Arthur D Little

HAZOP Training

Presentation to
NPC Iran

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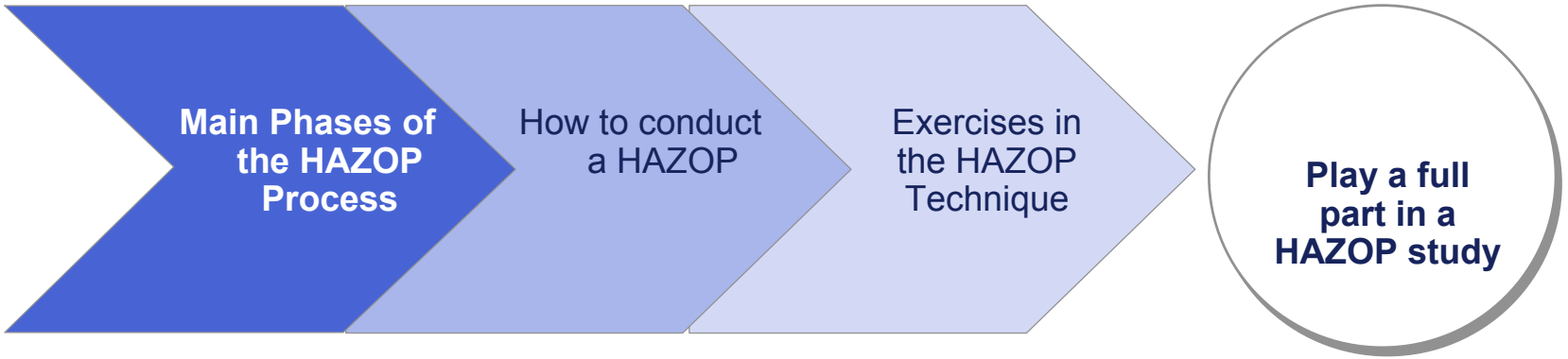
Contents

Purpose and Scope of this Training

- This guidance has been prepared to help you play a full part in a HAZOP study as a Team Member, HAZOP Recorder or Leader. It also explains what deliverables you can expect as a Manager commissioning a HAZOP study
- The course explains step by step how the technique works and gives guidance on each role to achieve the best outcome working collaboratively.
- Preparation is vital and suggestions are made to get you off to the best start



Lets introduce ourselves

Alfredo Verna
Senior Manager

Audit and HAZOP Expert
EPR Practice Cambridge UK

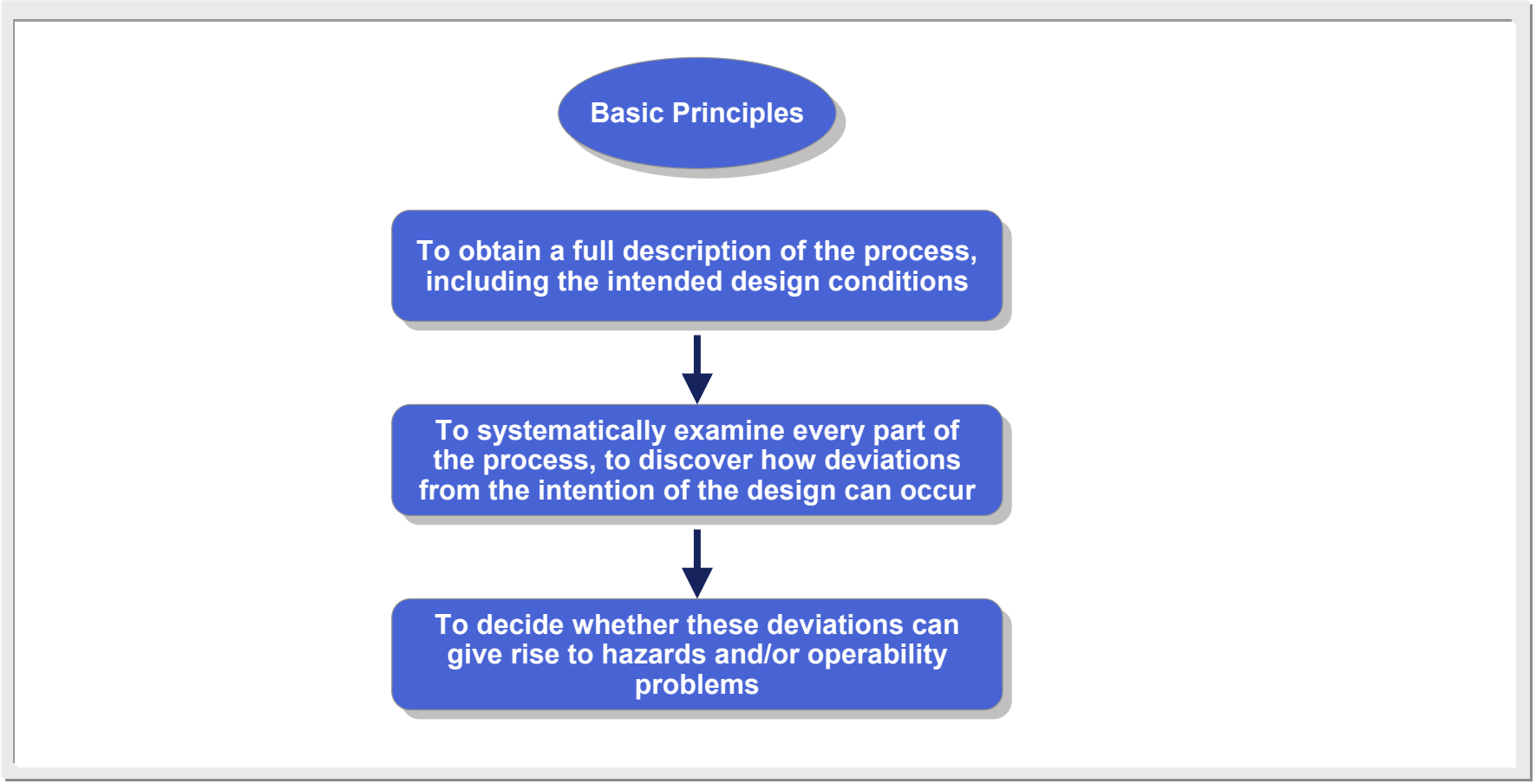
- 10 years of consultancy experience with two major global consulting firms
- Project experience covering all aspects of the pharmaceuticals value chain (R&D, Production, M&S, E-Business, IT)
- 7 years Industry Experience in Strategic Planning, Business Development, M&S and R&D with Schering AG, HQs and BMS, Germany
- Medical Doctor, training in economics

Geoff Stevens
Principal

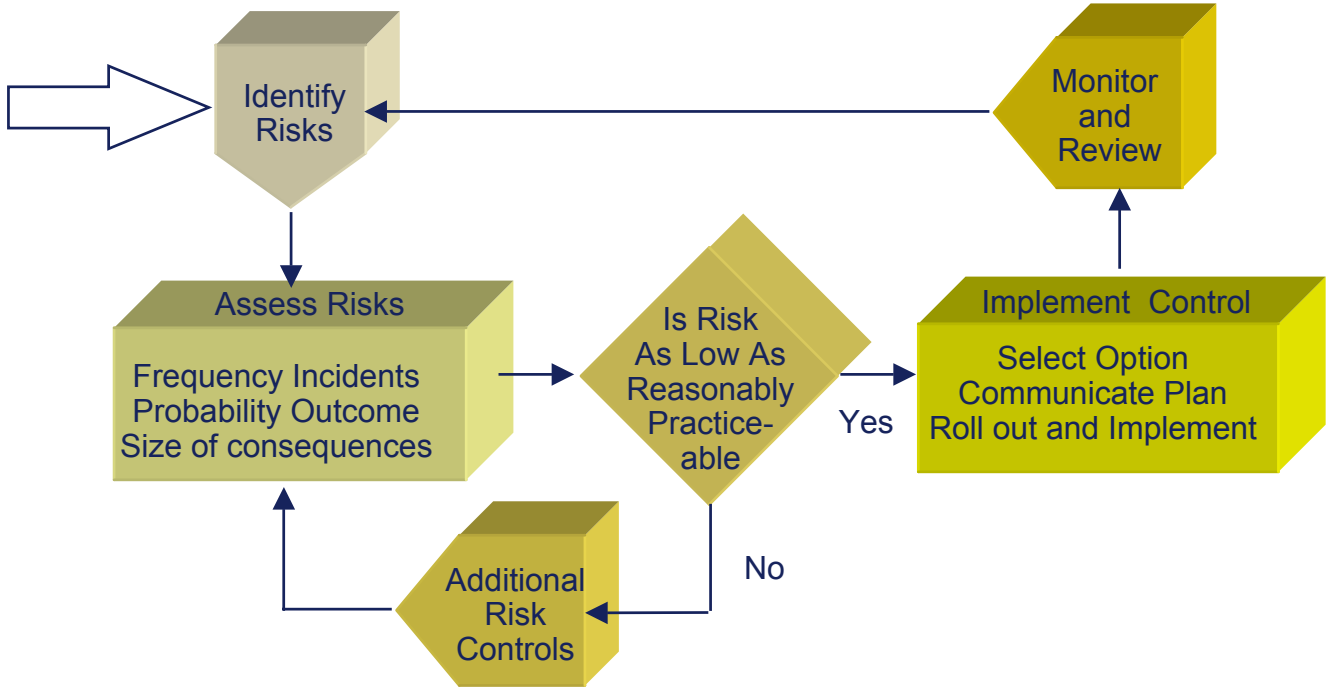
HAZOP and Risk Expert
EPR Practice Cambridge, UK

- 15 years of consulting experience in Oil and Chemicals Industries. Risk assessment and the cost benefit ranking of potential engineering improvements and safety organisation changes in plants in Saudi Arabia, Kuwait, Oman, South Korea, Japan, Singapore, New Zealand, Greece, Italy, France, Germany, Russia, Sweden, Norway and UK
- 17 years industry experience with BP in UK and North America
- BSc in Chemistry, PhD in Radiation Chemistry and an MA in Manpower Studies

A HAZOP is a group technique for identifying hazards and operability problems. It can be applied to operating process plants and to plants in various stages of design



Hazard identification is the first step in a systematic process which aims to improve the management of risk



- Failure to thoroughly identify sources of risk is a widespread general concern in Risk Management

A number of techniques can be used in the hazard identification process – the most appropriate one should be selected for each risk assessment

Requirement

- An appropriate technique should be used for hazard identification

How

- There are several techniques that can be used in hazard identification
- Each technique has advantages and disadvantages, and care should be taken in choosing an appropriate technique for the subject area
- Four techniques for hazard identification, which we will discuss in more detail, are:

Inspection	Checklist	Job or machine safety analysis	Hazard and operability (HAZOP) study

Increasing complexity

This section picks up from OHS training and describes HAZOP in greater detail

Several of these identification methods are incorporated into Process Hazards Assessment

- **Use of a checklist**
  Probably the simplest method using a tabulated series of questions or issues Exxon's "Knowledge based HAZOP"
- **A "What-if" study**
  Carried out using a brainstorming technique typically starting from hazards known to the group leading on to other potential scenarios
  Cited in OSHA 1910.119
- **A Failure Mode and Effect Analysis (FMEA)**
  A component by component assessment of the ways of failure of each item of equipment in a system and the effects on system operate that result
- **A HAZOP study**
  A group review using structured questioning to focus on deviations from design intent which may create hazard or operability problems.

In a HAZOP, the way the study team operates and the manner in which the scope of work is defined are defining characteristics of the technique

- **The HAZOP team**
  Comprises a **leader** who asks questions of the team, a **recorder** who records the discussion and **team members** who represent of each of the key disciplines involved in the facility such as:
  - Process design
  - Operations
  - Safety and maintenance
- **The plant to be studied**
  Is defined at the beginning of the HAZOP typically using a **Piping and Instrumentation Diagram** to clarify the battery limits and interfaces
- **The team operates**
  A question and answer approach using guidewords to search for deviations from design intent or failure modes of the plant.

The HAZOP study team follows a structured , systematic procedure to identify potential hazards

- The technique has been developed from its origins in process plants to many other types of complex system. HAZOP is used to identify:
  - **Hazards** (ways the system can fail leading to injury or damage)
  - **Operability** (ways in which the system can fail to perform)
- The approach is **formal and systematic** using a structured question and answer procedure to identify deviations from the intent of the system designer
- In this way the HAZOP team reviews the design and operation of a system to highlight deviations from normal operation which could be hazardous or problematic
- The study is performed by a team of people familiar with the system design and operation, working under the guidance of a leader who is experienced in the HAZOP method. A recorder makes a detailed tabulation of the team discussions summarising the recommendations they put forward

The team for a HAZOP is selected from the available staff who will need to be free of other duties for the period of the study

- The HAZOP team **members represent the main disciplines** concerned with the design and normal operation of the system such as a process plant
- Specialists may be co-opted from time to time to strengthen the technical knowledge of the team, for example particular aspects of equipment operation, maintenance or utilities supply

Typical Core Team Disciplines	Part-time co-opted specialists
Process design Operations Safety Maintenance	Instrumentation Rotating Equipment Mechanical, Electrical Control Systems Specialists

- The team **leader and recorder typically are independent** of the plant but need to be experienced in the HAZOP technique
- Team **size is typically 5-8**. Greater numbers reduce the pace and inhibit discussion but with too few members, the team may lack perspective

The method of working in a HAZOP is characterised by stepwise question and answer between leader and team

- The team works through the system design in a **diagrammatic form** such as plant P&IDs. Each section is examined critically to understand the design intent of the facilities between nodes selected by the leader
- A series of **questions** is posed by the team leader and the team members respond through joint discussion
  - The leader's questions are based on a systematic use of **guidewords**
  - The aim of the questions is to find out how the facility could **fail to operate as intended** by the designer
  - For each deviation the team discusses if **a hazard might arise**
  - The recorder notes the main points of discussion around each guideword and any recommendations for change

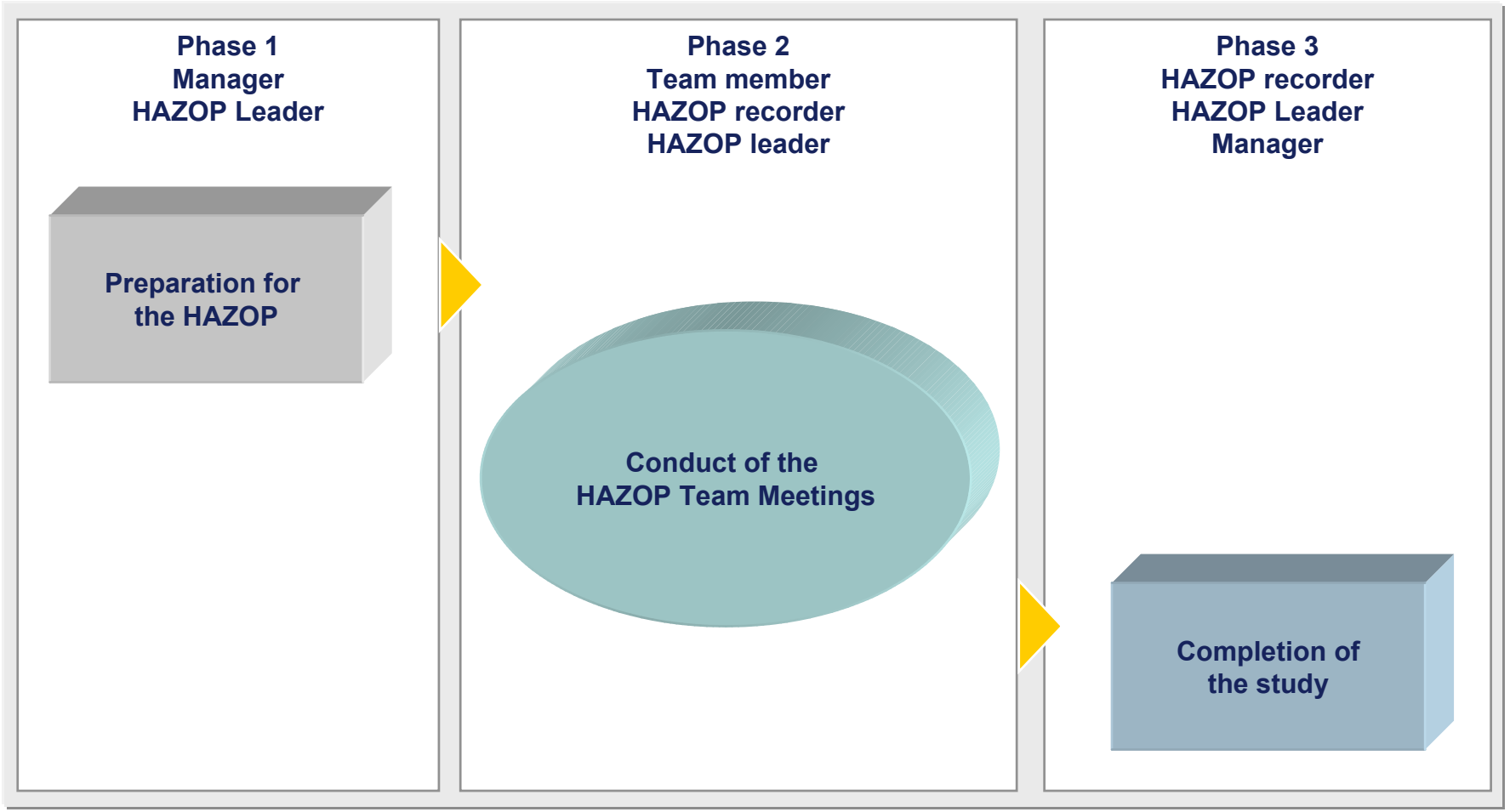
Team members are selected as representatives of the departments who's activities need to be coordinated to successfully operate the facility

- Each participant attends the meeting to represent one aspect of the managerial or technical skills collectively required to safely design and operate the facility. Participants should contribute in this representative context and not indulge their individual “hobby-horses” or pet ideas
- Participants need to show (and to earn) mutual respect. Where there is a variety of ranks or levels, junior team members should feel free to speak their minds and not have their ideas suppressed
- Any issues of business secrecy or technical confidentiality should be settled beforehand. Discussions should not be inhibited for instance by legal pressure not to concede the possibility of hazards leading to serious or fatal injury
- **Participants need to have an “open mind” and ability to recognise and articulate credible hazard scenarios**
- Participants should not need outside authority to recommend changes or revisions

Careful preparation and energetic follow-up are essential to get full value from the HAZOP study

- Careful **preparation** ensures the objective of the work and the extent of the facilities is defined before the HAZOP team meets
- Preparation includes ensuring the technical drawings such as **P&IDs and supplementary information** such as data sheets and manuals are complete and up to date
- For an existing plant this means “as built” P&ID are essential; if the plant is under design the latest revisions are required. Working from **incomplete or out-of-date documentation is a serious pitfall**
- At the end of the HAZOP expect a long list of recommendations. These need to be **allocated for review and implementation** with a budget and timetable
- Failure to follow-up a HAZOP study is a potential liability. If subsequently there is an accident leading to litigation, the study may be ‘discoverable’ and provide potent **evidence if hazards were identified but no action** was taken

HAZOP study does not just involve the team meetings themselves. Preparation and completion activities are an essential part of the study

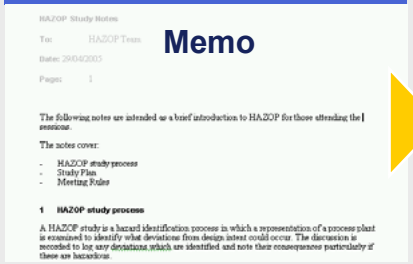
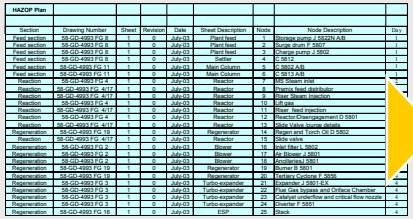


The following Terms are used:

- **HAZOP**
  Hazard and Operability Study of a complex system by a specialist team
- **Hazard**
  An unwanted event in the system with the potential to cause injury or loss.
- **Risk**
  The combination of size of loss and likelihood of that loss if a hazard occurs.
- **Parameter**
  A physical property of a component of the system at risk.
- **Guideword**
  The word or phrase expressing a deviation of a parameter from design intent.
- **Leader**
  The HAZOP member who leads the discussion using parameter-guidewords.
- **Recorder**
  The HAZOP member who keeps a record of the discussions.

