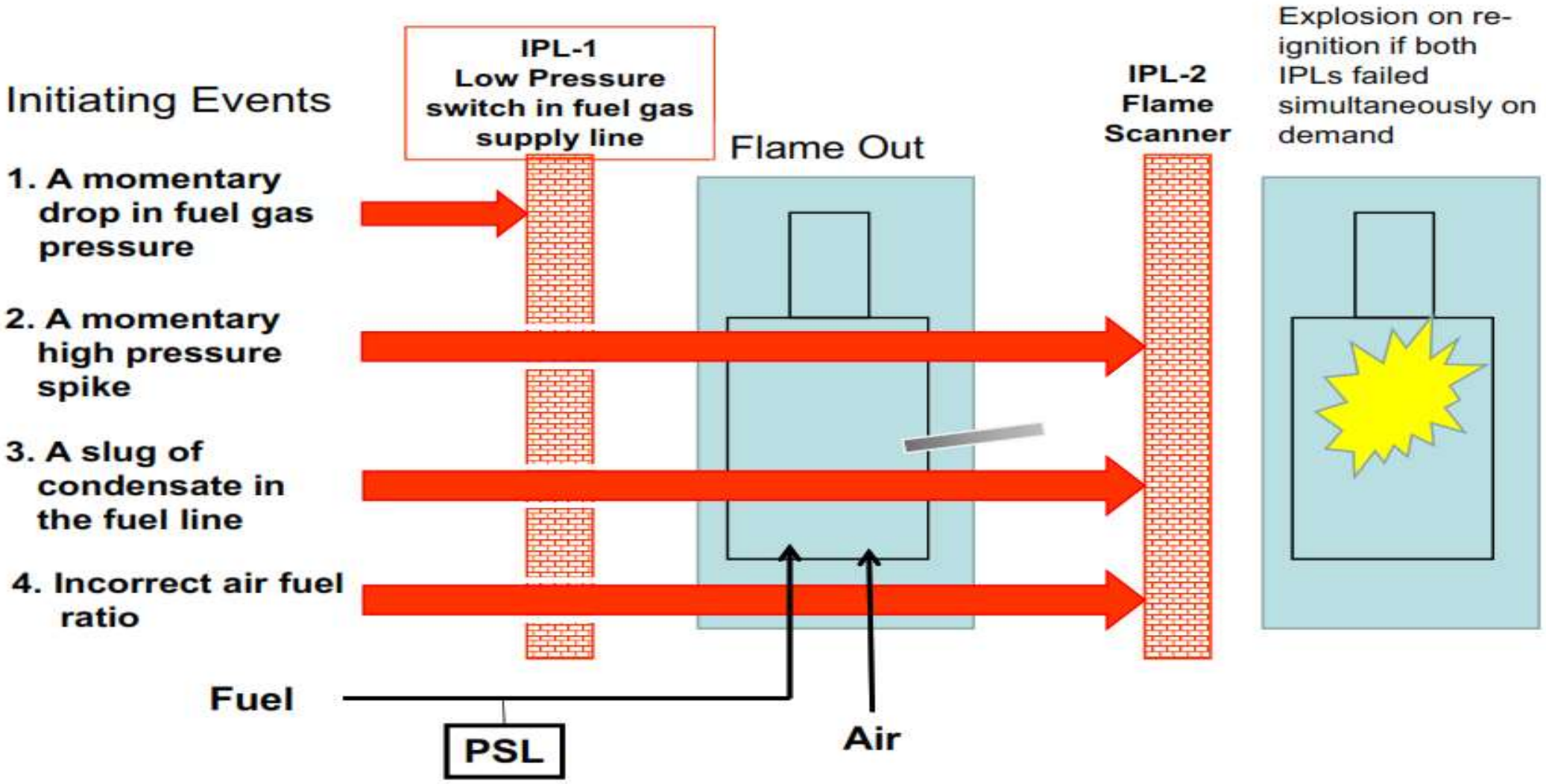
Effective & Non-Effective IPLs

Example –Gas Fired Boiler



Effective & Non-Effective IPLs

Example –Gas Fired Boiler

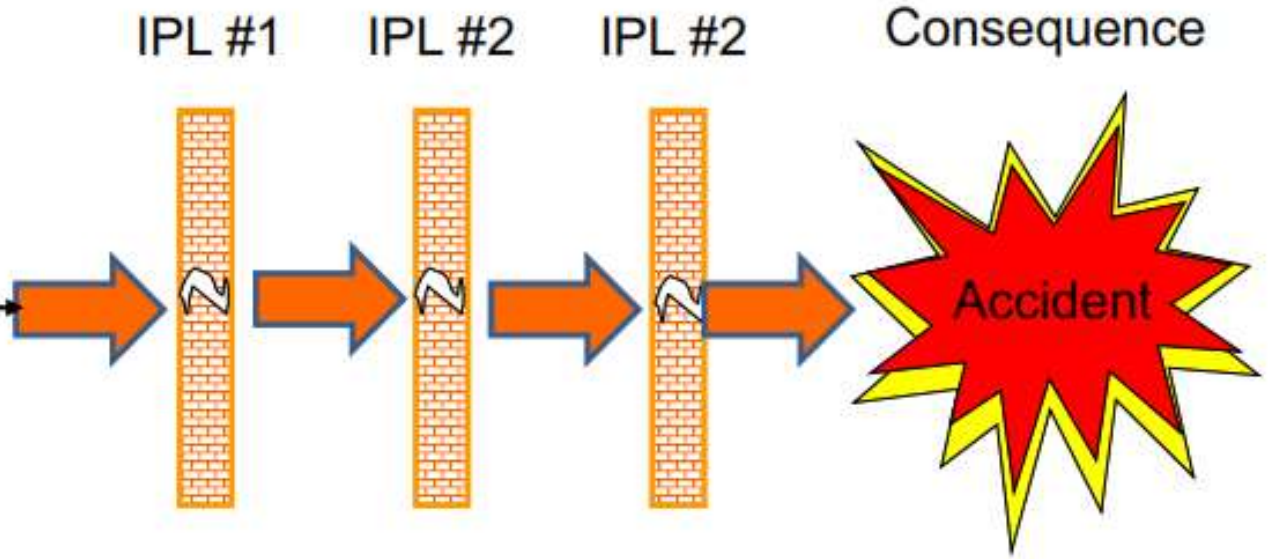
Initiating Event	IPL - 1	IPL-2
	Low Pressure Switch on Fuel Supply Line	Flame Scanner
A momentary drop in fuel gas pressure	Effective	Effective
A momentary high pressure spike	Ineffective	Effective
A pocket of inert gas in the fuel line	Ineffective	Effective
Incorrect air fuel ratio	Ineffective	Effective

Components in a Scenario

Initiating Event (Cause)
- Control failure
- Human error
- Leakage

Enabling Events & Conditions

Conditional Modifiers
- Probability of ignition
- Probability of fatal injury
- Probability of personnel in affected area



Typical IPLs:
- Process control system (PCS) control loop
- Alarms with operator response
- Pressure relief valve
- Vessel rupture disk
- Fire detection with water deluge system
- Gas monitors with automated deluge
- Check valve
- Flame arrestor
- Vacuum breaker
- Restrictive orifice
- Safety instrumented function (SIF)
- Process Design

Initiating events

- An initiating event starts the chain-of events that leads to an accident
- Initiating events can be the failure of a piece of equipment or an operator error

Examples:

- Failure of a cooling water pump
- Starting the wrong pump
- Inadvertent closure of a valve
- Pipe leakage

Initiating Events

Types of Initiating Events:

- **External events**
  - Earthquakes, tornadoes, hurricanes, or floods
  - Major accidents in adjacent facilities
  - Mechanical impact by motor vehicles
- **Equipment failures**
  - Component failures in control systems
  - Corrosion
  - Vibration
- **Human failures**
  - Operational error
  - Maintenance error

Inappropriate Initiating Event

Examples of inappropriate initiating events:

- Inadequate operator training / certification
- Inadequate test and inspection
- Unavailability of protective devices
- such as safety valves or over-speed trips
- Unclear or imprecise operating procedures

Initiating Events Frequency Estimation

Failure Rate Data Sources:

- Industry Data (e.g. OREDA, IEEE, CCPS, AIChE)
- Company Experience
- Vendor Data
- Third Parties (EXIDA, TUV etc.)