Contents

Before the meetings start, as a team member you can expect to receive some information about the study

Activity	Advantages
Memo 	■ About a week before the meeting you receive a memorandum describing – The date, time and place for the HAZOP – HAZOP study process – Study Plan – Meeting Rules
	■ The HAZOP team meets to visit the plant ■ For those who do not know the facility this allows a basic description of the process to be provided and gives members a 'mental model' of the plant ■ Visit the control room as well as tour outside facilities
 **Plan of Nodes**	■ The plan shows the sections of the plant ■ The way each section is broken into nodes for HAZOP study ■ Which day each node is expected to be examined ■ Details of the P&I Drawing related to the node

The HAZOP team is selected from the available qualified staff who will need to be free of other duties for the period of the study

- The HAZOP team members represent the main disciplines concerned with the design and normal operation of the plant
- Specialists may be co-opted from time to time to strengthen the technical knowledge of the team for particular aspects of equipment operation, maintenance or utilities supply

Typical Core Team Disciplines	Part-time co-opted specialists
Process design Operations Safety Maintenance	Instrumentation Rotating Equipment Mechanical, Electrical Control Systems Specialists

- The numbers in the team may vary from 4 to 12
  - Greater numbers reduce the pace and inhibit discussion
  - With too few members, the team may lack perspective

As a member of the team, your work is to answer questions from the HAZOP team leader based on guidewords for each process parameter

- The **parameters** are the main measurable characteristics of the system such as Flow, Pressure, Temperature and so forth and are applied systematically section by section of the P&ID
- The **guidewords** are the main deviations such as No, Low, High and so forth and these are interpreted in terms of typical events which cause deviations from design intent in the node under review

Parameter	Guideword	Typical Deviation
Level	High	Malfunction of level or flow controller
Flow	No	Blockage eg freezing, coking or deposits
Action	Before/After	Operator uses incorrect valve sequence
Containment	Part of	Leak for example a pump seal
Maintenance	Other than	Wrong procedure leaves blind in place
Utilities	Part of	Failure such as instrument air failure

The leader will explain the guideword-parameter combinations he proposes to use at the start of the meeting

- The table can be applied to the plant in any configuration for example, commissioning, start-up, shut down, emergency shutdown or regeneration as well as the normal process flow

Parameter	More	Less	No	Reverse	Part of	Other than
Flow	High Flow	Low Flow	No Flow	Back Flow		Loss of containment
Pressure	High Pressure	Low Pressure	Vacuum		Partial Pressure	
Temperature	High Temperature	Low Temperature			Cryogenic (Sub Zero)	
Level	High Level	Low Level	No level			
Composition	Additional Phase	Loss of Phase		Change of State	Wrong concentration	Contaminant Corrosive Wrong Material

- Other parameters such as viscosity can also be used

The guideword-parameter combinations are applied to a section of plant (called a node) selected by the HAZOP leader at the start of the study

HAZOP step	Leader Action	Specific example	HAZOP team input
Apply parameter guideword combination	Leader selects Flow-Reverse	How could feed pipe experience reverse flow?	If there were a loss of supply pressure
Develop a meaningful cause for deviation	Leader probes how deviation could occur	What could cause the loss of supply pressure?	1. Upstream pipe rupture 2. Inadvertent valve closure 3. Pump failure
Examine possible consequences	Leader checks if hazardous	Could there be a hazard if there were a pipe rupture	Depends on size of leak, location, chance of ignition and exposure of personnel
Discuss any protection	Leader checks on hazard potential	How do you plan to protect against this possibility	Design standards Regular maintenance inspection Emergency response team

- Deviations may have several causes each of which needs to be discussed
- Whether or not the team considers there is a hazard depends on the specifics of the situation

In addition to the parameter- guideword combinations, the HAZOP team can also use special guidewords to consider specific failures

- **Loss of containment**
  - Piping failures from corrosion induced leaks or mechanical impact
  - Failures of flanges and fittings
  - Leaks from valve stems or pump seals
  - Heat exchanger tube rupture or shell failure
  - Pressure vessel failure
  - Releases from small bore fittings, instrument bridles, drains and vents
  - Materials of construction, corrosion, embrittlement
- **Utilities failures**
  - Instrument Air or Nitrogen
  - Power
  - Cooling water or Steam failure
  - Fuel Gas or Fuel Oil failures
- **Environment impact**
  - Lightning, Wind or Flood
  - Earthquake
  - Noise

Special guidewords can also be applied for activities or facilities which are essential to the safe operation of the plant

These guidewords are not deviations from intent but act as reminders to consider plant hazards under these conditions

- **Testing**
  - Equipment such as alarms, trips PRV settings
  - Product or intermediate sampling and analysis
- **Maintenance**
  - Access and means of isolation
  - Draining, Purging and drying
  - Cooling or warming of equipment
  - Availability of spares/replacement items
  - Special activities (for example Hot Tapping)
- **Electrical**
  - Area classification
  - Isolation and earthing
- **Instrumentation**
  - Suitability/reliability/sufficiency of sensors and transmitters
  - Location, failure modes and effect on any voting logic
  - Alarms, hierarchy and ability of operator to respond

Most process plant operations will involve exposure of operators to toxic or other hazards

These guidewords are also reminders used at the appropriate point in the HAZOP when considering sections of plant where exposure may occur. Typical deviation is "no" personnel protection

- **Personnel protection**
  - Basic equipment, boots, hard hats, gloves goggles
  - Escape masks, breathing apparatus (Toxics or confined entry)
  - Permit to work and requirements (escape routes, ladders, ropes etc)
  - Protective instruments (oxygen analysers, flammable /toxic gas detectors)
- **Plant protection**
  - Fire and smoke detection
  - Flammable or toxic gas detection
  - Firewater systems, monitors, deluges and sprays
  - Passive fire protection
  - Chemicals storage and handling
  - Fences and measures against intruders, saboteurs
  - Housekeeping

Some HAZOP practitioners use additional guidewords which we do not recommend for the reasons given below

- **Relief** meaning relief philosophy, type of device and reliability
  - Typically this deviation is better covered by **Pressure High** (Pressure Safety Valve) or by **Temperature High** (Temperature Safety Valve)
- **Sampling** meaning sampling procedure and operator safety
  - Typically this deviation is better covered by loss of containment applied to a sample point. If a detailed HAZOP is required use the Human HAZOP guidewords applied to the sequence of sampling tasks

    No action, Part action, Wrong action, Other action, Action too late/early

    Action in wrong sequence
- **Abnormal operation** meaning purging , flushing, clearing blockages etc
  - Typically this deviation can be considered as part of actions in event **of low or no flow**
- **Ignition** meaning grounding arrangements, insulation, hot surfaces etc
  - Typically this deviation can be considered as a consequence of **loss of containment**
- **Safety** meaning toxic properties, fire and gas detection, alarms etc
  - Properties are part of design intent; the deviation leading to operator exposure is **loss of containment**

Practice with guidewords

- The following table shows a parameter and guideword illustrated by a particular event with practical consequences

Parameter	Guideword	Illustrated by....	Practical consequences...
Level	High	Overfilling a tank	Liquid spill

- Select one answer from the following examples.

Parameter	Guideword	Illustrated by....	Practical consequences...
Pressure	No	Failure of compressor Vacuum Broken pressure gauge	Loss of reaction pressure Tank sucked in Lack of pressure reading

Practice with guidewords.

- Try two more examples:

Parameter	Guideword	Illustrated by....	Practical consequences...
Containment	Part of	Mechanical failure pump seal Overflow of tank Vessel manhole cover dropped	Leak and ignition at pump Oil spill Damage by mechanical impact

Parameter	Guideword	Illustrated by....	Practical consequences...
Action	other than	Instead of action fails to act Performs extra action Wrong action performed	Forgets to change filter Opens in service and standby filter Opens filter in service

Why I think the answer you chose is not correct …

- You selected

Parameter	Guideword	Illustrated by....	Practical consequences...
Containment	Part of	Mechanical failure pump seal	Leak and ignition at pump
		Overflow of tank	Oil spill
		Vessel manhole cover dropped	Damage by mechanical impact

…but that is not what went wrong. The tank has not failed but the operator failed to control the level so I would have chosen 'Level High' for this case

Control of levels in Tank Farms is a perennial problem and fitting LAH is not the answer unless there is regular procedure to dip the tanks to check the LI/LAH is working. LAHH to close the inlet line valve is an option.

Management of drains in tank bunds is related. Do they leave the drain valves closed (and get a flood if it rains?) or opt for convenience and leave the drains open (so any spill escapes to sewer)

Why I think the answer you chose is not correct …

- You selected

Parameter	Guideword	Illustrated by....	Practical consequences...
Containment	Part of	Mechanical failure pump seal Overflow of tank	Leak and ignition at pump Oil spill
		Vessel manhole cover dropped	Damage by mechanical impact

…well the cover is ‘part of the containment’ but that is not how the ‘HAZOP grammar’ works. Using ‘Part of’ is intended to imply the parameter to which it applies is not complete. In this case containment is not complete

What you chose is a credible hazard typically called ‘dropped object’ It’s a worry especially in congested plant offshore. I would normally take this in a HAZOP on a special topic day under ‘Maintenance’. Typically it happens because of an error either in slinging heavy lifts or lack of protective scaffolding. It matters went maintenance is done on an operating plant

Yes I would have chosen the same answer...

- You selected

Parameter	Guideword	Illustrated by....	Practical consequences...
Containment	Part of	Mechanical failure pump seal	Leak and ignition at pump
		Overflow of tank	Oil spill
		Vessel manhole cover dropped	Damage by mechanical impact

…It's a frequent source of trouble on single seal pumps (check the accident lists for CDU)

There are two things to debate … using double mechanical seals and installing an ROV to separate the pump from upstream inventory. This matters when the upstream is volatile (LPG) or hot (above auto-ignition) and above a critical volume (typically 7 m3). If you go for an ROV remember to fire proof (check the Avon Coker Accident) and to protect the pump by limit switches on the valve (check the C&E diagrams)

Why I think the answer you chose is not correct…

- You selected

Parameter	Guideword	Illustrated by....	Practical consequences...
Action	other than	Instead of action fails to act	Forgets to change filter
		Performs extra action	Opens in service and standby filter
		Wrong action performed	Opens filter in service

…I think failing to act would be ‘ Action No’

The mistake (forgetting about filters) is easy enough. Typically look for a differential pressure indicator (dPI) across an important filter but avoid long runs of high pressure small bore tubing. In these cases think about two PI with differential by DCS software

Why I think the answer you chose is not correct…

- You selected

Parameter	Guideword	Illustrated by....	Practical consequences...
Action	other than	Instead of action fails to act	Forgets to change filter
		Performs extra action	Opens in service and standby filter
		Wrong action performed	Opens filter in service

…I think this is 'Action As well as'

In the example chosen there is probably not a big problem (until both filters block at the same time and perhaps force a shutdown)

Its always worth checking emergency procedures especially where an emergency logic adds extra actions which the operator would not carry out. Emergency depressuring is a potentially hazardous example because of the stress caused and the loading on the blowdown system

Yes I would have chosen the same answer...

- You selected

Parameter	Guideword	Illustrated by....	Practical consequences...
Action	other than	Instead of action fails to act Performs extra action	Forgets to change filter Opens in service and standby filter
		Wrong action performed	Opens filter in service

…it happens very occasionally on filters and on other types of equipment

In one plant the PSV arrangement was such that it was guesswork to decide which of the two valves was in service. Make a mistake and the technician could be exposed to high pressure hydrogen rich gas

Sometimes plants car seal valves (a wire with a lead seal) but this is not foolproof. In one instance an operator broke the seal, opened a valve and exploded a low pressure steam drum putting a steam cracker out of service for 6 months

Practice with guidewords

- Complete the following proforma by saying for each of the following parameter-deviation combinations
  - How the deviation would be noticed
  - A practical illustration

Parameter	Guideword	Noticed because...	Illustrated by....
Level	High	Liquid spill	Overfilling a tank
Flow	Reverse		
Pressure	No		
Temperature	Low		
Containment	Part of		
Contamination	As well as		
Action	Other than		
Action	Before		

Practice with guidewords

- Complete the following proforma by saying for each of the following parameter-deviation combinations
  - How the deviation would be noticed
  - A practical illustration

Parameter	Guideword	General effect	Illustrated by....
Level	High	Liquid spills	Overfilling a tank
Flow	Reverse	Flow in wrong direction	Failure of check valve
Pressure	No	Vacuum	Tank sucked in - vent blocked
Temperature	Low	Cooling or Freezing	Ice causes seizure of let down valve
Containment	Part of	Leak of gas or liquid	Mechanical failure of pump seal
Contamination	As well as	Wrong phase or composition	Particulates block filter
Action	Other than	Wrong action performed	Opens standby filter
Action	Before	Right action in wrong sequence	Opens filter before draining contents

Contents

The recorder needs to be a professional and is an important participant in the proceedings

- The recorder must maintain concentration to unravel the essential points made in discussion by each participant
- Respond attentively to the leader when he sums up discussion and proposes recommendations
- Provide the administrative support for the team including follow-up questions and clarifications
- Exercise discretion to prompt the leader where a possible oversight is spotted and to participate in the discussions without undermining the leader's efforts to pace the work of the group
- Avoid interrupting the leader's flow to seek minor clarifications of the record (raise these later when the day's work is to be reviewed)

The discussion is recorded in a tabular fashion

Company: Sponsor Company
Facility: Pipeline Distribution System
Process:
HAZOP Date: 4 October 1997

Sheet Name: 1
Leader / Recorder: Geoff Stevens / Mark Harrison
Team Members: See attached list

HAZOP Item No.	Plant Section	Item	Deviation	Cause	Consequence / Implication	Indication / Protection	Questions / Recommendations	Answers / Comments
Drawing number XXXXXX Revision xx Title - Pipeline HAZOP illustration (Name of Section under review)								
110	Main Transmission Line	Line 18" XX-10-xxx	Reverse Flow	110. 1.Upstream pipe rupture 110.2. Shut down at inlet metering station 110.3. Compressor failure	110.1 Potential for ignition and fire with radiation to adjacent population. Depends on size of leak, location, chance of ignition and public exposure 110.2..... 110.3.....	110.1 Routing studies, Regular patrol, Emergency response team	R110.1 Recommend installation of non return valve at station outlet	

A line of enquiry usually results in one of four types of conclusion

- A **note** (denoted N) simply recording how the system already operates or setting out protective measures which are considered adequate
- A **recommendation** (denoted R) where the HAZOP team agree to suggest an improvement aimed at improving safety or plant performance
- A **question** (denoted Q) where the team have insufficient information to respond and require additional data from outside the meeting
- An **answer** (denoted A) which records the answer to a question in the record. Where the answer is considered to imply a hazard, a further recommendation may follow
- The record is numbered sequentially to aid subsequent action plans (e.g. N1, R2, Q3, A4, etc)

As well as the tabular section the recorder needs to complete the template sections which explain the design intent of the node under review

General description of section and individual node

Company **Facility** **HAZOP Date**	JGC Corporation Sohar Refinery Project - 2800 Huels Selective Hydrogenation Process Unit 06 - 09 Oct 2003	**Team members:** **Team Leader/Assistant**	see attached list Mr. Stevens/Ms. Tan
Section ID	**Reaction Section**		
General Section Description:	Feedstock comprising 4% C3 in C4 (n butane, iButane, butene and 0.17% butadiene is fed to a two stage reactor under hydrogen. The process conditions are very mild, temperature 80-100C . Butadiene is converted to butene and But-1-ene is isomerised to but-2-ene mainly in the second reactor. The catalyst is nickel based. There is no presulphiding only a low temperature hydrogen strip below 100C. The reactors operate on 50% recycle		

			Drawing Number/Sheet Number /Rev.Number/Date	D-280-1225-102 Rev.1 29 AUG '03 D-280-1225-103 Rev.1 29 AUG '03 D-280-1225-105 Rev.1 29 AUG '03			
			Design intent	**Holds feed and provided water boot for any entrained material** **BL Pressure = 17.3 barg** **Water Wash Column Design Pressure = 29 barg** **BFW supply pressure = 21 barg**			
			Node Equipment	**Surge Drum V 2802** **Feed Pump P2802 A/B**			
23	Node 2	Water Wash Column (C-2801) overhead line to FV-010	General	P-2802A/B seal ruptures	Leak of HC to surroundings with potential for ignition	Hand switch HV-008 provided in the field	280Q23.1 Clarify why the hand switch HV-008 at is located in field and not in the control room. 280A23.1 ITT specify that all trips are activated by HS in field 280R23.1 Evaluate if better reliability is obtained if HS-008 is provided in CR as well as in field

The recorder must organise a computer and template for recording.

Activity Name and Identification number:	1.7 Set up a computer for the recorder with template	**Essential**	X
Activity Description:	The HAZOP recorder should set up a computer in the HAZOP room and work with the Leader to prepare a recording template with the nodes and guidewords ready	**Useful**	
Objective of Activity:	Smooth working of the Leader-Recorder partnership	**Optional**	

How to conduct the Activity

1. Make sure the recorder has a suitable computer and set it up in the HAZOP room to check power and other facilities
2. Set up before the HAZOP starts a recording template which contains all the nodes and the guidewords which will be used
3. Prepare a complete recording template ie all parameter guidewords for all nodes
4. Divide the template into sections for different days to provide flexibility to adapt if there is a change in HAZOP sequence
5. A spare computer is desirable, switched on and ready to use to reduce to a minimum the impact of a failure during the meeting
6. Whether the template is Excel, Word or HAZOPTIMIZER make sure the Recorder can operate speedily in the meeting language.

What to avoid during this Activity

1. Avoid printing problems either by bringing your own printer or using a system like Microsoft Office so you can print on the local network
2. Check the local version of 'Office' so you save in compatible format
3. Do not be tempted to project the recorder's screen for the Team unless the recorder is confident and the leader can control any tendency to waste meeting time doing 'real-time' editing. This is best done afterwards
4. Avoid large files which exceed the capacity of a diskette
5. Avoid re-inventing the template… use a standard from previous studies
   Avoid colours which limit black and white printing

A well organised recorder can manage even in cramped conditions

As an illustration of two records consider the following comparison made of two different HAZOP discussions on furnace tube rupture

- The Company X HAZOP is limited in its comments. It places a reliance on design and on the spot inspection. There is no discussion of reverse flow from the reaction section into the firebox (one of the main practical hazards which has to be managed) There is no recognition of the hazards of inspection
- The ADL HAZOP discusses the protection for reverse flow and itemises the operators actions including depressuring and nitrogen circulation. The issue of attendance at the furnace is covered by Q and A clearly records the operators opinion
- As an aside, the use of RVs in this duty is quite unusual and other licensors are quite clear that the valves cannot be trusted to work. However the depressuring procedure is generally considered an effective approach

In the company X HAZOP the record simply records protection but does not indicate if these are considered adequate

Worksheet

Company:

Page: 16 of 245

Unit

Session: (2) 2003-09-30
Node: (3) LIQUID FEED 3
Drawings: V-81001 sh.3, V-81001 sh.5
Parameter: Flow

GW	DEVIATION	CAUSES	CONSEQUENCES	SAFEGUARDS	REF#	RECOMMENDATIONS	BY
		88. Tube burst in H-8101	88.1. Uncontrolled fire in H-8101	Proper design of heater piping and material selection of piping. Presence of pipe wall temperature measurement. Regular inspection of heater piping and flame patterns. Trip of H-8101 at low flow.			

In the ADL HAZOP the record summarises quite detailed discussions

Flow Reverse	for tube rupture in furnace		NRV to prevent reverse flow from reactors on common line and on each coil; emergency procedure involves reducing firing but keeping burner alight if possible, depressuring with HV 11 bypass and recycle gas compressor running, at low pressure introducing N2 using 3" at MUG and when fire goes out shut furnace and immediately purge with snuffing steam	Q 781 Why are 4 NRV needed, one on each coil of the furnace instead of putting an extra NRV upstream of the existing one?	A 781 To prevent reverse flow from other coils.
Loss of Containment	782.1 Hydrogen migration into thermowells in the furnace 782.3 small leaks from furnace tubes	782.1 Risk of leakage and ignition	782.1 No experience of leakage but sealing is not done in the way it is on the reactors	Q 782 According to Emergency procedures no difference between full bore rupture and leak; in the 2nd case trip of furnace and rapid depressuring, would this be a stress for the furnace and lead to more damage in the furnace ?	A 782 In theory but control of small leak requires operator to be close to furnace observing and this is considered dangerous if it is known there is a leak

Example of a very sparse record

Project: 117681 New tank
NODE: 3

Node des: TANK

Deviation	*Reason*	*Consequence*	*Protection*	*Recommendation*	*Ans*	*Status*	*Date*	*ID*
High Flow	Several pumps supply tank	High level, no effect	See note 1					
Low Flow								
Reverse flow	Draining to another tank	See note 2	Blinds					
High Pressure	Inlet and Nitrogen both full open	Nothing	SV overpressure opens					
Low pressure	Blocked drain Nitrogen fails to open	Nothing	Vacuum breaker opens					
High/Low level			See Note 1, 3					
High temperature	NA		See Note 4					
Low temperature	NA							
Instrumentation	Fail open of PCV	SV lifts	alarm	Complete with PAH	L E			
Material								
Other				See Note 5,	Project			

In low or high case what if valve fails to act? Consequences should be discussed. Does SV discharge to flare ? What are consequences ? Does vacuum breaker admit air / moisture ? what are consequences ?

This discussion is not complete. The consequence should be described and then consider if the proposed protection has sufficient reliability. Its not adequate to say 2oo3 therefore don't think about it

1) 2 oo3 function inlet and outlet valves, LSHH (Radar, Pressure transducer, LS on roof)
2) Quality problem can occur if blins are removed.
3) If low level LALL. Roof can land on base, ~80 cm, no difficulty. Vacuum valve on inner tank protects against total collapse
4) Comrolled by process run-down, alarm + 40 Gr C (Design tank 65 Gr C)
5) TI to control room (Divided double transmitter scheme in preparation)

Instrumentation is not a deviation. Failure of instrumentation is but needs inclusion of all failures ...often several modes

With what consequence (stuck, bottom puncture ?

Tank comment.doc

Diagram for Exercise 2

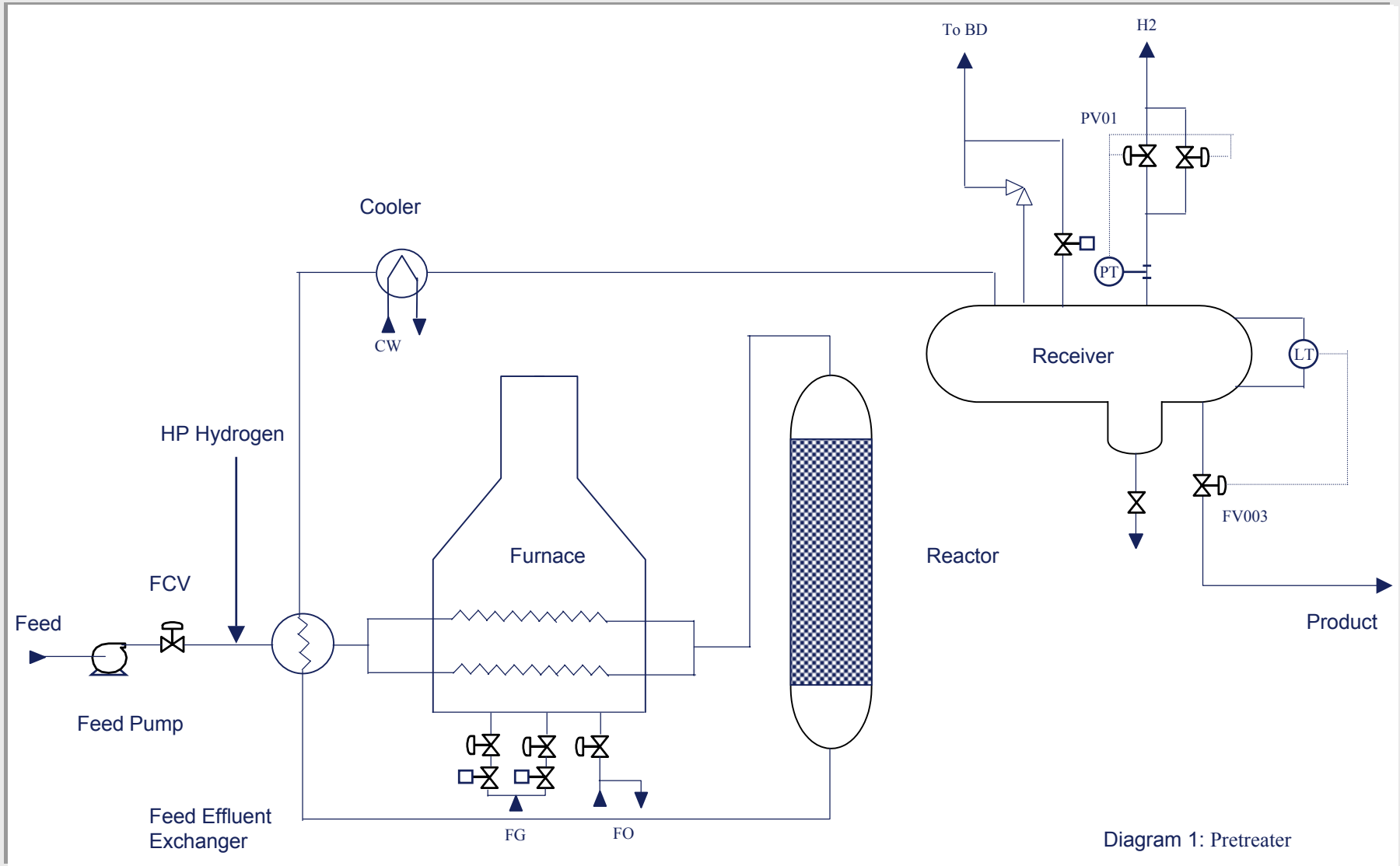


Diagram 1: Pretreater

Interpreting the HAZOP record

- Try to complete the following HAZOP sheet to record hazards associated with rupture of process piping. Use enter answers you consider to be credible

Plant Section	Item	Deviation	Cause	Consequence or Implication	Indication or Protection	Question or Recommendation
Lead Reactor	Feed Inlet	Reverse Flow	1. Feed pump fails	1. Reactor pressure causes reverse flow	1. Check valve on pump discharge	?
			2. Heat Exchanger Tube rupture	2. Overpressure of exchanger shell side	?	?
			3. Furnace Tube Rupture	?	?	?

Interpreting the HAZOP record

- Try to use the following HAZOP sheet to record hazards associated with rupture of process piping. Complete the record using a made up example which you consider to be credible

Plant Section	Item	Deviation	Cause	Consequence or Implication	Indication or Protection	Question or Recommendation
Lead Reactor	Feed Inlet	Reverse Flow	1. Feed pump fails	1. Reactor pressure causes reverse flow	1. Check valve on pump discharge	1.1 Automatic start of standby feed pump on FAL 1.2 Regular inspection check valve
			2. Heat Exchanger Tube rupture	2. Overpressure of exchanger shell side	2 Design specs of exchanger shell	2 Install PSV if necessary e.g. if an existing exchanger is to be used
			3. Furnace Tube Rupture	3 Fire in furnace as reactor contents ignite	3.1 Tube skin temp 3.2 O2 analyser 3.3 FAL on tube	3. Review ESD/ need for reactor blow down

Interpreting the HAZOP record

- Two options are suggested (this is OK provided each is properly identified so that the recommendations can be evaluated separately later)

Plant Section	Item	Deviation	Cause	Consequence or Implication	Indication or Protection	Question or Recommendation
Lead Reactor	Feed Inlet	Reverse Flow	1. Feed pump fails	1. Reactor pressure causes reverse flow	1. Check valve on pump discharge	1.1 Automatic start of standby feed pump on FAL 1.2 Regular inspection check valve

- 1.1 is the ‘design’ solution It is conventional on some types of equipment such as boilers for feed water supply but rarely used by refinery designers even on critical services
- 1.2 is a typical ‘maintenance ‘ response. Check valves are a source of worry in some plants and can be overlooked in a turnaround

Interpreting the HAZOP record

- Harder because you needed to answer in two columns

Plant Section	Item	Deviation	Cause	Consequence or Implication	Indication or Protection	Question or Recommendation
Lead Reactor	Feed Inlet	Reverse Flow	2. Heat Exchanger Tube rupture	2. Overpressure of exchanger shell side	2 Design specs of exchanger shell	2 Install PSV if necessary eg if an existing exchanger is to be used

- Normally you expect the exchangers to be designed to consider tube rupture. Typically the difference in shell/tube design pressures should not exceed 150%
- If this is not the case (perhaps the plant has been revamped) PSV protection is typically added. This must be sized for tube rupture not just for fire

Interpreting the HAZOP record

- The line has been completed for the typical alternitives found to protect against furnace tube rupture

Plant Section	Item	Deviation	Cause	Consequence or Implication	Indication or Protection	Question or Recommendation
Lead Reactor	Feed Inlet	Reverse Flow	3. Furnace Tube Rupture	3 Fire in furnace as reactor contents ignite	3.1 Tube skin temp 3.2 O_2 analyser 3.3 FAL on tube	3. Review ESD/ need for reactor blow down

- The consequence of rupture is (additional) fire in the furnace box. Flames might come out from a register or inspection port
- Various protections have been suggested. The O2 detector is using an existing item to detect a small leak. Skin temperature (if fitted) may not be reliable. To work FAL must be on each furnace pass (preferred protection)
- Try to check the operator's knowledge of these emergency procedures which will differ for small leak and full rupture

Contents

The Team Leader's primary role is to facilitate the team discussion

- **Keep the team focused:**
  - Concentrate on identifying hazards, not re-designing the plant
  - Where the data is insufficient, record questions and move on
- **Respond to team personalities:**
  - Be tolerant and maintain a positive atmosphere.
  - Restrain the extroverts
  - Draw out the quiet thinkers
- **Use own knowledge to:**
  - Encourage thoroughness
  - Obtain consensus
  - Phrase recommendations

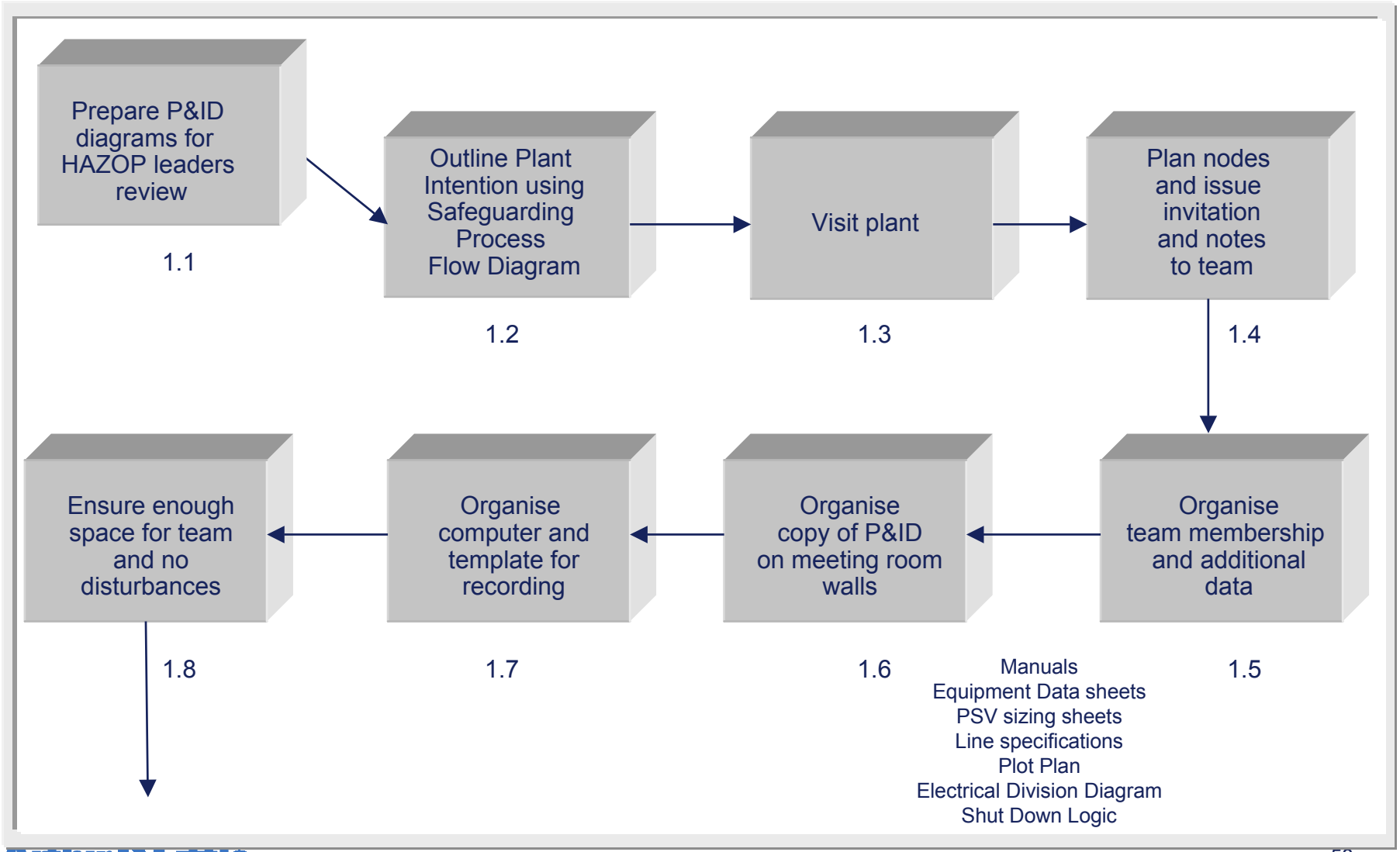
HAZOP leadership is an expression of personal style… but leaders can strengthen the range of skills and behaviours they have available