Initiating Events Frequency/ Failure Rate Data Estimation

Choosing failure rate data

- It is a Judgment Call
- Some considerations:
  - Type of services (clean / dirty ?)
  - Failure mode
  - Environment
  - Past history
  - Process experience
  - Sources of data

Initiating Event Frequency

If initiating event frequency data is not available, then it can be estimated using Fault Tree Analysis.

Initiating Events Frequency Estimation

Example

Corporate records indicate 8 Compressor tripping in the last 10 years in a plant with 6 industrial Process Gas Compressors. What is the compressor tripping event rate?

$$\text{Event Frequency} = \frac{\text{Number of Events}}{\text{Time in Operation}}$$

$$\text{Boiler explosion event rate} = \frac{8 \text{ trips}}{6 \text{ Compressors} \times 10 \text{ years}}$$

= 0.13 tripings per year per compressor

Initiating Events Frequency Estimation

Example

- A plant has 157 relief valves which are tested annually.
- Over a 5 year period 3 valves failed to pass the function test.
- What is the failure rate for this plant's relief valves?

$$\text{Event Frequency} = \frac{\text{Number of Events}}{\text{Time in Operation}}$$

$$\text{Failure Rate for Relief Valve} = \frac{\text{3 function test failures}}{\text{157 valves x 5 years}}$$

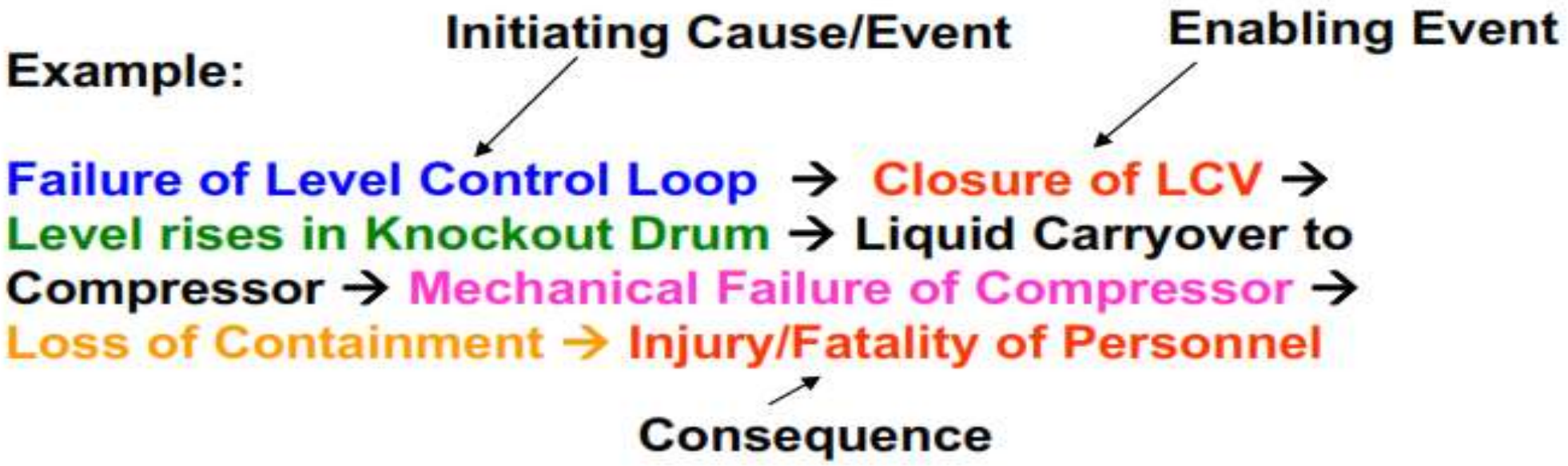
= 0.0038 failures per year per valve

Enabling Events/ Conditions

- Do not directly cause the scenario
- Used when the mechanism between the initiating event and the consequences need to be clarified.

Enabling Event

Initiating Cause/Event



Conditional Modifiers

- Probability of ignition
- Probability of fatal injury
- Probability of personnel in affected area

Conditional Modifiers

Probability of Ignition

- Chemical's reactivity
- Volatility
- Auto-ignition temperature
- Potential sources of ignition that are present

Probability of Personnel in the Area

- Location of the process unit;
- The fraction of time plant personnel (e.g. personnel from operation, engineering and maintenance) spent in the vicinity

Probability of Injury

- Personnel training on handling accident scenario
- The ease of recognize a hazardous situation exists in the exposure area
- Alarm sirens and lights
- Escape time
- Accident scenario training to personnel

Independent Protection Layers

All IPLs are safeguards, but **not** all safeguards are IPLs.

- An IPL has two main characteristics:

How **effective** the IPL in preventing the scenario from resulting to the undesired consequence?

- Is the IPL **independent** of the initiating event and the other IPLs?

Independent Protection Layers

Typical layers of protection are:

- Process Design
- Basic Process Control System (BPCS)
- Critical Alarms and Human Intervention
- Safety Instrumented System (SIS)
- Use Factor
- Physical Protection
- Post-release Protection
- Plant Emergency Response
- Community Emergency Response

Independent Protection Layers

Safeguards **not** usually considered IPLs

- Training and certification
- Procedures
- Normal testing and inspection
- Maintenance
- Communications
- Signs
- Fire Protection (Manual Fire Fighting etc.)
- Plant Emergency Response & Community
- Emergency Response

Characteristics of IPL

1. Specificity: An IPL is designed solely to prevent or to mitigate the consequences of one potentially hazardous event (e.g., a runaway reaction, release of toxic material, a loss of containment, or a fire).

Multiple causes may lead to the same hazardous event, and therefore multiple event scenarios may initiate action of one IPL.

2. Independence: An IPL is independent of the other protection layers associated with the identified danger.

3. Dependability: It can be counted on to do what it was designed to do. Both random and systematic failure modes are addressed in the design.

Auditability: It is designed to facilitate regular validation of the protective functions.

Functional testing and maintenance of the safety system is necessary.

Use of Failure Rate Data

Component Failure Data

Data sources:

- Guidelines for Process Equipment Reliability Data, CCPS (1986)
- Guide to the Collection and Presentation of Electrical, Electronic, and Sensing Component Reliability Data for Nuclear-Power Generating Stations. IEEE (1984)
- OREDA (Offshore Reliability Data)
- Layer of Protection Analysis –Simplified Process Risk Assessment, CCPS, 2001

Human Error Rates

Data sources:

- Inherently Safer Chemical Processes: A life Cycle Approach , CCPS (1996)
- Handbook of human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, Swain, A.D., and H.E. Guttman, (1983)

Safety Instrumented Function {SIF)

Instrumented loops that address a **specific** risk

- It intends to achieve or maintain a safe state for the **specific hazardous event**.

  SIS (Safety Instrumented System)
- A SIS may contain one or many SIFs and each is assigned a **Safety Integrity Level (SIL).**

- As well, a SIF may be accomplished by more than one SIS.

Examples of SIFs in Process Industry

- Flame failure in the furnace initiates fuel gas ESDVs to close
- High level in the vessel initiates Compressor shut down
- Loss of cooling water to reactor stops the feed and depressurizes the reactor

Safety Instrumented System (SIS)

- A safety instrumented system (SIS) is a combination of sensors, logic solvers and final elements that performs one or more safety instrumented functions (SIFs).

Safety Instrumented Functions

- Specific **single** set of actions and the corresponding equipment needed to identify a **single** emergency and act to bring the system to a safe state.
- SIL is assigned to each SIF based on required risk reduction.
- Different from a SIS, which can encompass multiple functions and act in multiple ways to prevent multiple harmful outcomes
- SIS may have multiple SIF with different individual SIL, so it is incorrect and ambiguous to define a SILfor an entire safety instrumented system

Safety Instrumented System

- Functionally SIS are independent from the BPCS **Basic Process Control System**

- Reliability of SIS is defined in terms of its Probability of Failure on Demand (PFD) and Safety Integrity Level (SIL)

Independence between Initiating Cause & IPL

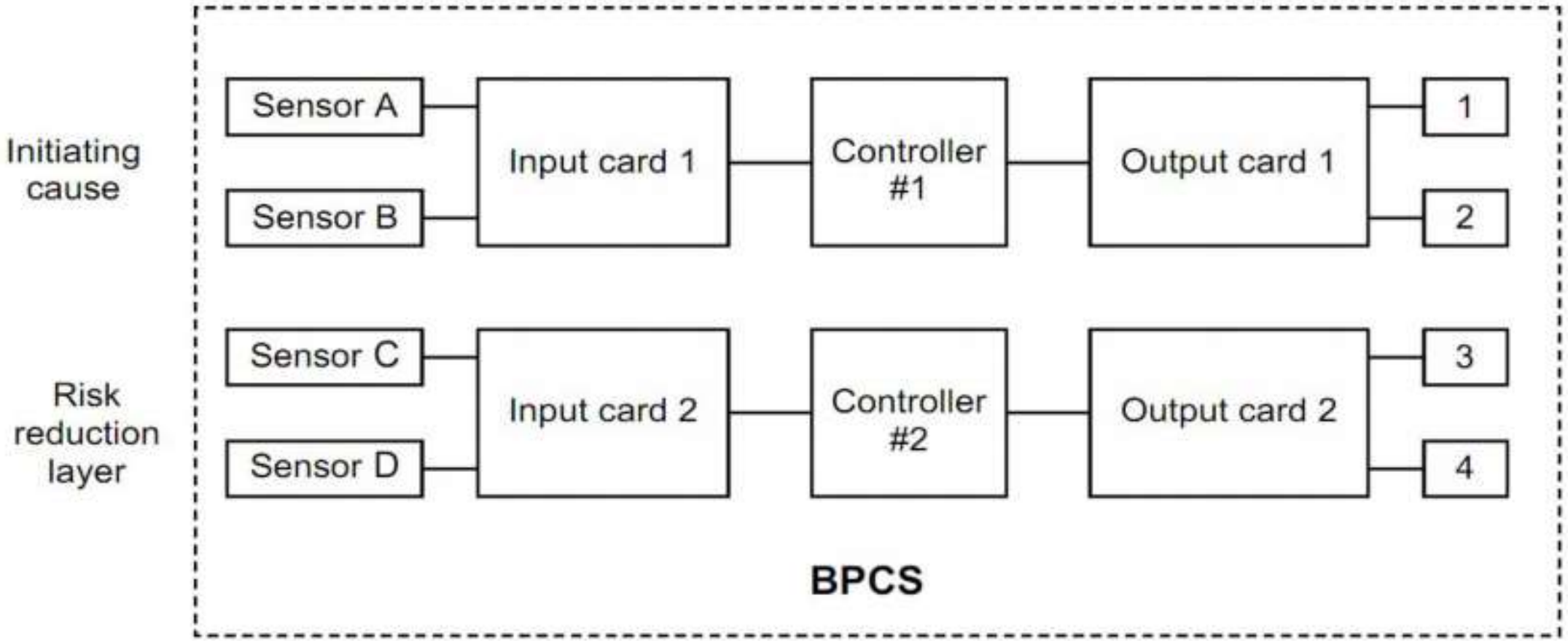
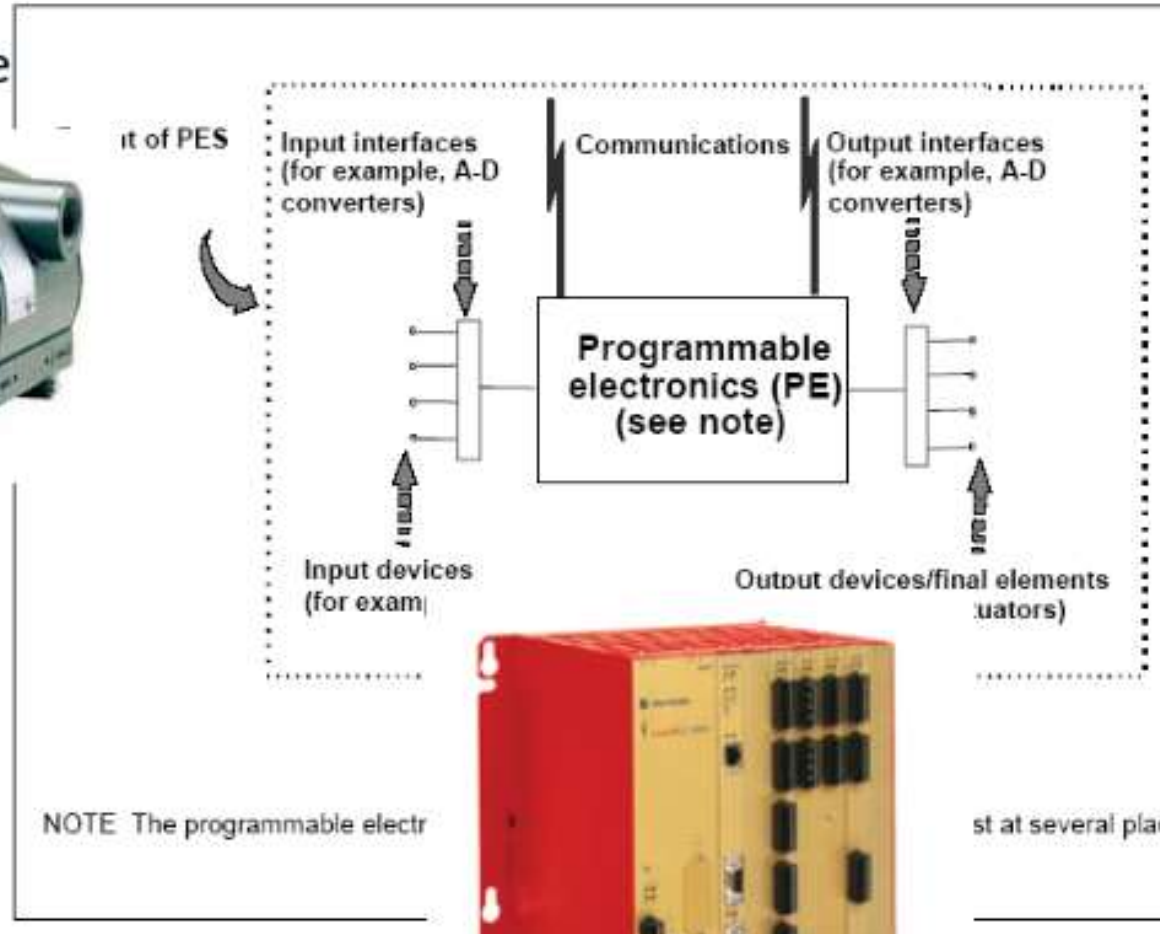