- The leader must stick to the principles of the HAZOP procedure but the pace and manner allow wide latitude for personal style
- Guidance for HAZOP leaders includes a flow chart to monitor progress and check completeness. For our own leaders we have developed files for planning, recording and assessing the results of the study
- Experience is an important factor helping to improve performance. For the recorder this means working with different leaders to experience the variety of approaches and recording styles
- For leaders we have a questionnaire (HeLP) which provides a framework for the recorder to give feedback on the conduct of the study. If we approach the feedback positively, recognising that we all have room to learn and improve, we should improve our HAZOP facilitation

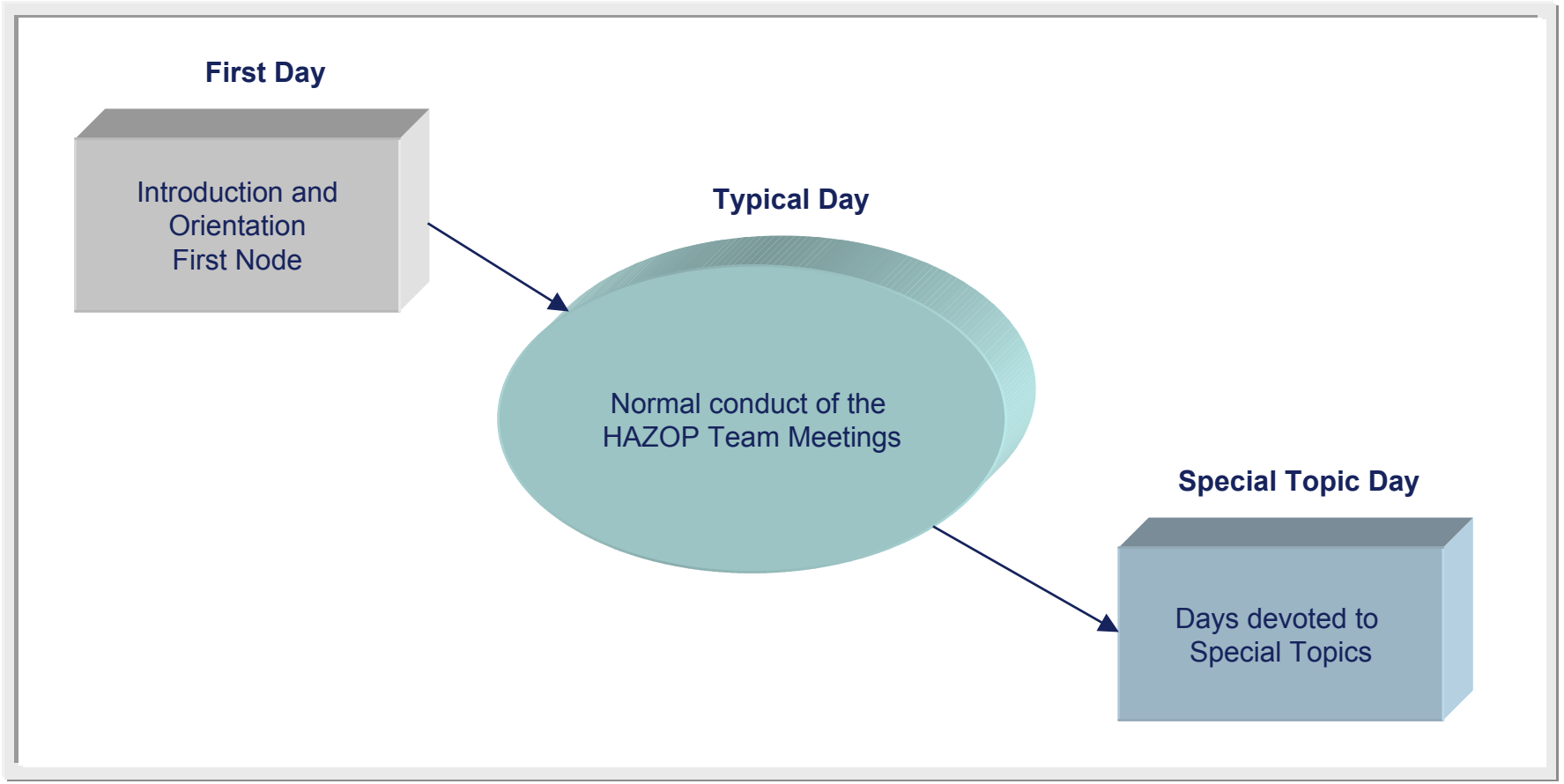
The HAZOP leader needs to define with the manager commissioning the study the extent of the facilities to be studied before the HAZOP starts

- Technical drawings of the facility such as Piping and Instrumentation Diagrams (P&ID) are typically used to define the plant within battery limits
- Supplementary materials are useful to clarify team discussions:
  - Process flow sheets
  - Equipment specifications and vendor detail drawings
  - Piping class and relief valve specifications
  - Plot layout and classification
  - Operating manuals and emergency shut down procedures
- **Working from incomplete or out-of-date documentation is a serious pitfall**
- **For a HAZOP on an existing facility "as built" P&ID are essential; if the plant is under design a consistent set of the latest revisions is required**

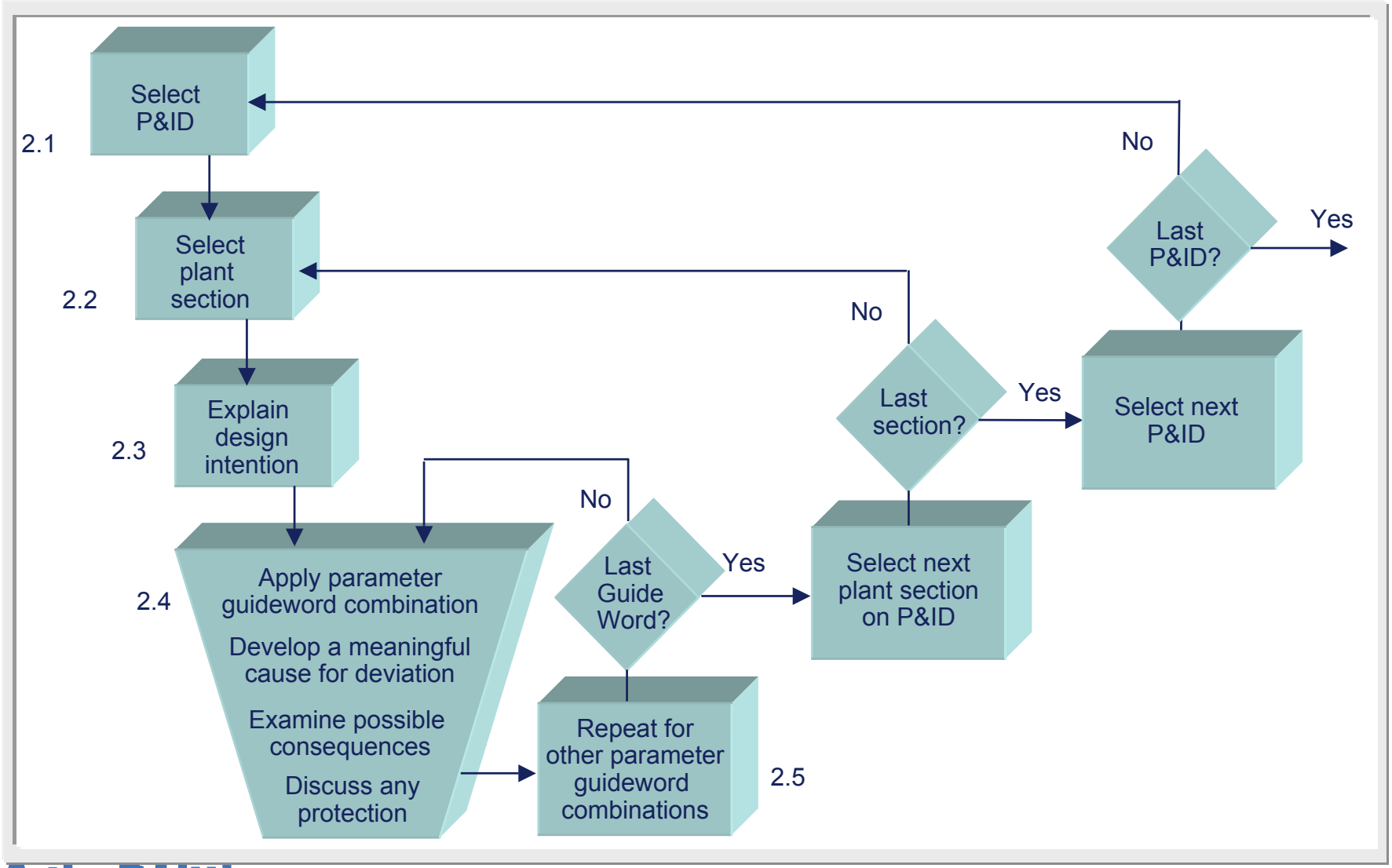
The HAZOP Leader must supervise study preparation



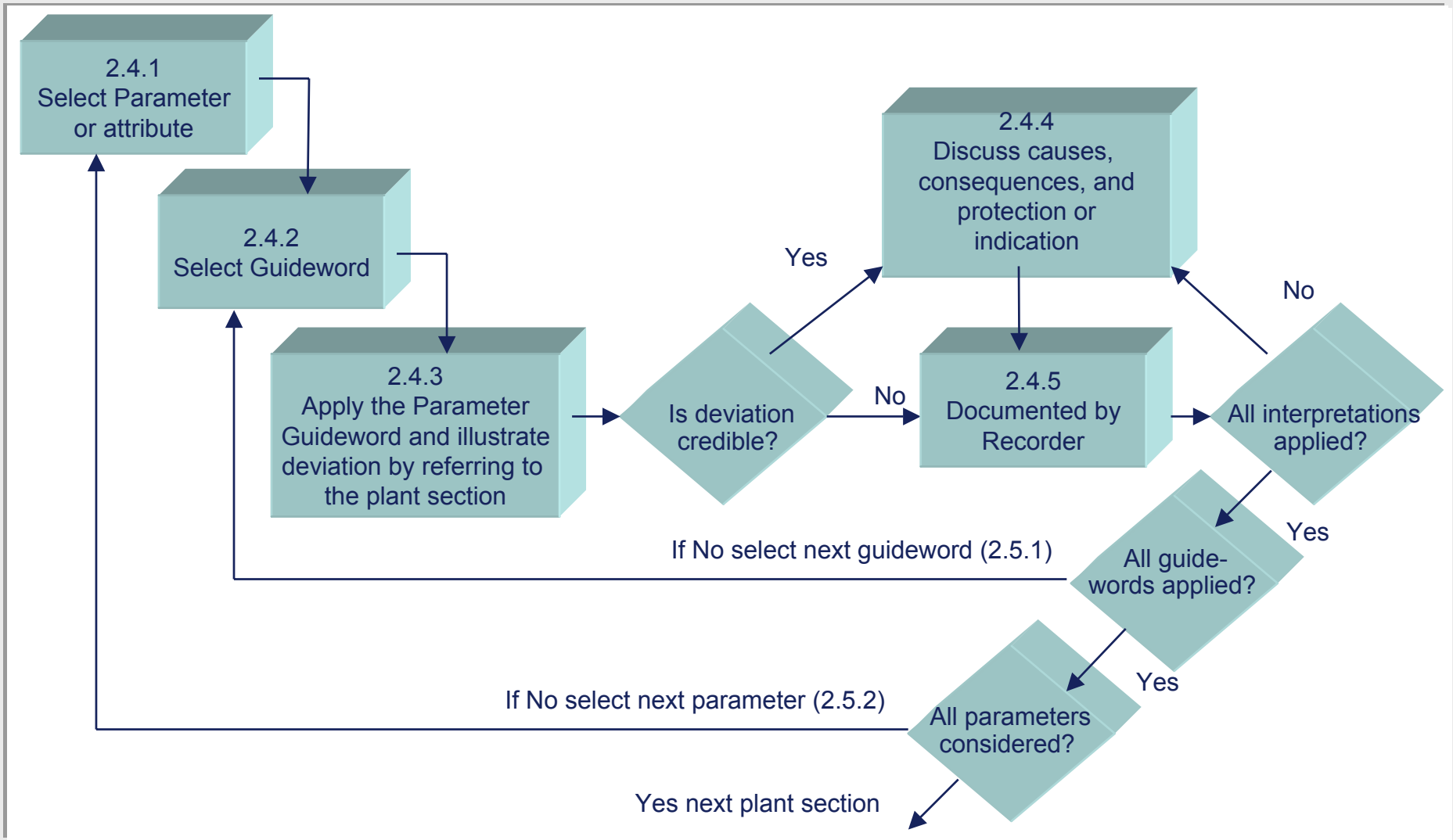
The HAZOP meeting develops a rhythm after the first day which often includes some introductory discussion to orient the team



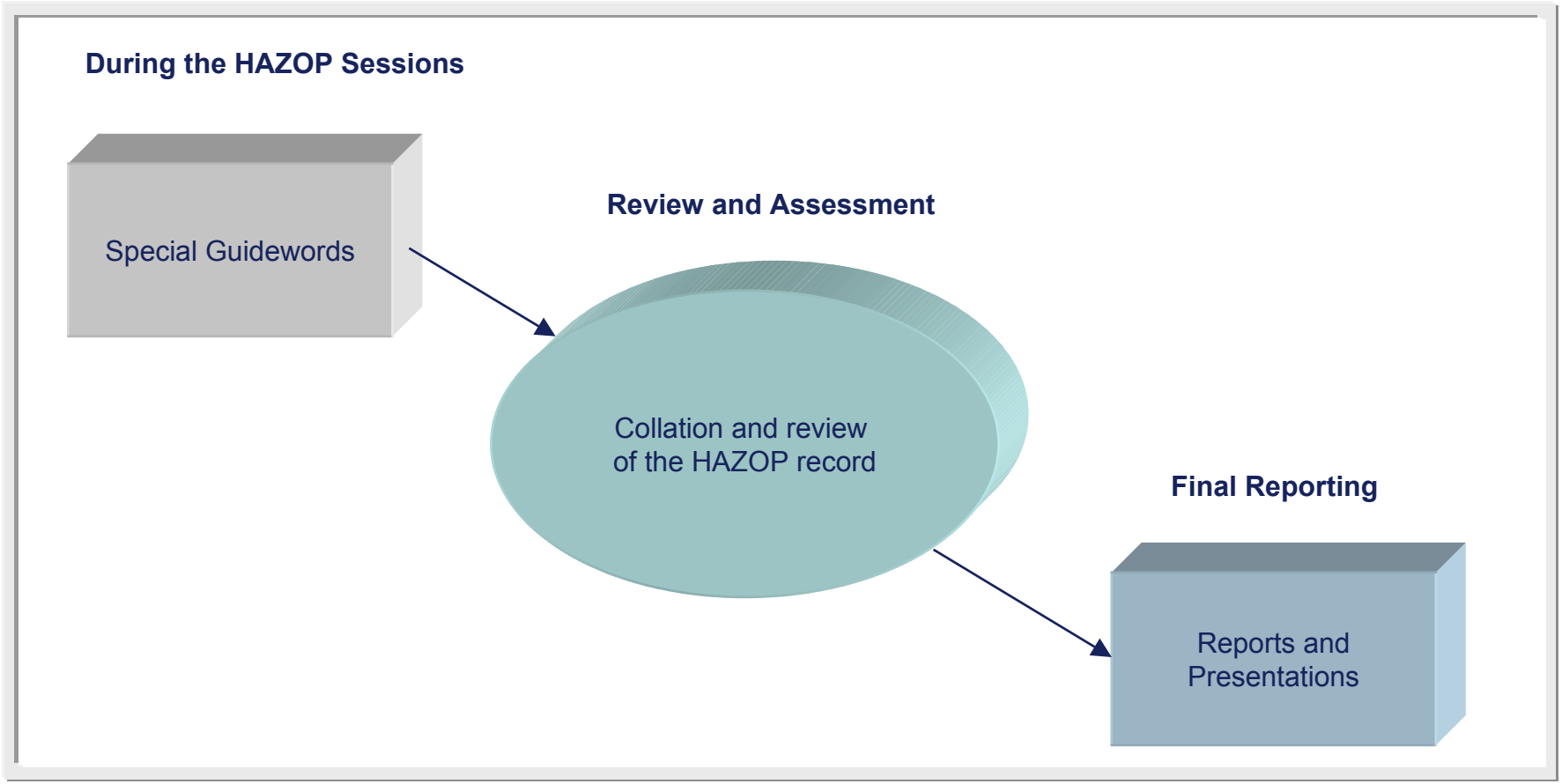
Steps in a normal HAZOP day



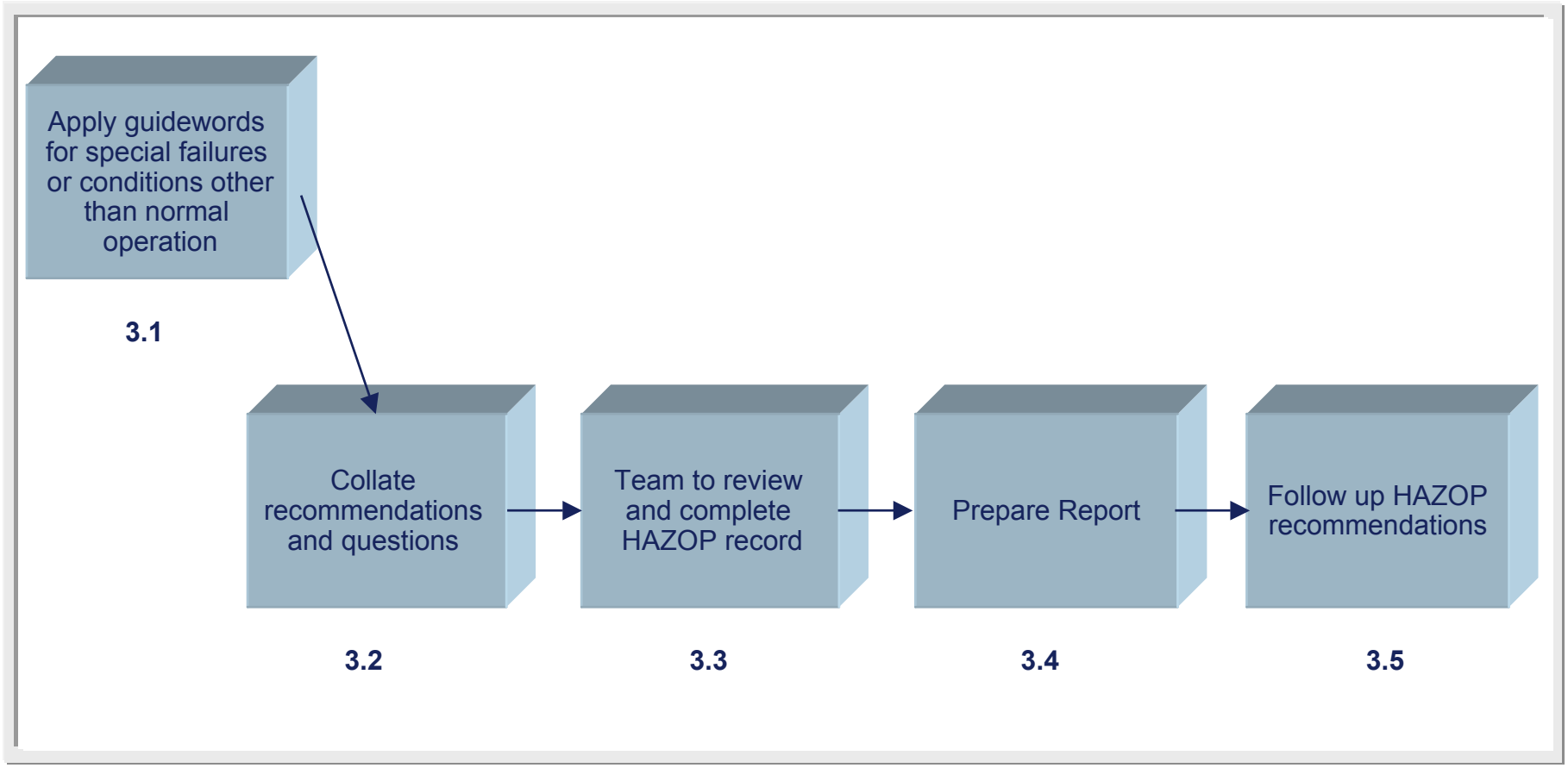
Details for study of a single plant section



The leader must keep in mind a number of activities needed to conclude the study



The HAZOP is completed with some activities outside the HAZOP sessions.



Prepare P&I Diagrams for HAZOP leaders review

Activity Name and Identification number:	1.1 Prepare P&ID for HAZOP leaders review	**Essential**	X
Activity Description:	HAZOP leader reviews diagrams to ensure they are comprehensive and complete to become familiar with process and equipment and its representation	**Useful**	
Objective of Activity:	Ensure the P&ID are an adequate basis for the proposed study	**Optional**	

How to conduct the Activity

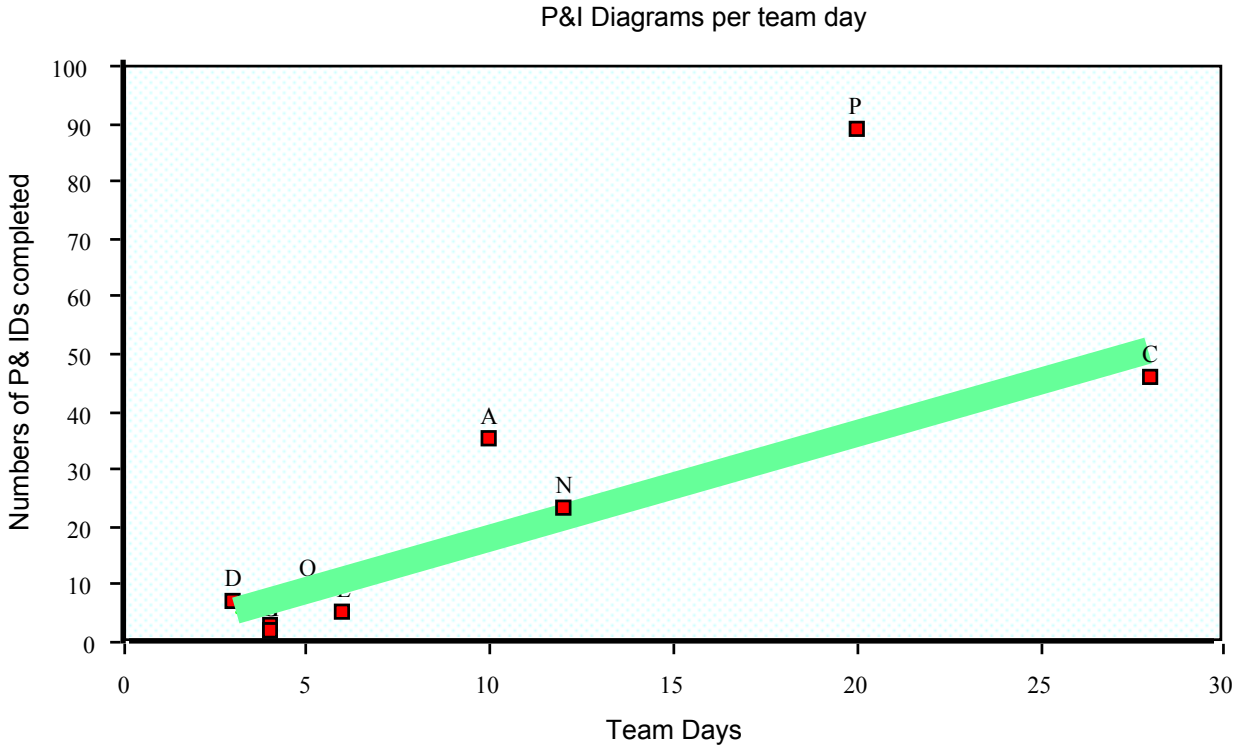
1. The plant engineer organises a copy of the P&ID which is sent to the HAZOP leader at least 1 week in advance of the meeting
2. The leader arranges the diagrams into a coherent process flow which will be the basis for the conduct of the HAZOP
3. Verify that the diagrams clearly define the plant battery limit and ensure the limit conforms to the terms of reference of the study
4. Note the issue date of the diagrams. If there is a date sequence change make sure the latest 'as-built' versions are being used
5. If the drawings are old, confirm with the plant engineer that the drawings he has sent are 'as built'
6. Compare the number of P&IDs, their quality and the number of days allowed for the HAZOP. The attached graph is a guide.

What to avoid during this Activity

1. Do not accept a HAZOP under conditions which give too little time for review. Never start a HAZOP meeting without first having seen the P&IDs
2. If the diagrams do not match, ask. Make sure you follow all the main process lines and do not assume it will work out in the meeting.
3. Avoid diagrams which do not show the battery limit. It will be important later in the HAZOP to investigate the interfaces (but not at this stage).
4. Do not conduct a HAZOP on drawings which do not represent the plant 'as-built' (or for a new plant) after Design Review.
5. Avoid illegible drawings for example if they have been marked up following a major revamp. Ask the engineer for clearer copies.
6. Do not be unreasonable. CAD diagrams are nice to work with but when the job is on an older plant you may have to get by with a lower standard

Past studies provide a guide to the number of P&IDs which can be reviewed per day to give an overall estimate of the time needed for study

- **The rate varies with the quality of the diagrams but is typically 2-3 per day**
- The team leader's skill is a crucial factor in maintaining the rate of progress



Outline Plant Intention using safeguarding Process flow Diagram

Activity Name and Identification number: 1.2 Draw a safeguarding Process Flow Diagram

Activity Description: HAZOP leader arranges for a safeguarding process flow diagram to be drawn. This is a PFD with critical control equipment added and shows the process intention

Objective of Activity: Understanding the plant operation and developing a summary diagram

Essential ☐

Useful ☐

Optional ☒

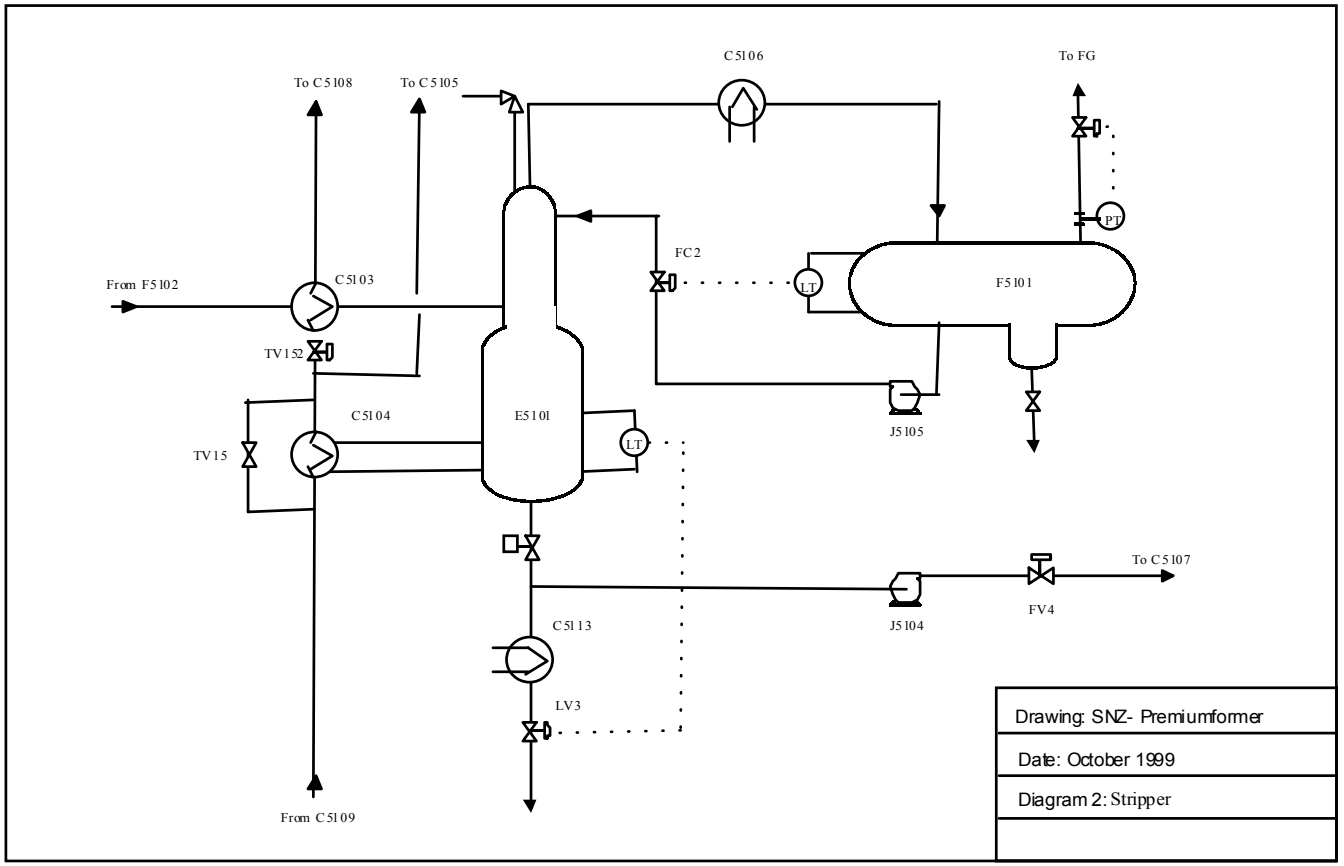
How to conduct the Activity

1. Obtain a copy of the plant process flow diagram and add to it the main control instrumentation
2. Add any emergency shut-down or plant protection systems
3. Refer to the drawing during the HAZOP sessions. It can be very useful for considering system wide failures.
4. Consider using the diagram for emergency conditions, start-up including catalyst regeneration,and shut down.
5. In a last resort, use the diagram for HAZOP itself when you are very short of time or are addressing plant wide loss scenarios.
6. If the drawings are used during the HAZOP include a copy as an appendix to the HAZOP report

What to avoid during this Activity

1. As leader you will probably not have time to do this yourself. However, it it is a good exercise for the recorder especially if the plant is unfamiliar
2. Avoid using shutdown logic drawings during a HAZOP unless the group contains a specialist. The safeguarding PFD is much easier to understand.
3. Do not use your own drawings unless the plant engineer has reviewed and corrected them

Example of a typical safeguarding process flow diagram



Arrange a visit to the plant

Activity Name and Identification number:	1.3 Arrange for members of the HAZOP team to visit the plant	**Essential** ☐
Activity Description:	Those members of the HAZOP team who are not familiar with the plant carry out a plant inspection lasting 2-3 hours to include control room and main equipment	**Useful** ☒
Objective of Activity:	Provide members of the HAZOP team with a 'mental model' of the plant	**Optional** ☐

How to conduct the Activity

1. The plant engineer organises a visit to the plant for those in the HAZOP team who are not familiar with it
2. The team should comply with the safety instructions applicable to the plant including protective equipment.
3. It is better to limit the numbers to avoid a large group which may disturb plant operations
4. The timing of the visit is difficult. It is useful as part of preparation but it can also be very helpful to visit specific locations where Issues have been raised during the HAZOP

What to avoid during this Activity

1. Do not make a visit unless accompanied by the plant engineer to answer any questions which arise or note any problem areas
2. Avoid conducting the visit as if it were an audit. The aim of the visit is orientation to get a better understanding of the plant and to form an impression of the standard of operations

HAZOP team is pictured inspecting a refinery plant

Plant Inspection is done in small groups observing the plant safety precautions

The HAZOP Team →

Plan the study Nodes and issue Notes to HAZOP team

Activity Name and Identification number:	1.4 Plan the study nodes and brief the HAZOP team	**Essential**	☐
Activity Description:	HAZOP leader works through the P&ID deciding which nodes will be examined on which day of the study. He also prepares a briefing note summarising meeting arrangements	**Useful**	X
Objective of Activity:	Plan the study and brief the HAZOP team members	**Optional**	☐

How to conduct the Activity

1. Prepare a note to invite members to attend the HAZOP meeting. giving time, location and an explanation of the proceedings
2. Ensure the note is distributed in good time to the attendees and maintain liaison with the personnel arranging the HAZOP
3. Arrange the nodes in a logical sequence. Allow for relatively slow progress initially but accelerate later using bigger nodes
4. Document the plan thoroughly collating node, diagram and functional description into a coherent sequence
5. Use the plan to indicate progress and maintain team morale If you consistently fall behind plan, then rethink the scope
6. As a last resort consider big nodes using the safeguarding process flow diagram.

What to avoid during this Activity

1. Avoid explanations which are too long or complicated
2. Standard notes are available for process HAZOP and Human Factors HAZOP. Avoid undue effort but spell participants names correctly
3. Avoid planning nodes diagram by diagram. Keep a sequence which logically follows the process flow jumping from diagram to diagram
4. Avoid jumping between process streams. Try to close the process loop. E.g. complete the gas recycle system before taking liquid products.
5. Avoid being too mechanistic. If important issues are identified stay with the HAZOP process rather than pressing forward to fulfil the plan
6. Pretending to the client that this short cut is a 'classic' HAZOP. It is a device to provide some hazard identification against extreme time pressure.