Figure 2 – BPCS function and initiating cause independence illustration

Safety Instrumented System

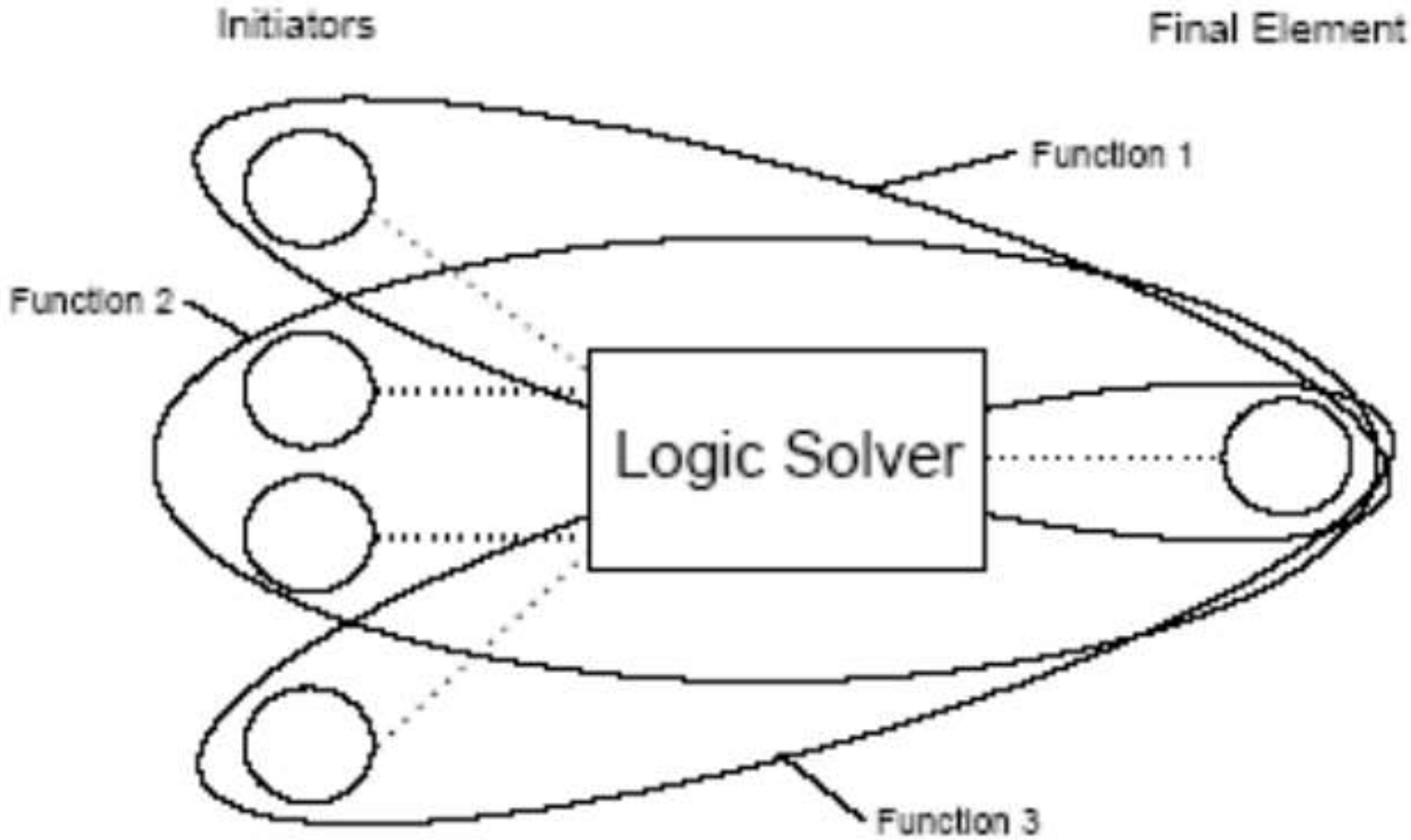
Measure



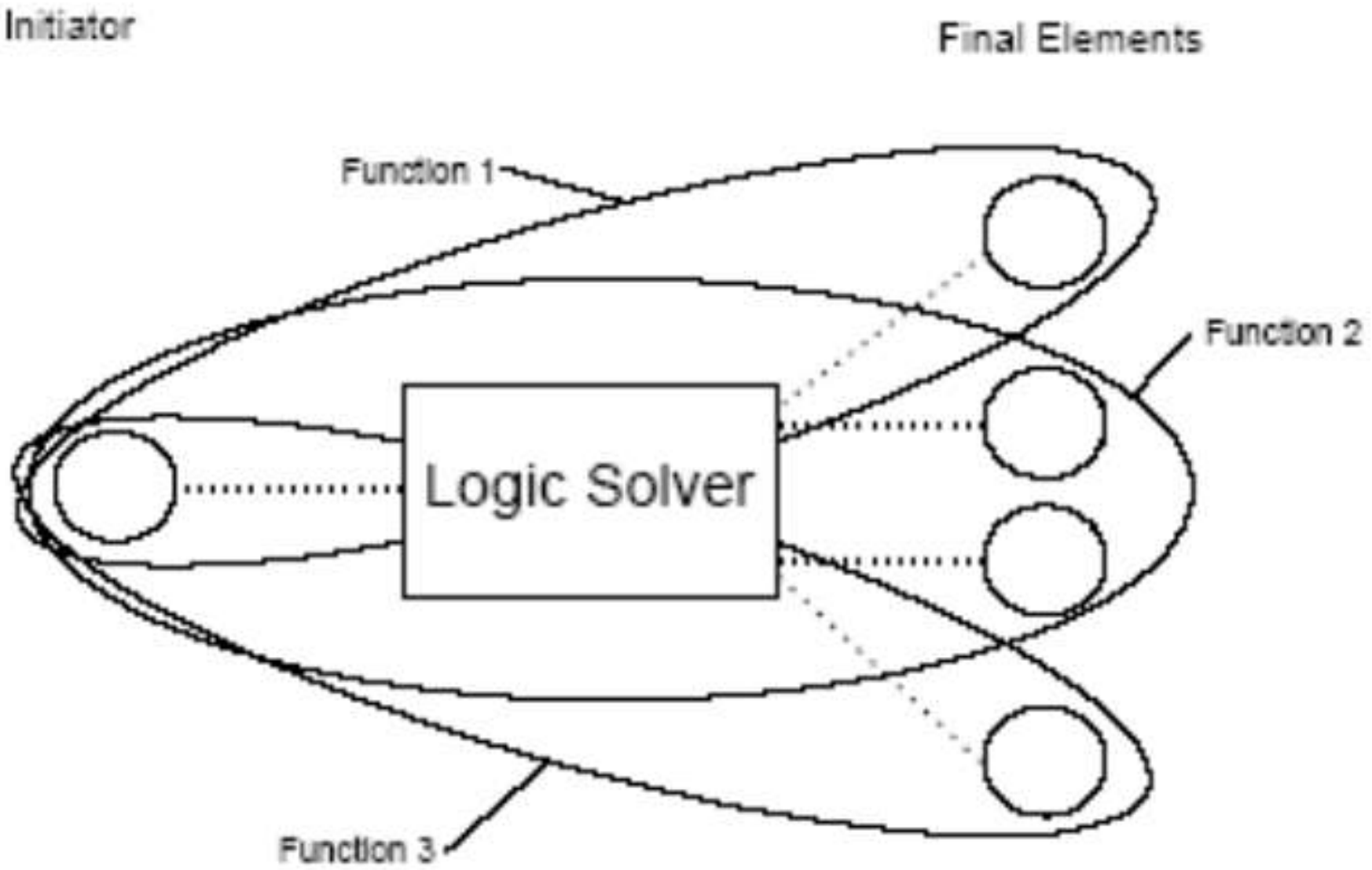
Response

Think

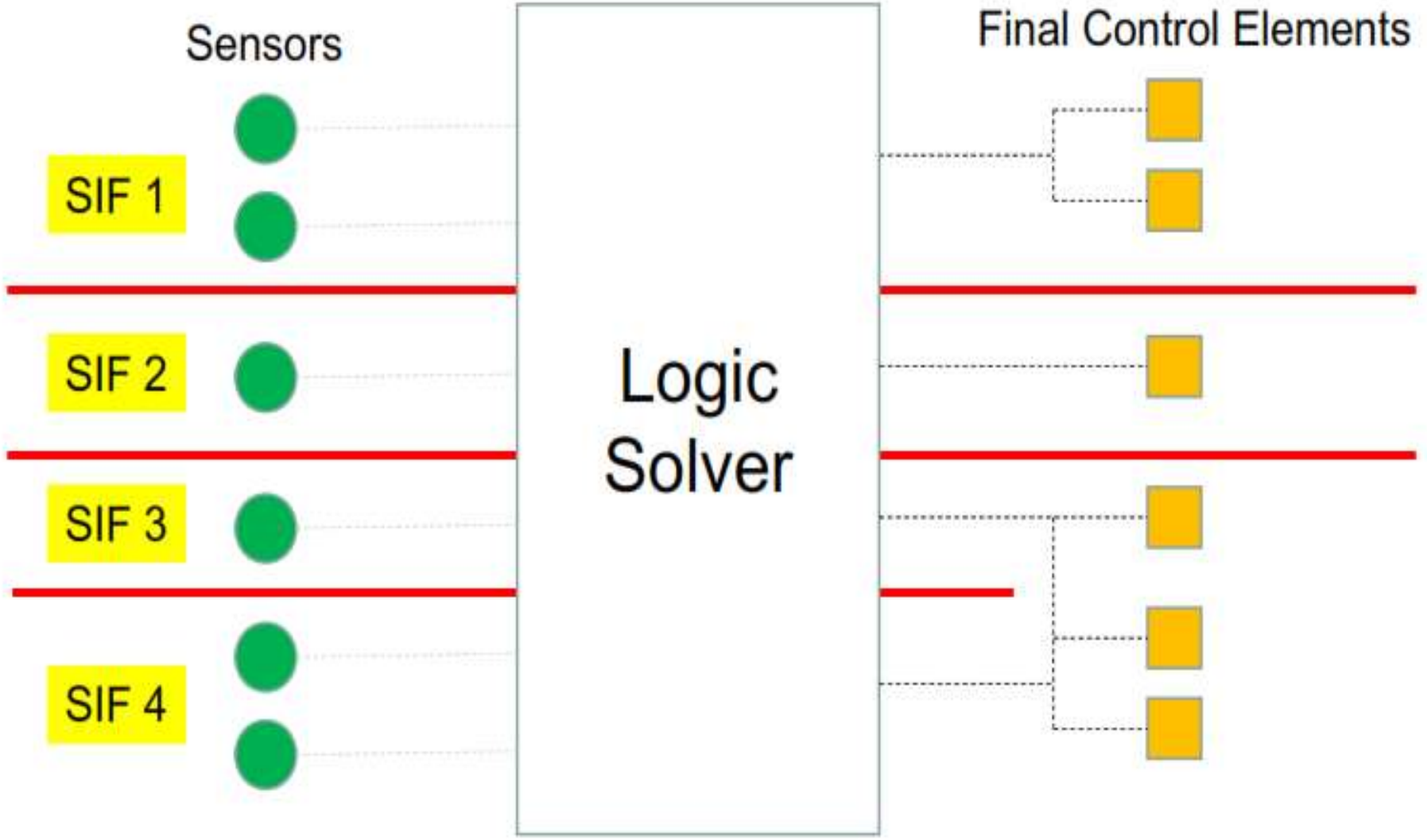
Multiple Initiators tripping one Final Element