A template is provided to assist planning the study nodes

Number nodes in sequence

Cite the drawing and the equipment - it helps keep track in the meeting

Plan each day to complete process themes

HAZOP Plan								
Section	Drawing Number	Sheet	Revision	Date	Sheet Description	Node	Node Description	Day
Feed section	58-GD-4993 FG 8	1	0	July-03	Plant feed	1	Storage pump J 5822N A/B	1
Feed section	58-GD-4993 FG 8	1	0	July-03	Plant feed	2	Surge drum F 5807	1
Feed section	58-GD-4993 FG 8	1	0	July-03	Plant feed	3	Charge pump J 5802	1
Feed section	58-GD-4993 FG 8	1	0	July-03	Settler	4	C 5812	1
Feed section	58-GD-4993 FG 11	1	0	July-03	Main Column	5	C 5802 A/B	1
Feed section	58-GD-4993 FG 11	1	0	July-03	Main Column	6	C 5813 A/B	1
Reaction	58-GD-4993 FG 4	1	0	July-03	Reactor	7	MS Steam inlet	2
Reaction	58-GD-4993 FG 4/17	1	0	July-03	Reactor	8	Premix feed distributor	2
Reaction	58-GD-4993 FG 4/17	1	0	July-03	Reactor	9	Riser Steam Injection	2
Reaction	58-GD-4993 FG 4	1	0	July-03	Reactor	10	Lift gas	2
Reaction	58-GD-4993 FG 4/17	1	0	July-03	Reactor	11	Riser feed injection	2
Reaction	58-GD-4993 FG 4	1	0	July-03	Reactor	12	Reactor/Disengagement D 5801	2
Reaction	58-GD-4993 FG 4/17	1	0	July-03	Reactor	13	Slide Valve /purge details	2
Regeneration	58-GD-4993 FG 19	1	0	July-03	Regenerator	14	Regen and Torch Oil D 5802	3
Reaction	58-GD-4993 FG 4/17	1	0	July-03	Reactor	15	Slide valve	3
Regeneration	58-GD-4993 FG 2	1	0	July-03	Blower	16	Inlet filter L 5802	3
Regeneration	58-GD-4993 FG 2	1	0	July-03	Blower	17	Air Blower J 5801	3
Regeneration	58-GD-4993 FG 2	1	0	July-03	Blower	18	AncillariesJ 5801	3
Regeneration	58-GD-4993 FG 19	1	0	July-03	Regenerator	19	Burner B 5801	3
Regeneration	58-GD-4993 FG 19	1	0	July-03	Regenerator	20	Tertiary Cyclone F 5856	4
Regeneration	58-GD-4993 FG 3	1	0	July-03	Turbo-expander	21	Expander J 5801-EX	4
Regeneration	58-GD-4993 FG 3	1	0	July-03	Turbo-expander	22	Flue Gas bypass and Oriface Chamber	4
Regeneration	58-GD-4993 FG 3	1	0	July-03	Turbo-expander	23	Catalyst underflow and critical flow nozzle	4
Regeneration	58-GD-4993 FG 3	1	0	July-03	Turbo-expander	24	Diverter F 5851	4
Regeneration	58-GD-4993 FG 16	1	0	July-03	ESP	25	Stack	4

Organise team membership and additional data

Activity Name and Identification number:	1.5 Organise team and additional data for the HAZOP meetings	**Essential**	X
Activity Description:	Organise the plant engineer to provide essential staff and data such as Manuals, Equipment data sheets, PSV sizing calculations, piping specifications, Plot Plan, Electrical classification etc	**Useful**	
Objective of Activity:	Ensure the HAZOP has available relevant staff and information to answer questions	**Optional**	

How to conduct the Activity

1. Provide the Plant engineer with a list of the information needed in the HAZOP meeting room, It is not necessary to make copies.
2. Ensure that key staff and documents are available. Equipment sheets, piping specifications and PSV sizing are essential
3. Copies of operating and emergency manuals are desirable. Plot plan and Electrical classification diagram are also helpful.
4. If there is a shutdown system, some representation of the logic is essential
5. Try to share the work of looking up data amongst HAZOP team. Even a simple job like looking up Heat Exchanger specs can help a very junior engineer feel useful to the team

What to avoid during this Activity

1. Avoid requesting this information without explaining that it is needed to reduce the number of questions requiring attention after the HAZOP
2. If the PSV calculation sheets are not complete many questions will be left to answer after the HAZOP.
3. Try to avoid lengthy descriptions of operating procedure which are a recital of personal opinion. Many issues arise when what operators say they do differs from the instructions in the manuals
4. Beware of specialist representations of system logic unless the team includes an expert who can reliably interpret the information
5. Avoid making one person do all the work… even if he is the most competent team member and you are short of time

Arrange a copy of the P&ID on the meeting room walls.

Activity Name and Identification number:	1.6 Prepare the HAZOP room using the walls for P&IDs	**Essential**	
Activity Description:	Where the HAZOP will follow process streams across numerous P&Ids, it is useful to arrange a sequential copy on the meeting room walls marked up with connections	**Useful**	X
Objective of Activity:	Facilitate following the process flow during the HAZOP	**Optional**	

How to conduct the Activity

1. Preferably before the HAZOP sessions begin stick on the walls a set of P&IDs
2. The P&IDs should be arranged sequentially to best follow the process flow planned by the leader
3. Mark the interconnections between P&IDs with coloured pen to make it easy to follow during the HAZOP session
4. Check the line numbers when marking up

What to avoid during this Activity

1. Blue tack seems to work best and comes away without (usually) damaging paintwork.
2. Avoid putting up only a few diagrams. Better display a complete plant section so that a coherent process functionality is represented.
3. Avoid inconsistent use of colours. It is best to use a colour code eg brown for oils, blue for H2 rich, green for H2S rich for speed and clarity
4. Do not assume continuity or rely only on line size

The HAZOP team has space to organise supplementary data, hang a copy of P&IDs on the meeting room walls and work in comfort.

Organise a suitable room for the HAZOP away from disturbances.

Activity Name and Identification number:	1.8 Organise the room for the HAZOP	**Essential**	
Activity Description:	The HAZOP leader and his contact at the plant should review the options for available rooms for the meeting	**Useful**	X
Objective of Activity:	Ensure the meeting is not disrupted by unsuitable facilities	**Optional**	

How to conduct the Activity

1. Choose a room which is convenient to get to and large enough for the group who are meeting
2. It is preferable if the room has no telephone. Those not involved in the HAZOP should not disturb the team on non-HAZOP affairs
3. Consider using a room in a hotel if the plant facilities are too cramped or noisy
4. Make sure the table is large enough for the Leader to work from a full sized P&ID. Team members need individual A3 copies

What to avoid during this Activity

1. Do not use a room if access is delayed by excessively tedious security procedures… it will waste too much time better spent in HAZOP
2. Avoid excessive use of radios. It has to be accepted that key personnel are on call if there is an emergency but discourage disturbance to the HAZOP.
3. Avoid noise or odour which can be wearing during a long HAZOP This may include the air conditioning as well as outside plant/construction

Carefully select the meeting room and the location for the study

- The room for the HAZOP meetings needs to be spacious
  - A table is needed large enough for each participant to comfortably arrange their papers and working copies of P&Ids
  - The secretary requires space for the computer used for on-line recording
  - It is useful to hang a complete set of P&IDs on the room walls to assist continuity during the study and examine interfaces in their context
  - A flip chart and an overhead projector are useful for explanations
- **The meeting room needs to be separate from those used for everyday work so that participants are free from interruption from colleagues or phone calls**

The First day of the meeting will involve some introductory discussion

Activity Name and Identification number:	HAZOP First day	**Essential**	X
Activity Description:	Introduction of the Team and orientation to the process in the following days	**Useful**	
Objective of Activity:	Settling the team and commencing the HAZOP	**Optional**	

How to conduct the Activity

1. Ask each team member to sign in using a sign-in sheet. If they do not usually work together ask them to say a few words about themselves and their backgrounds

2. The HAZOP leader and Secretary should introduce themselves Generally they will be independent of the plant facility

3. Quickly review the HAZOP briefing note. Ask if there are any questions about the procedure or the parameter-guidewords which have been suggested

4. Confirm the working hours to ensure these are compatible with local requirements and check arrangements for lunch and meeting breaks

5 Explain the intended path through the process using the Nodes or process flow diagrams prepared previously

What to avoid during this Activity

1. Not learning team members names and/or misspelling them

2. Avoid spending too long. The intention is to get everyone to speak and feel comfortable in the room

3. Avoid forgetting the preparation step 1.4…..parameter guidewords are best introduced in the invitation note.

4. Working hours are best introduced in the note of invitation step 1.4 Do not plan to work more than 6 hours per day. HAZOP requires concentration and quality will deteriorate if the Team become fatigued

5. Leader and Recorder must avoid exhausting themselves in the HAZOP After each day they will have 2-3 hours extra work reviewing records.

Select the P&ID and Plant section for review

Activity Name and Identification number:	2.1 Select P&ID, 2.2 Select Plant Section	**Essential**	X
Activity Description:	The HAZOP leader selects the P&ID for team study	**Useful**	
Objective of Activity:	Lead the Team through the HAZOP procedure	**Optional**	

How to conduct the Activity

1. The sequence of study will have been introduced on the first day based on either the nodes planning table or the process flow diagrams prepared earlier
2. It may be useful to leave a summary plan on a flip chart to help the team monitor progress
3. Deviate from the plan when necessary to maintain a coherent flow sequence
4. Apply the HAZOP process to a complete process at special times eg design approval for construction, major turnaround

What to avoid during this Activity

1. Avoid forcing the Team along a process sequence they object to Respond to the suggestions especially of the operations people
2. Avoid becoming too mechanistic. The quality of hazard identification is more important than maintaining a schedule based on unrealistic expectations
3. Avoid taking on a HAZOP limited to 1 or 2 days. The expense of preparation and mobilisation rarely justifies a short study
4. Avoid repeating a HAZOP too often. It is an expensive and time consuming exercise and other techniques may be more appropriate depending on circumstances

Explain the design intention

Activity Name and Identification number:	2.3 Explain the design intention	**Essential**	X
Activity Description:	The design intention of the node selected by the leader is explained	**Useful**	
Objective of Activity:	Ensuring the Team understand the process functionality of the node under review	**Optional**	

How to conduct the Activity

1 The explanation is preferably by the system designer or operator depending on who is represented.

2. If time is short and he has adequate experience, the team leader can explain how he thinks the node functions and ask for correction of any errors.

3. The main reason for the introduction is to ensure that all members of the team are “up to speed” on the intended operation of the section under review.

4. The introduction should avoid being too long (5-10 minutes is usually enough)

5. The introduction should not degenerate into a P&ID review focussing on the design preferences of team members

What to avoid during this Activity

1. Avoid hurrying on because time is short and leaving team members confused

2. Avoid speaking too much as leader… the group may loose concentration

3. The Recorder should not interrupt this process except at the end of the explanation if there are no questions from other team members Recorder should be properly briefed earlier eg by doing step 1.2

5. As in other aspects of the HAZOP the leader must strike a balance between encouraging contributions and directing the group. He should try to interrupt only when essential and remain deferential to the views of the team members

Select a parameter relevant to the plant section under discussion

Activity Name and Identification number:	2.4.1 Select Parameter	**Essential**	X
Activity Description:	Leader selects a parameter relevant to the node under discussion	**Useful**	
Objective of Activity:	Identification of deviations from design intent which could cause loss	**Optional**	

How to conduct the Activity

1. Use the parameters introduced on the first day and apply them systematically
2. Apply the same parameters in the same order to each node to encourage consistency and help the team follow
3. Select the parameters suitable to the study. Where possible use the same set of parameters for HAZOP of particular types of systems (eg Operating Manuals, Process Flow, mechanical devices)

What to avoid during this Activity

1. Avoid introducing new parameters part way though or skipping ones you applied on earlier nodes
2. If you intend a full recording HAZOP ensure there is an appropriate remark for each item even if no hazardous deviations were identified

Apply a Guideword to the selected parameter

Activity Name and Identification number:	2.4.2 Select Guideword	**Essential**	X
Activity Description:	Leader selects a guideword relevant to the node under discussion	**Useful**	
Objective of Activity:	Identification of deviations from design intent which could cause loss	**Optional**	

How to conduct the Activity

1. Use the guidewords introduced on the first day and apply them systematically
2. Apply the same guidewords in the same order to each parameter to encourage consistency and help the team follow
3. Parameter-Guidewords sound arcane to the unfamiliar. Try to explain by frequent practical examples what is meant to help team understanding
4. Take a moment to reconsider the guideword -parameter combination specifically in connection with the node you are studying Try to find new interpretations rather than sticking to the same repetition of familiar illustrations of meaning.

What to avoid during this Activity

1. Avoid introducing new guidewords part way though or skipping ones you applied on earlier nodes
2. If you intend a full recording HAZOP ensure there is an appropriate remark for each parameter-guideword even if no hazardous deviations were identified

The team use the Parameter-Guideword combination to start discussions

Activity Name and Identification number:	2.4.3 Apply parameter guideword combination	**Essential**	X
Activity Description:	Leader applies Parameter-Guideword to node expressing the deviation in practical terms perhaps by reference to an incident with which he is familiar	**Useful**	
Objective of Activity:	Ensuring the Team understands and is focussed on the deviation under discussion	**Optional**	

How to conduct the Activity

1. The leader should concentrate on asking questions based on the guidewords and let the team answer
2. The leader has wide scope to vary the method of questioning which can adhere closely to the parameter-guideword or can be more practical/ experiential provided the systematic nature of the questioning is retained
3. Deviations must be expressed in practical and credible terms. Some 'jokes' tend to recur (ones like the plant being hit by a jumbo jet or a meteor shower). Try to keep the interest of the team by diverting from the trivial to the serious potential conditions faced by the plant.

What to avoid during this Activity

1. Help the team by introducing variety into your questions and giving a practical bias
2. Discourage any members who try to dominate discussion or dismiss the proceeding as naïve. When the team understands how the framework of questioning leads to the recognition of hazardous conditions the value of team discussions improves enormously
3. Do not allow one disaffected team member to undermine the serious efforts of the others
4. Do not allow the team to continue if the discussion is becoming trivialised Generally this is because the team is tired, bored or both. Give them a break and then resume.

Identify deviations from the design intent and any existing protection

Activity Name and Identification number:	2.4.4 Discuss Causes, Consequences, and protection	**Essential**	X
Activity Description:	Leader guides the team to seek causes for deviations from design intent, discusses consequences and any existing protection	**Useful**	
Objective of Activity:	Identification of deviations from design intent which could cause loss	**Optional**	

How to conduct the Activity

1. Concentrate on deviations which are hazardous. If there are none, record that no new issues were discussed and move on
2. The leader should encourage participation of all team members but with regard to their experience and speciality
3. Make sure all the team understands the deviation; give practical illustrations where appropriate
4. Ensure the deviations are meaningful that is are practical problems not theoretical ones which are very unlikely to occur
5. Encourage team to share their experiences. These can be valuable learning even for an experienced leader
6. Discuss any protection objectively. How can it be improved?

What to avoid during this Activity

1. Avoid re-designing the plant; concentrate on hazard identification and let the team answer; do not tell them what to think
2. Discourage any members who try to dominate discussion. Do not over-rule or lose patience with team members
3. Do not allow one member of the team to dismiss a deviation because ‘it never happened to us’
4. Avoid unrealistic assessment of consequences Neither exaggerate nor dismiss them.
5. Examine the effectiveness of any protection and do not dismiss a hazard because there is a nominal indication/protection
6. Do not accept that human error or equipment failure is impossible

Recorder will summarise the discussion in the HAZOP record sheet

Activity Name and Identification number:	2.4.5 Record Discussion	**Essential**	X
Activity Description:	Recorder makes a summary of the discussion using a HAZOP recording template	**Useful**	
Objective of Activity:	Recording the result of the HAZOP team discussions	**Optional**	

How to conduct the Activity

1. Concentrate on recording accurately the recommendations dictated by the HAZOP leader
2. The leader should summarise the discussion of the Team by dictating to the recorder a summary recommendation and noting the recommendation separately eg on the P&ID
3. Make sure all the team understands the recommendation and try to draw out and reconcile any differences of opinion in the team
4. If the opinions of the team cannot be easily drawn to consensus record the differences and move on.
5. Be clear so that both the team and the recorder can follow your summary of the discussion. Check there is agreement

What to avoid during this Activity

1. Avoid missing the recommendation because you were spending too much time on other sections … these can be completed later
2. Avoid curtailing useful discussion just to hurry on. Team members loose confidence in the process if they see that detailed points are being skipped in a rush to stay with planned rate of progress
3. Avoid overruling team opinion. If there is not consensus or you are unable to quickly convince a team member that you view is correct record the difference of opinion
4. Avoid lengthy discussion which is inconclusive
5. At times some junior members of the team may loose track. Try to explain things to them and keep the team together

Repeat for other parameter guideword combinations to completion

Activity Name and Identification number:	2.5 Repeat of other Parameter-Guideword combinations	**Essential**	X
Activity Description:	Leader repeats the process with other Parameter-Guideword to the selected node, and then other nodes	**Useful**	
Objective of Activity:	Identification of deviations from design intent which could cause loss	**Optional**	

How to conduct the Activity

1. The aim is for the leader to continue the questioning process so that the HAZOP team itself identifies any hazards
2. The progress of the team should accelerate as they meet unit operations they have already discussed in earlier nodes
3. It is important to recommend consistent safeguards for similar hazards. The leader should remain alert for such variations
4. Consider the use of design standards or a cause and effect approach to establish a consistent relationship between severity of hazard and level of protection recommended by the team
5. Continue to apply the guidewords consistently and do not skip because time is short. If you sense there is a problem, explore it thoroughly until you find something or are convinced all is well

What to avoid during this Activity

1. As leader avoid telling the team what to think… the process works as they acknowledge and discuss the mitigation of hazardous situations
2. Avoid repeating the same recommendation again and again. Either make a general recommendation for the plant or refer back to the first instance in subsequent nodes where a similar hazard may arise
3. Avoid letting the recommendations focus too much on what is normal practice on the plant under review. Relate to industry 'best practice'
4. Allow team members to tell their 'war stories' without being too heavy handed. Often this is valuable shared experience and it helps members relate to each other and develop mutual respect
5. Avoid stopping discussion before a node has been completed. Aim to stop each day at a logic point which achieves effective topic closure

Allow time for special topics when specialists can join the HAZOP team

Activity Name and Identification number:	Special topic days	**Essential**	☐
Activity Description:	The leader may pass certain aspects during normal days and leave them for a special topic day when the team can be joined by a specialist	**Useful**	☐
Objective of Activity:	Allowing the HAZOP team to benefit from specialist contributions	**Optional**	X

How to conduct the Activity

1. Recognise when the team is 'out of its depth' and set aside a time when specialists can join the HAZOP to assist
2. Examples of Special topics include complex instrumentation or advanced controls, compressors or specialist packages, power generation or operations such a ex situ regeneration
3. Other HAZOP team members benefit from the learning which occurs in these special topic sessions.
4. In a successful HAZOP the leader also learns. Special topic days allow time for this to occur

What to avoid during this Activity

1. Avoid jeopardising the completion of the HAZOP through too long distraction with specialist topics which are not hazardous
2. Avoid protracted arguments between specialists and other HAZOP members. The specialist should be treated as a guest and given wide latitude within his specialisation unless it is apparent to several members of the team that poor advice is being offered
3. Avoid bunching special topic days. Where possible space them to give Added variety and interest in a long HAZOP

Apply guidewords for special failures or conditions

Activity Name and Identification number:	3.1 Special Guidewords	**Essential**	X
Activity Description:	The leader must include at some stage in the HAZOP consideration of guidewords for special failures including utilities or special operations	**Useful**	
Objective of Activity:	Ensuring a full coverage of all aspects of plant operation	**Optional**	

How to conduct the Activity

1. The leader must bear the special guidewords in mind and ensure adequate discussion. This can be by deliberate use of the guideword prompt or by adaptation of the main guideword set during the normal HAZOP sequence

2. Conduct the HAZOP under normal conditions and then, when there is a good understanding repeat the process under conditions such as start-up, emergency shut down or catalyst regeneration or activation for example using PFD

3. When planning the HAZOP and reviewing the process flow (Steps 1.2 and 1.4) give consideration to how you you will introduce these special guidewords and when. Many options can be chosen provided the conditions are not forgotten (a greater proportion of accidents occurs during non - normal operations such as start-up and shut down)

What to avoid during this Activity

1. Avoid exclusive focus on normal operation. Ensure there is enough time to deal with other conditions, especially emergency response

2. Do not forget maintenance and instrumentation/trip testing when doing 'normal' HAZOP. Do not forget leaks and other 'loss of containment' conditions and operator response.