One Initiator tripping multiple Final Elements



Overall Safety Instrumented System showing SIFs



Understanding Safety Integrity Level (SIL)

What does SIL mean?

- Safety Integrity Level
- A measure of probability to fail on demand (PFD) of the SIS.
- It is statistical representation of the integrity of the SIS when a process demand occurs.
- A demand occurs whenever the process reaches the trip condition and causes the SIS to take action.

SIL Classification

SIL	Probability Category
1	1 in 10 to 1 in 100
2	1 in 100 to 1 in 1,000
3	1 in 1,000 to 1 in 10,000
4	1 in 10,000 to 1 in 100,000

1 in 10 means, the function will fail once in a total of **10** process demands
1 in 1000 means, the function will fail once in a total of **1000** process demands

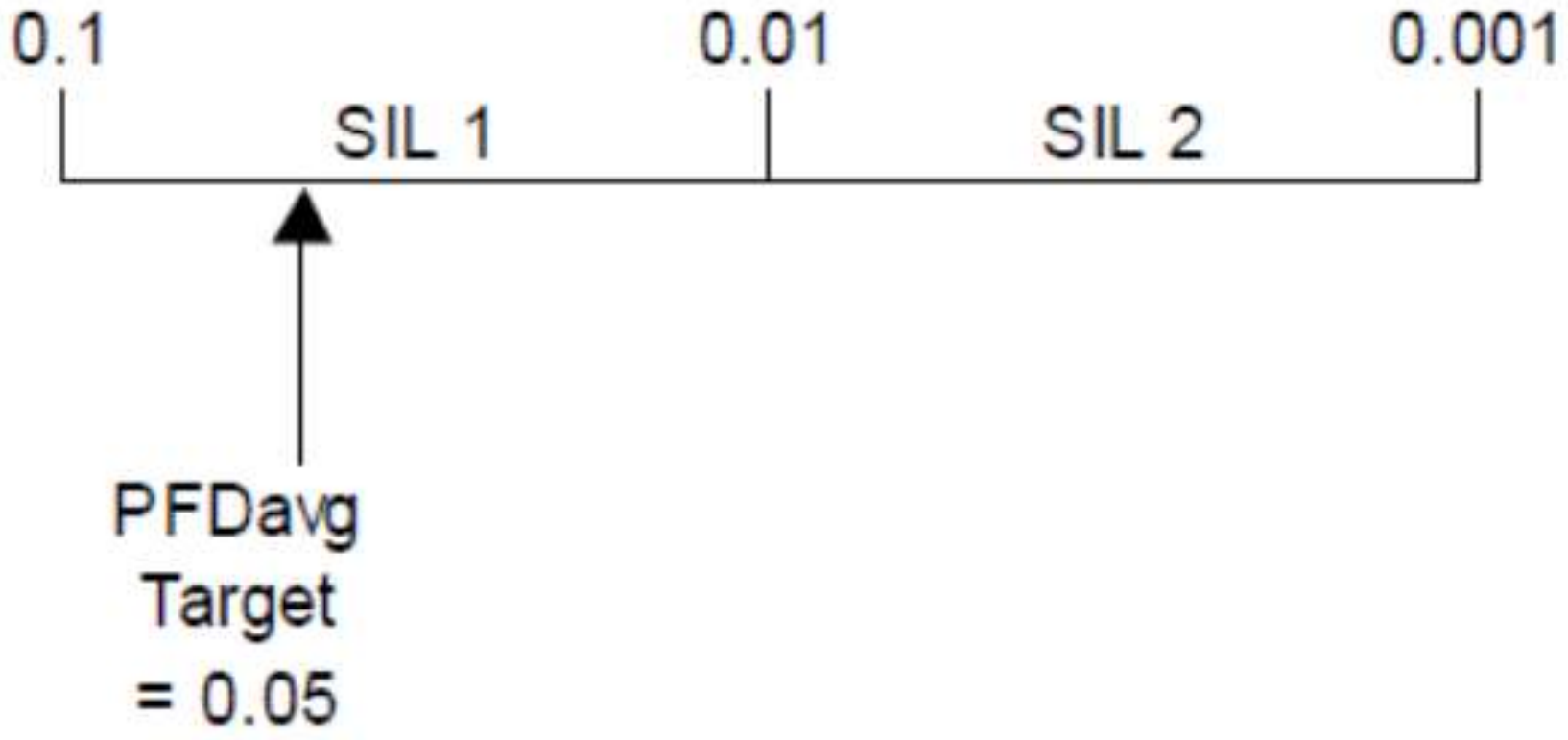
SIL Classification

Safety Integrity Levels

SIL Level	Probability of failure on demand (Demand Mode of Operation)		Risk Reduction Factor
SIL 4	$>=10^{-5}$ to $<10^{-4}$	>=0.00001 to <0.0001	100000 to 10000
SIL 3	$>=10^{-4}$ to $<10^{-3}$	>=0.0001 to <0.001	10000 to 1000
SIL 2	$>=10^{-3}$ to $<10^{-2}$	>=0.001 to <0.01	1000 to 100
SIL 1	$>=10^{-2}$ to $<10^{-1}$	>=0.01 to <0.1	100 to 10

Target vs Selected SIL Rating

- For example, the required risk reduction from a safety instrumented function needs a PFD_{avg} target of 0.05



SIL Methodology

1 Identify the specific hazardous event

2 Determine the severity and target frequency

3 Identify the Initiating Causes

4 Scenario Development

5 Protective Measure Listing (IPLs)

6 Completion of LOPA standard proforma

Setting Tolerable Frequency

For example, if there are 10,000 plants in the country and the operating company accepts the risk equivalent to one catastrophic accident leading to multiple fatalities every 10 years, then the tolerable frequency of the operating company for such an accident would be:

Tolerable Frequency = 1 occurrence per 10,000 plants every 10 years

= 1 / 10,000 / 10

= 1.0E-05 occurrence per year per plant

Or probability of catastrophic accident leading to multiple fatalities per year per plant

It would be wrong to take inverse of 1.0E-05, which would be 100,000 years, and say that a plant will have catastrophic failure every 100,000 years

Frequency Calculation

For example,

If the statistical data indicates that 1 out of 300 smokers die every year, then the frequency can be calculated as follows:

Frequency = 1 death per 300 smokers every year

= 1 death / 300 smokers / 1 year

= 3.3E-03 deaths per smoker per year

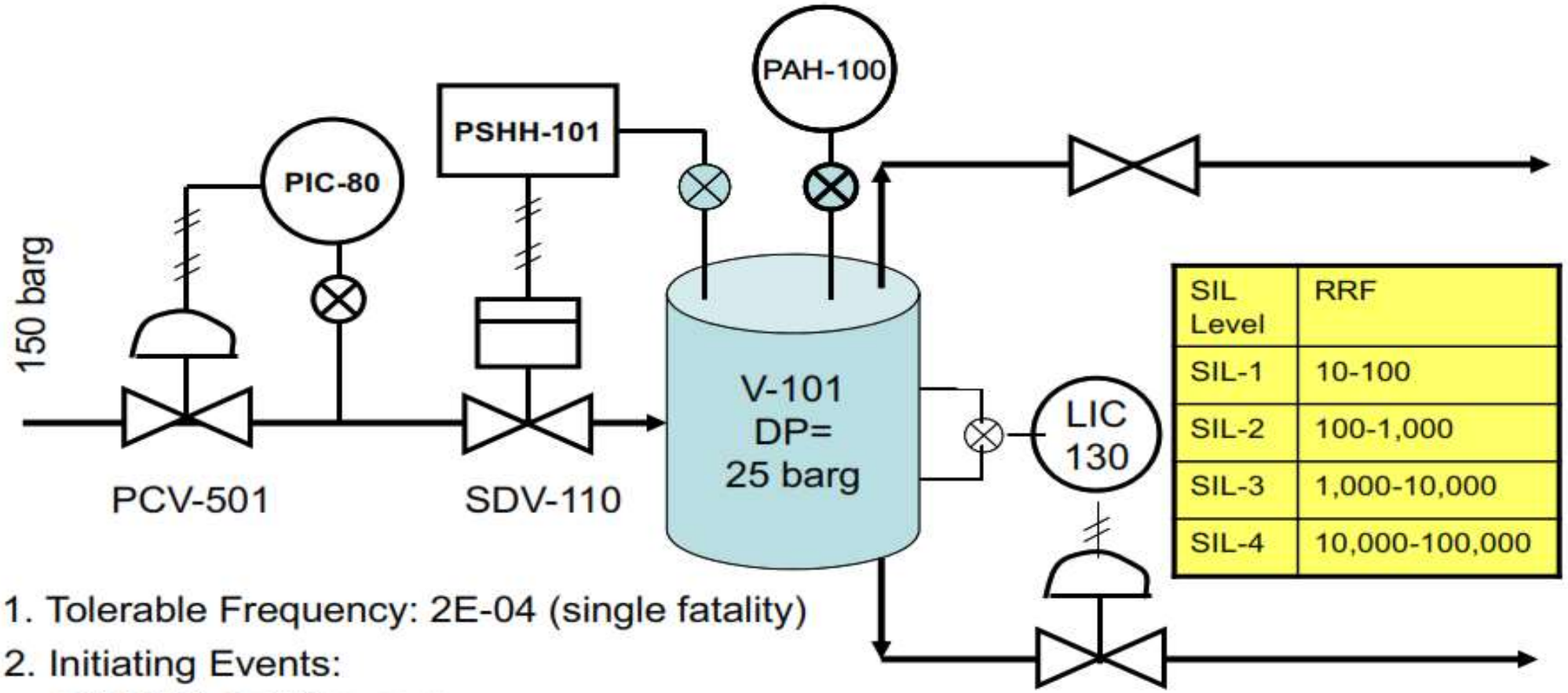
Or probability of a smoker dying per year

It would be wrong to take inverse of 3.3E-03, which would be 300 years, and say that a smoker would die every 300 years

Tolerable Frequencies

Tolerable Frequency	People	Environment	Assets	Reputation
2E-05 /yr	Multiple fatalities or permanent disabilities	Massive Effect- Persistent severe environmental damage	Substantial or a total loss of operations (>$10,000,000)	Extensive adverse coverage in international media.
2E-04 /yr	Single fatality or permanent disability	Major effect- severe environmental damage	Partial operation loss and/or prolonged shutdown (<$10,000,000)	National public concern. Extensive adverse coverage in the national media.
2E-03 /yr	Serious injuries (lost time cases)	Localized effect- Limited loss of discharge of known toxicity	Extended plant damage and/or partial shutdown (<$500,000)	Regional public concern. Extensive adverse coverage in local media.
2E-02 /yr	Minor injuries (medical treatment cases)	Minor Effect Contamination	Moderate plant damage and/or brief operations disruption (<$100,000)	Some local public concern. Some local media coverage.
2E-01 /yr	Slight injuries (first aid cases)	Slight release Local Environment damage	Minor plant damage and no disruption to Operations (<$10,000)	Public awareness may exist, but there is no public concern.

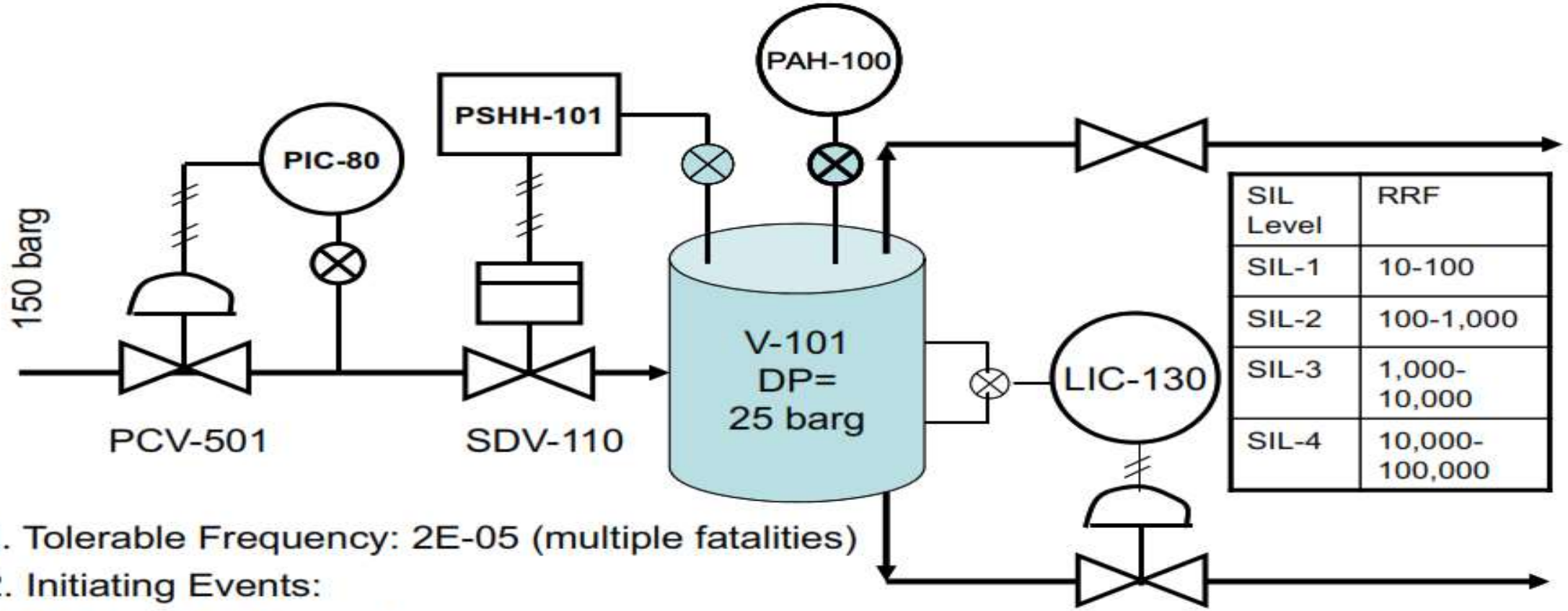
SIL Calculation



SIL Level	RRF
SIL-1	10-100
SIL-2	100-1,000
SIL-3	1,000-10,000
SIL-4	10,000-100,000

1. Tolerable Frequency: 2E-04 (single fatality)
2. Initiating Events:
   PCV-501 Fail Opened
   Initiating Event Frequency → 0.1/yr
3. Independent Protection Layers (IPLs):
   High Pressure Alarm, PAH-100
   Prob. of Failure on Demand → 0.1
4. Actual Frequency:
   0.1/yr x 0.1 = 0.01/yr
5. Risk Reduction Factor:
   =Actual Frequency / Tolerable Frequency
   =0.01/2E-04
   =50 (SIL-1)