Collate recommendations and questions

Activity Name and Identification number:	3.2 Collate recommendations and questions	**Essential**	
Activity Description:	The HAZOP recorder extracts from the HAZOP record a separate list of questions which could not be answered during the HAZOP and recommendations	**Useful**	X
Objective of Activity:	Ensuring the HAZOP record is complete	**Optional**	

How to conduct the Activity

1. The HAZOP recorder extracts questions and recommendations each evening from the day's record into a separate tabulation.
2. At the end of the HAZOP, the plant study co-ordinator has a list of questions which have to be answered. He must action the work necessary to answer the outstanding questions and provide the answers for review by the HAZOP leader
3. The HAZOP leader reviews the answers and decides if they are satisfactory or reveal additional hazards. In this case he makes additional protection recommendations.
4. The HAZOP cannot be considered completed until all outstanding questions have been answered

What to avoid during this Activity

1. Avoid inventing your own form for this activity … use the template
2. Avoid long delay between completion of the HAZOP and response to outstanding questions… the longer you take the harder it gets
3. Avoid adding a high profile recommendation at this stage without involving the HAZOP Team. The ranking exercise (step 3.4) provides A good opportunity for further discussion.
4. As Leader avoid not issuing any kind of report… better a report in draft with unanswered questions than no record

Team review and completion of HAZOP record

Activity Name and Identification number:	3.3 Team review of HAZOP record	**Essential**	X
Activity Description:	The leader reviews each day's HAZOP record and corrects it as necessary to issue to the HAZOP team who in turn review and correct the record	**Useful**	
Objective of Activity:	Ensuring an agreed record is prepared	**Optional**	

How to conduct the Activity

1. The HAZOP leader reviews the day's record in the evening at the conclusion of each session and corrects any mistakes or omissions
2. The HAZOP recorder prints each day's HAZOP record the following morning and distributes it to the team members at the start of the next day's session
3. Team members review the record and correct it to ensure it properly reflects their opinion or statement during the HAZOP
4. The corrected reports are collated by the recorder and used as the basis for the final HAZOP report

What to avoid during this Activity

1. Try to avoid completing the HAZOP without receiving members comments. It becomes a progressively larger and more complicated task the later it is left
2. Avoid recording only one version if there is a dispute between members which cannot be resolved. If there is no option, record both sides of the disagreement
3. As Leader avoid not issuing any kind of report… better a report in draft without the Teams' detailed comments than no record

Prepare report and presentation

Activity Name and Identification number:	3.7 Prepare Report and presentation	**Essential**	X
Activity Description:	HAZOP leader and recorder prepare and issue a report to document the work conducted	**Useful**	
Objective of Activity:	Ensuring a full coverage of all aspects of plant operation	**Optional**	

How to conduct the Activity

1. Prepare a comprehensive report describing the findings of the HAZOP Team and the main recommendations

2 Discuss the main findings in some detail so that the team recommendations can be understood quickly by someone who knows the plant but was neither in the HAZOP nor has time to go through the detail in the HAZOP record

3. Where possible, use graphics to summarise the HAZOP findings to show the distribution of recommendations

4. Add detailed tabulations of the HAZOP record and recommendations in appendices for later reference

5. Aim to produce a report which can be audited later and will stand as a complete record for future reference

6. Ensure that the HAZOP records are signed by:
   - HAZOP leader
   - Responsible of 'Funzione/Gestione'
   - Responsible 'TEC' for the facility
   - INSV (if project exceeds 500 million lire)

What to avoid during this Activity

1. Avoid abbreviating the report to give selective findings without any detailed support of interest to subsequent readers

2. Avoid lengthy pages of text…the report needs to convince those who have only a short time to read the main recommendations as well as serve as a reference for detailed engineering of recommendations in implementation. This is best done with short succinct text and tables for the detail

The recommendations made by the HAZOP team may improve safety by reducing either the likelihood or consequence of the hazard

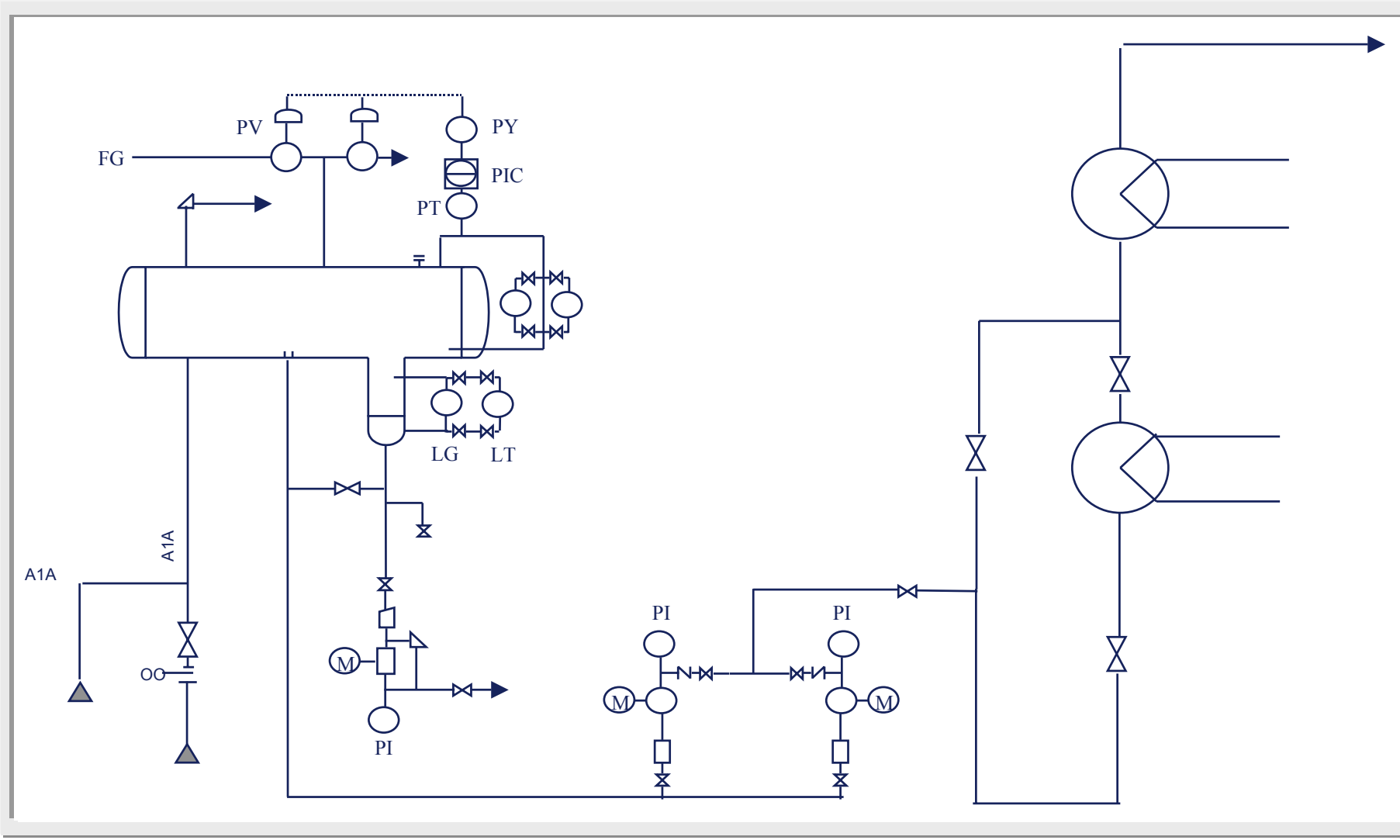
- There are a number of lines of approach:
  - More resistant equipment or safer materials
  - Standby equipment or instrumentation
  - More frequent testing of equipment, instrumentation and protective systems
  - Revised operating procedures or improved operator training
- At the end of the study, it is desirable for the team to rank its recommendations as an guide for implementation
- Each recommendation needs to initiate action. Generally this is outside the remit of the HAZOP team (who may lack either budgets or authority to initiate mitigation work). Nevertheless the organisation sponsoring the HAZOP should:
  - Institute an action program for each recommendation
  - Issue a close-out report to show how each issue has been resolved

HAZOP on a small section of plant

- The attached section of a P&ID details a charge pump and part of a feed pre-heat train. Assume the feed is Atmospheric residue
- Select one of your group to act as leader and another to record the HAZOP using the following template
- Conduct a HAZOP using the following parameter-guideword combinations to identify any hazards with the arrangements

Parameter	Guideword
Flow	High, Low, No, Reverse Loss of Containment
Pressure	High, Low, Vacuum
Temperature	High, Low, Freezing
Contamination	Part of

Exercise 3



Record your HAZOP using the following proforma and those provided in Attachment 1

ID	Plant Section	Item	Deviation	Cause	Consequence or Implication	Indication or Protection	Question or Recommendation	Answers/ Notes

Exercise 3

HAZOP Item No.	Plant Section	Item	Deviation	Cause	Consequence / Implication	Indication / Protection	Questions / Recommendations	Answers / Comments
Drawing number Exercise 3 Revision Simple			Title – FEED inlet					
1	Inlet to surge drum	Spectacle Blind	Flow- High	High Flow on inlet	Detect by level guage		R1 FI on line 1 Possible control on line	Best to control the flow in the line from Tank eg use the return line from the feed tank pump
2	Inlet to surge drum	Level Guage	Flow-Low	Excessive pumping rate on main feed pump	Surge drum drained. Risk of cavitation/ damage of feed pump	Relies on manual inspection by field operator	R2 Install LAL/LAH on LT for control room	
3	Inlet to surge drum		Flow No					
4	Inlet to surge drum		Flow Reverse	High pressure in main flow causes back flow in secondary feed		None	R4 Install non return valve	
5	Inlet to surge drum		Loss of Containment	5.1 Unable to swing blind because cannot isolate from upstream 5.2 Rupture of small bore tubimg	5.1 Chance of large loss of inventory, likely to contaminate ground/ water course 5.2 Loss of containment	None Standard of bracing	R5.1 Install double block and bleed for maintenance isolation R5.2 Review procedures to minimise spills of heavy material R5.3 Remove lines less that 1.5 ins wherever possible	

6	Inlet to surge drum		Pressure — High	6.1 Excessive pressure of fuel gas 6.2 Rundown of hot feed or feed with volatile components and 6.3 Pressure relief valve fails closed 6.4 Blockage of inlet or outlet of relief valve	Might exceed design pressure of surge drum	PSV provided	Q6.1 If PSV lifted would it reseat ? Q 6.2 How is maintenance anticipated Q6.3 What provision made for residue to drain rather than block pressure relief path ? 6.4 Locate so gas cleans the PSV inlet	A6 System likely to operate OK even if PSV not available R 6 Adopt standard design for PSV which allows for regular maintenance and inspection. Requires LO upstream and downstream valves with bypass
7	Inlet to surge drum		Pressure - Low	Failure of Fuel Gas supply or inlet valves	Main pump continues and draws vacuum in surge tank	Level guage	R7 Install PSLL to stop the feed pump so that vacuum is not drawn on the feed tank if FG is blocked	
8	Inlet to surge drum		Vacuum	During maintenance vessel is steam cleaned	Might cool blocked in and experience vacuum		Q8 Is vessel designed for vacuum ?	

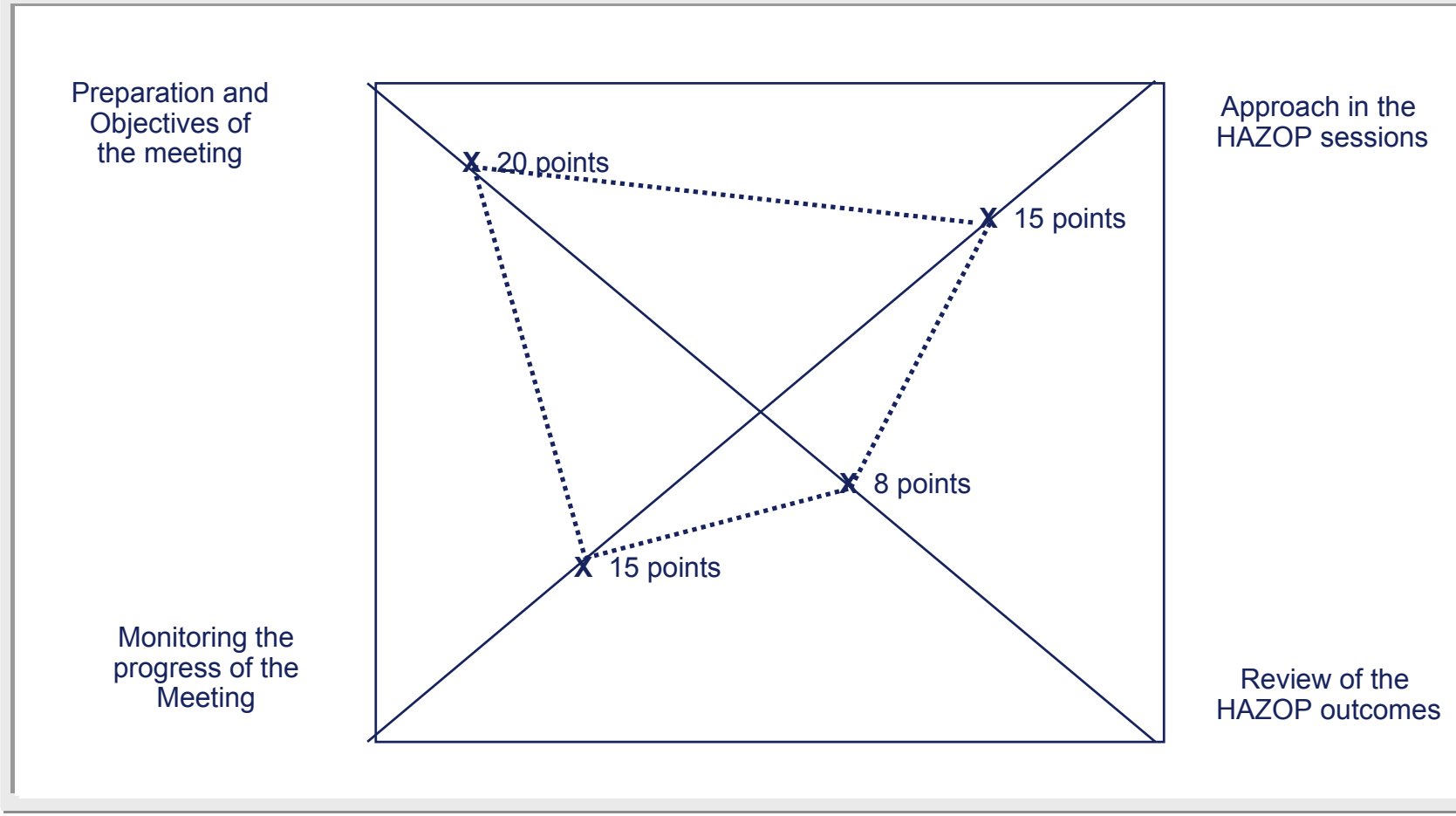
To assist feedback and personal learning, we have prepared a questionnaire to be completed by the recorder giving the leader structured feedback on the conduct of the meeting

- Style is largely a matter of behaviour appropriate to the circumstances. This means we do not intend the scoring to be read from ‘good’ to ‘bad’ but simply to allow the recorder to indicate his or her perception of what happened
- The objective is to encourage leaders to reflect on the style and tactics they adopted with the group in question so as to assess, in quiet, the effectiveness of their approach. The scales themselves suggest alternative approaches and may prompt or encourage leaders to ‘try something different’ where they judge it may have a better effect
- The profile (HeLP for HAZOP evaluation / Leader Profile) we believe will become more useful as a variety of recorders complete the form and leaders can see how their style has been reflected in the comments from different HAZOP teams

The HAZOP evaluation/Leader Profile (HeLP) is based on performance in four stages of the HAZOP process

- Preparation and Objectives of the meeting
  - How well has the meeting been prepared and the objectives communicated?
- Approach in the HAZOP sessions
  - What approach has the leader chosen to adopt?
- Monitoring of the progress of the meeting
  - Has the leader sustained the interest and commitment of the team?
- Review of HAZOP outcomes
  - How have the results of the HAZOP been assessed?