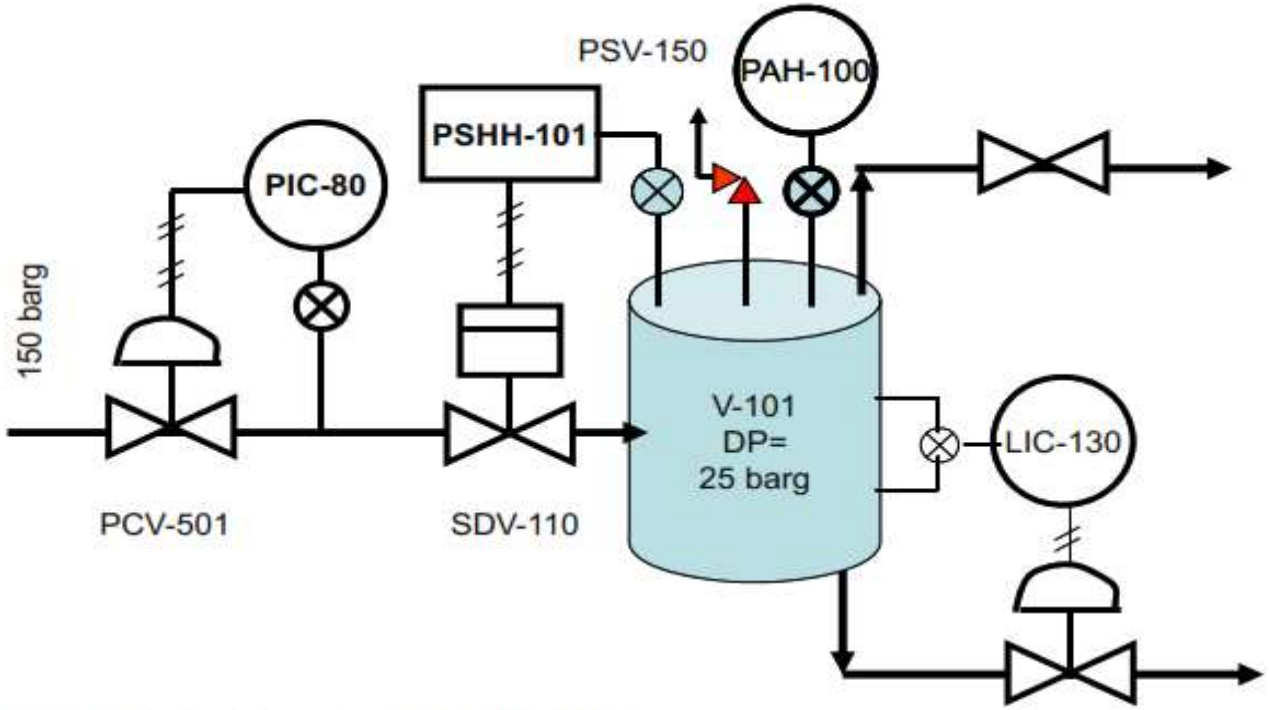
SIL Calculation



SIL Level	RRF
SIL-1	10-100
SIL-2	100-1,000
SIL-3	1,000-10,000
SIL-4	10,000-100,000

1. Tolerable Frequency: 2E-05 (multiple fatalities)
2. Initiating Events:
   PCV-501 Fail Opened
   Initiating Event Frequency → 0.1/yr
3. Independent Protection Layers (IPLs):
   High Pressure Alarm, PAH-100
   Prob. of Failure on Demand → 0.1
4. Actual Frequency:
   0.1/yr x 0.1 = 0.01/yr
5. Risk Reduction Factor:
   =Actual Frequency / Tolerable Frequency
   =0.01/2E-05
   =500 (SIL-2)

SIL Calculation



SIL Level	RRF
SIL-1	10-100
SIL-2	100-1,000
SIL-3	1,000-10,000
SIL-4	10,000-100,000

1. Tolerable Frequency: 2E-05
   (multiple fatalities)
2. Initiating Events:
   PCV-501 Fail Opened
   Initiating Event Frequency → 0.1/yr
3. Independent Protection Layers (IPLs):
   High Pressure Alarm, PAH-100; PFDavg → 0.1
   Pressure Safety Valve, PSV-150; PFDavg → 0.01
4. Actual Frequency: 0.1/yr x 0.1 x 0.01 = 0.001/yr
   (Alarm) (PSV)
5. Risk Reduction Factor:
   =Actual Freq. / Tolerable Freq.
   =0.001/2E-05
   =50 (SIL-1)

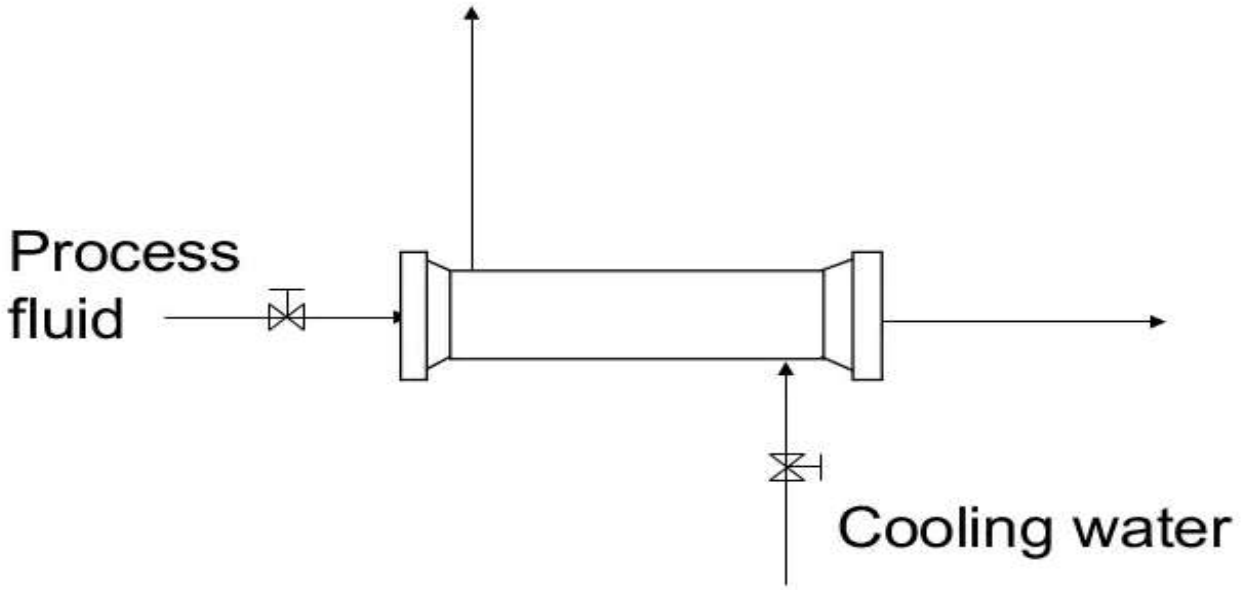
DAY 5

Simple Case Study

Shell and Tube Heat exchanger

Case Study – Shell & Tube Heat Exchanger

- Using relevant guide works, perform HAZOP study on shell & tube heat exchanger



Guidewords/ Keywords

The basic HAZOP guide-words are:

Guide-word	Meaning	Example
No (not, none)	None of the design intent is achieved	No flow when production is expected
More (more of, higher)	Quantitative increase in a parameter	Higher temperature than desired
Less (less of, lower)	Quantitative decrease in a parameter	Lower pressure than normal
As well as (more than)	An additional activity occurs	Other valves closed at the same time (logic fault or human error)
Part of	Only some of the design intention is achieved	Only part of the system is shut down
Reverse	Logical opposite of the design intention occurs	Back-flow when the system shuts down
Other than (Other)	Complete substitution – another activity takes place	Liquids in the gas piping

Additional guidewords

Guide-word	Meaning
Early/ late	The timing is different from the intention
Before/ after	The step (or part of it) is effected out of sequence
Faster/ slower	The step is done/not done with the right timing
Where else	Applicable for flows, transfer, sources and destinations

ADNOC HAZOP work sheet

Site:	Plant:	Unit
Team members (including roles):		
Design intent:		
Node: Node Description:		
P&ID number:	Associated Dwg./Doc:	

Deviation	Cause	Consequence	Severity (assuming no safeguards)				Overall Severity (S)	Current Safeguards	Likelihood (L) (considering current safeguards)	Overall Mitigated Risk (R)	Recommendations	Likelihood (L) (considering recommend-dations)	Overall Residual Risk (R)
			Health & Safety	Environment	Financial	Reputation							

HAZOP on Heat Exchanger – Answer 1

Guide Word	Deviation	Causes	Consequences	Action
Less				
More				
More of				
Contamination				
Corrosion				

HAZOP on Heat Exchanger – Answer 2

Guide Word	Deviation	Causes	Consequences	Action
NONE				
MORE				
LESS				
REVERSE				
CONTAMINATION				

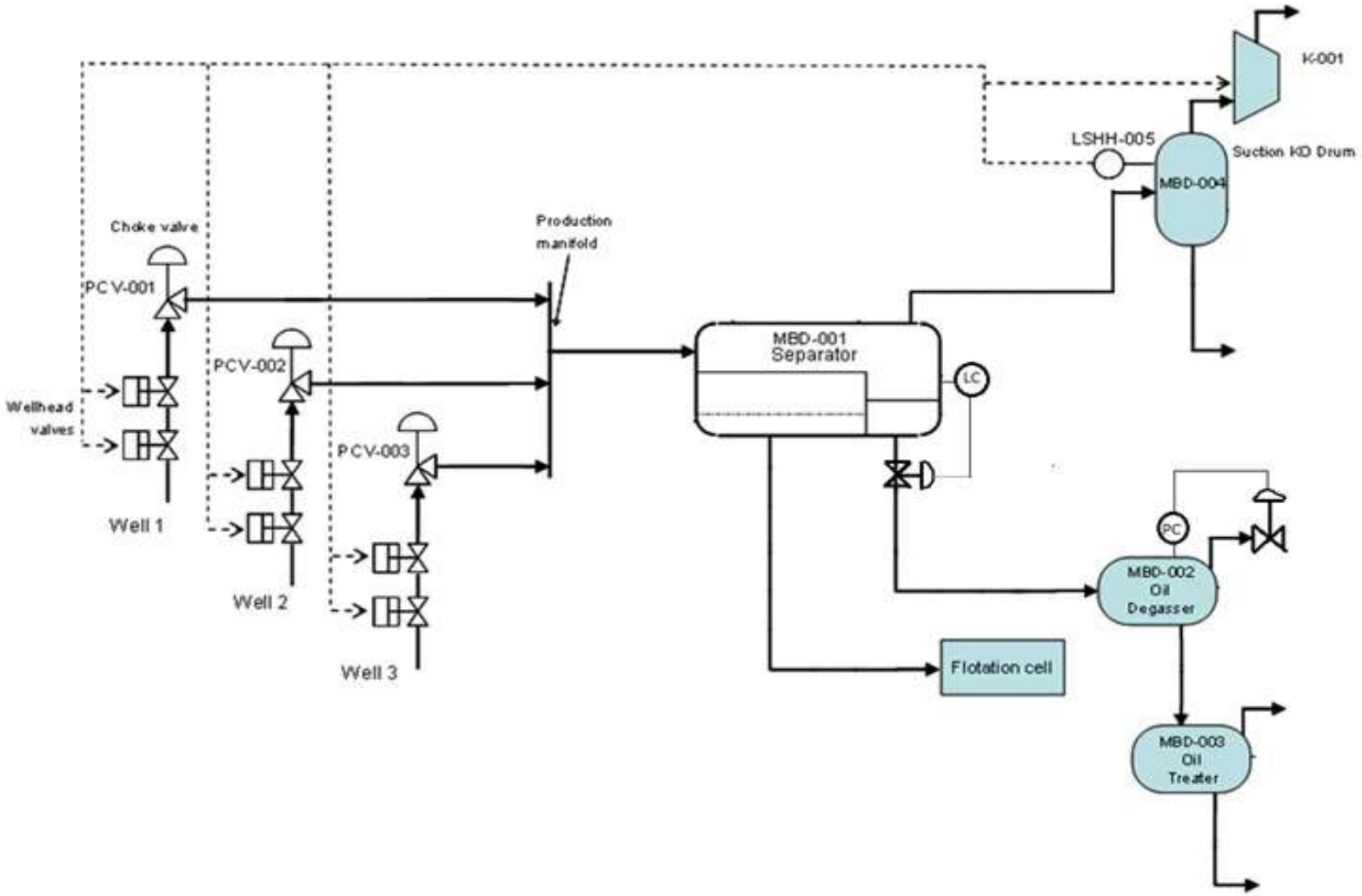
Complex Case Study

Separator and Wells

EXERCISE:

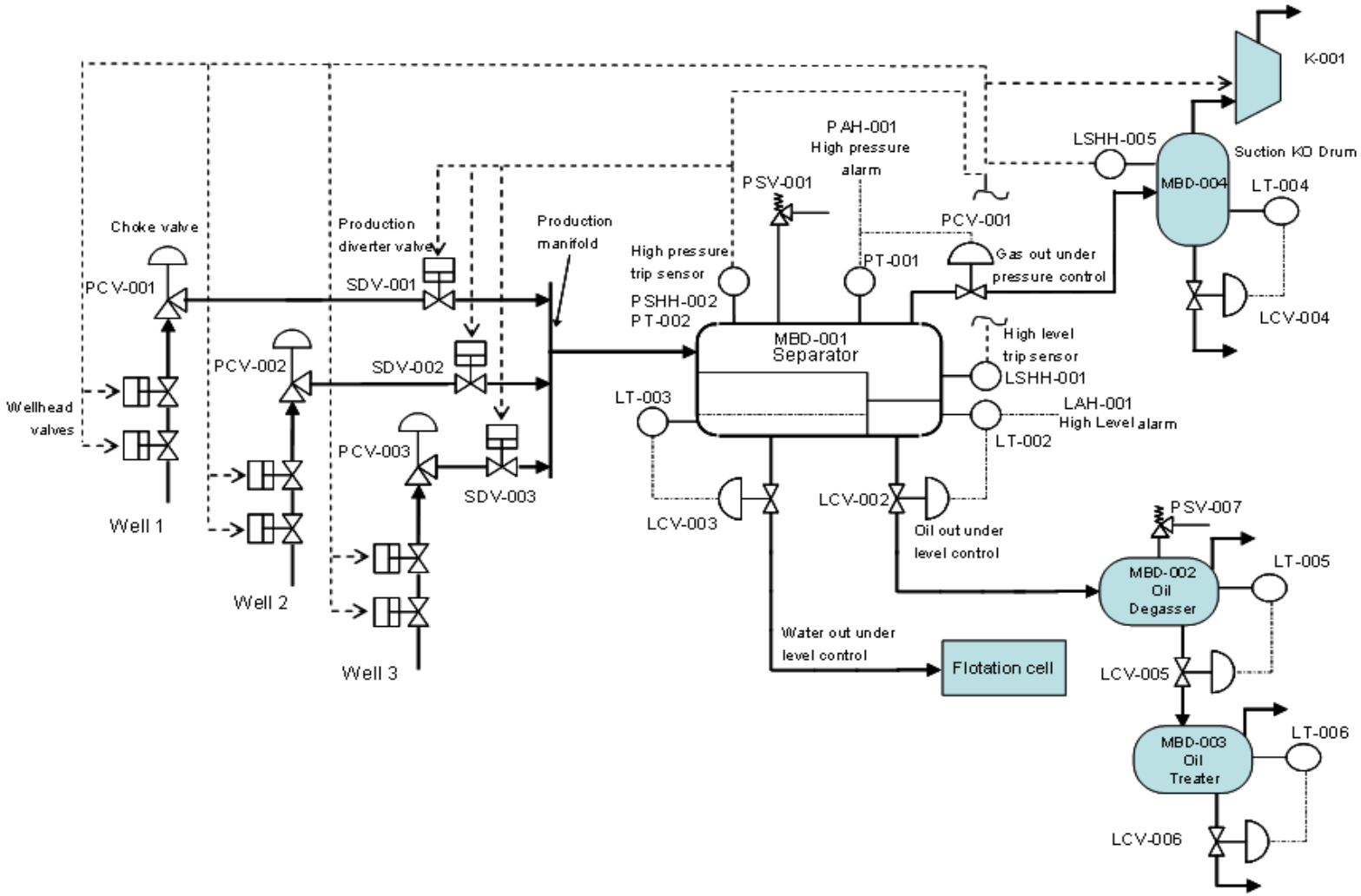
CONDUCT A HAZOP ON THE SEPARATOR AND WELLS

Exercise Example for Separator and Wells



This is just an example with poor design to demonstrate Hazop improvement

Exercise Example - Solution



This is a re-design after all the HAZOP changes have been done, which was originally a very poor design

LINKS TO ADNOC STANDARDS

- ADNOC HSE Impact Assessment (HSEIA) Standard, HSE-RM-ST02
- ADNOC Safety Integrity Levels (SIL) Determination Standard, HSE-RM-ST05
- ADNOC Corporate Risk Matrix, AHQFIIERMREC001R019

أدنـوك
ADNOC

Any Questions?

IF NO

Thanks for your care and attention

Have a nice and a safe day

THANK YOU
ANY QUESTIONS?