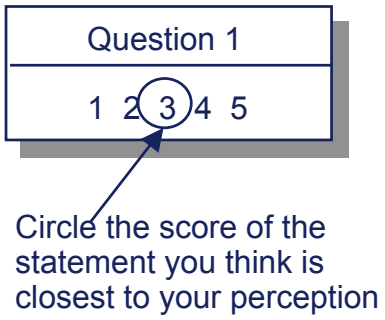
The greater the area of the HeLP spider diagram the more comprehensive the leader's performance



The HeLP profile uses numbered statements reflecting different criteria relevant to leading a HAZOP study

- A five point scale is used with statements at positions 1, 3 and 5. The blank cells 2 and 4 are left for those who judge the real situation lies intermediate between two of the statements
- Statements in positions 1 and 5 are intended to reflect the opposite ends of the spectrum of possibilities. Statement 3 is intended to be a halfway house. Remember the questionnaire is about style so the exact words are less important than the attitude/manner projected by each statement
- The answer is scored using the box on the right

1	2	3	4	5
Extreme Statement A		Middle of road Statement		Extreme Statement B



Preparation and Objectives of the meeting

Questionnaire

		1	2	3	4	5
1.1	Briefing of team (guidewords etc)	No time… we had to start right away		Written memo distributed.. Not sure if they read it		Memo sent to all and verbal cross check at start
1.2	Preparation of Drawings	P&IDs not available till day of meeting		P&IDs were reviewed		Safeguarding PFD drawn and P&IDs compared
1.3	Nodes	Not needed..the leader should be free to decide as he goes along		No time… we had to start right away		Nodes allocated for each day in agreement with client
1.4	Definition of Objectives	Self evident.. why bother?		Objective included in proposal		Objective included in briefing notes and repeated at start of session
1.5	Communication	If they can't be bothered to read the notes that's up to them		Prefer to explain things verbally at start of meeting		Combination of well written notes and verbal explanation as judged appropriate

Score

1.1	1	2	3	4	5
1.2	1	2	3	4	5
1.3	1	2	3	4	5
1.4	1	2	3	4	5
1.5	1	2	3	4	5
1	1	2	3	4	5

Approach in the HAZOP sessions

Questionnaire

		1	2	3	4	5
2.1	Use of guidewords	I find lists unhelpful ..vary guidewords as I go along		Use standard set but record by exception for normal operation		Full recording for all phases of plant operation
2.2	Use of diagrams	P&IDs should be up to date.. Can't stand it when they are in error		Prefer to use P&IDs but will supplement with board/flip chart if out of date		Safeguarding PFD prepared before start and used if P&IDs out of date
2.3	Selection of nodes	Vary as we go along depending on progress		Hold to plan if possible but may resort to 'big nodes'		Regularly review progress against plan and revise with client
2.4	Handling of discussion	Mostly waste of time.. Team should answer my questions		Allows discussion but same people seem to dominate		Contributions encouraged from each member in balanced manner
2.5	Team building	Some people are just a nuisance and you have to shut them up		Difficult to give fair turn to everyone.. Experience matters		Specific efforts made to give fair turns to all team members

Score

2.1	1	2	3	4	5
2.2	1	2	3	4	5
2.3	1	2	3	4	5
2.4	1	2	3	4	5
2.5	1	2	3	4	5
2	1	2	3	4	5

Monitoring the progress of the meeting

Questionnaire

		1	2	3	4	5
3.1	Leadership	Recorder even got left behind at times		Part of team lost but some followed most of process		Team had a clear idea where they going
3.2	Variation	HAZOP is about P&IDs so I stick to that		Occasional use of white board/flip chart to respond to 'low energy' in team		Variation of type of drawing and method of delivery to hold attention
3.3	Attention	Many of team lost interest, some wandered away		Team did tire at end of long sessions		Regular breaks; team stayed fresh and involved
3.4	Degree of Integration	Mostly the leader and one team member do work		One or two seemed to remain 'outsiders'		As team settled, worked well and co-operatively
3.5	Relationship to business decision-making	HAZOP was a requirement so we got it done		Attempts were made to link HAZOP to clients business processes		HAZOP was clients chosen route to improved operations

Score

3.1	1	2	3	4	5
3.2	1	2	3	4	5
3.3	1	2	3	4	5
3.4	1	2	3	4	5
3.5	1	2	3	4	5
3	1	2	3	4	5

Review of the HAZOP outcomes

Questionnaire

		1	2	3	4	5
4.1	Loss History	These war stories are just a chance to waste time.		Some tit-bits of past experience were shared		Regular reference to accidents in industry and on plant
4.2	Standards and recommendations	You can't get any standardisation; its up to the leader on the day		Some confusion ; recommended one thing here.. Another there		Client recognised attempts to create coherent pattern of recommendation
4.3	Method of assessment	Too subjective its just a waste of time		'High, Medium, Low' is about as good as it can get		Systematic method eg based on Matrix or QRA basis
4.4	Involvement in assessment	No time for assessments.. We concentrated on HAZOP		One or two people lead the assessment the others went along		Assessment was a team effort
4.5	Level of feedback	As soon as its over client puts the report on the shelf		Client would like to change but a problem getting funds/ commitment		Active client interest evidenced by feed-back to senior management

Score

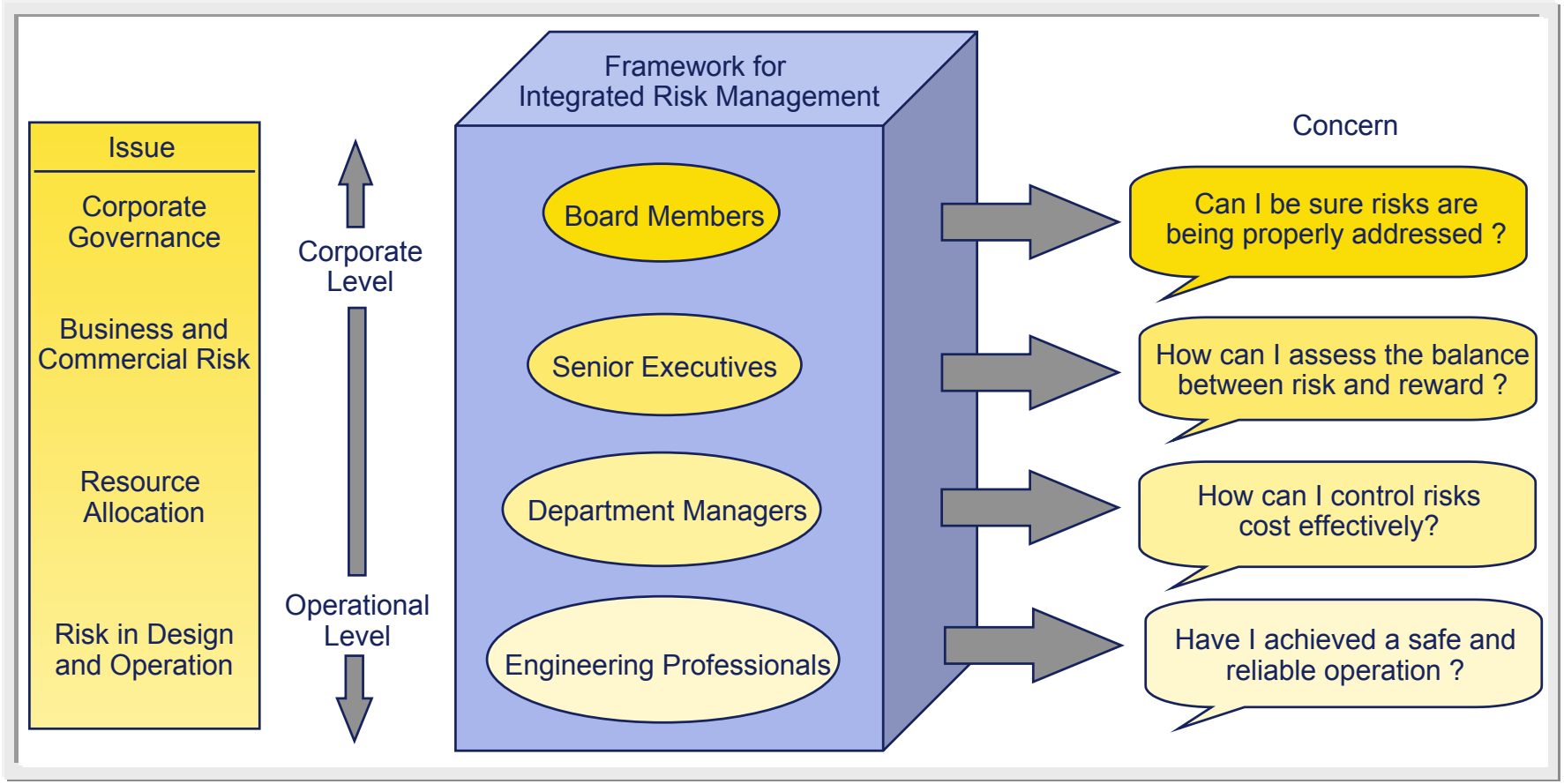
4.1	1	2	3	4	5
4.2	1	2	3	4	5
4.3	1	2	3	4	5
4.4	1	2	3	4	5
4.5	1	2	3	4	5
4	1	2	3	4	5

Contents

The HAZOP approach is a very well established and respected technique which has been successfully applied to many different types of system

- The method was developed in the Chemical Industry for examination of process plant design and operation but has been widely applied elsewhere
- The method works with any diagrammatic representation of a system. In the original application these were Piping & Instrumentation Diagrams but the method is equally effective with information flow diagrams for software, one line diagrams for power distribution or task diagrams for operating manuals
- Because the method is structured when properly conducted it provides assurance of a comprehensive hazard identification
- The method uses a team which shares its professional experience. It is less vulnerable to oversight than other methods where individuals work alone
- It readily forms part of an overall Risk Management approach incorporating hazard identification, risk assessment and loss control

The HAZOP process is able to address a variety of issues of concern at different levels of a company within a common framework



Despite its strengths there are a number of characteristics which can become a problem in certain circumstances

- HAZOP is expensive. It takes time and requires the undisturbed concentration of key personnel involved in plant operation. These people are often in demand for other tasks
- The HAZOP approach requires completeness of system description. This means the diagrams and other documentation must be fully available to the team and up to date. If they are not the process is greatly devalued
- HAZOP is effective only where the participants are experienced and work openly and in harmony. It is unsatisfactory if the team includes:
  - Trainees with little idea of the plant or its basis of operation
  - Contracts people or lawyers using the process in relation to a dispute
  - An inexperienced leader unable to guide the group effectively
- HAZOP is not a substitute for design review. It works to examine a given design but often goes astray when the team tries to redesign the plant

HAZOP is not an approach which you can 'outsource' entirely .The quality of the internal resources you devote is a critical factor for success

- Some managers imagine they can 'get a consultant in' to do a HAZOP. This is not the case
- The leader and recorder may be from an outside firm (if, for example, you lack sufficient in-house experience of HAZOP) but the main resource must come from your own staff with first hand experience of the system under review
- HAZOP requires your experts to participate. The leader may bring experience but it is not his job to provide all the answers and recommendations. A team comprising trainees is unlikely to conduct a thorough or worthwhile HAZOP
- HAZOP requires open flow of information. If there are issues of confidentiality these should be settled by appropriate agreement before the team meeting
- HAZOP requires an honest admission of the potential for loss. In some legal environments, counsel may advise, for example, that the possibility of fatal injury should not be admitted. HAZOP cannot proceed on this basis

The fact of completing a HAZOP in itself does little to improve safety or performance

- Some managers imagine they can ‘tick the box - HAZOP completed’ and in this way satisfy code or regulatory requirements. This is not the case
- Essential to the HAZOP is the follow-up. Each of the recommendations made by the team requires action. This means:
  - The action must be allocated to someone or some group with the resources to take it forward. For example, few HAZOP recommendations are likely to be implemented solely within the existing budget of the operations manager
  - A register of risks and control actions is useful as a way of monitoring progress. This register starts with the HAZOP recommendations and shows who has been allocated the action, when it is due, and records for audit any added risk controls which have been implemented

The best results are not always achieved by HAZOP. Other approaches to hazard identification may be just as effective in given circumstances

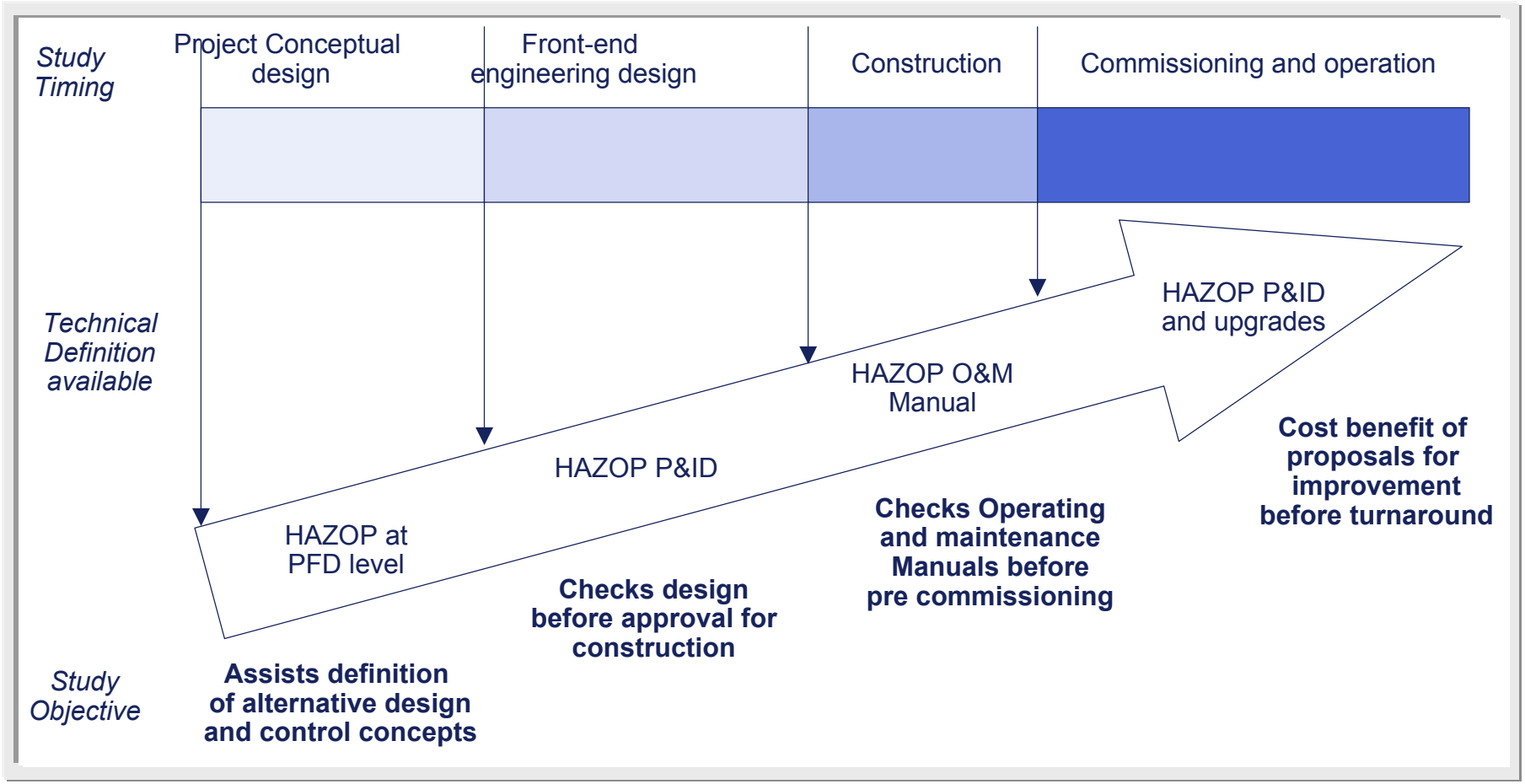
- Design Review is the process of P&ID review and consideration of alternative designs is an important but separate activity
- The simplest method of hazard identification uses a checklist of hazards typically in the form of a tabulated series of questions or issues. This approach can work for simple or familiar situations if the checklist is comprehensive
- Workshop approaches to hazard identification typically use a brainstorming technique starting from hazards known to participants. This works well if there is good facilitation, it is shorter than a HAZOP but is less systematic
- A Failure Mode and Effect Analysis (FMEA) provides an item by item listing of the ways in which each item in a system can fail, the likelihood and the effect if it does fail. The approach works well for electro-mechanical systems

The manager contemplating commissioning a HAZOP should consider if one of these alternatives is more appropriate to the issue at hand

HAZOP is a technique best applied infrequently to a system, at major points in the facility lifecycle

- Because it is expensive, HAZOP offers value when focussed on crucial points in a project life-cycle:
  - When the design is fixed and P&IDs are ready for 'approval for construction'
  - Prior to major plant modification when the design is fixed but not approved
  - At major plant turnaround to support investment and engineering planning
- HAZOP may also be appropriate at other times, for example, decommissioning when special procedures or special risks are experienced.The HAZOP procedure is flexible and can be adapted to project phases
- There is little value in commissioning another HAZOP on a plant a few years after one was completed especially if there has been little change in operating procedures or plant configuration
- It is especially demoralising if a HAZOP is repeated when there has been little or no follow-up to the recommendations in the earlier study

In a phased approach to HAZOP, the technique is adapted to different objectives and the scope of technical definition available at the time



The HAZOP method works with many different types of system, not just those concerned with process flow

- Although we are focusing on a HAZOP for a refinery plant it is useful to recognise that the approach works equally well in other contexts

Topic of study	Typical Diagram	Parameter Type
Power Distribution and Switchgear	One line Diagram	Electrical
Safety Critical Software	Information Flow Chart	Data
Electro-pneumatic Equipment	Electrical and Pneumatic Circuit	Electro Mechanical
Operations Manual	Hierarchical task Analysis	Human Action

- It is essential for the HAZOP that the documentation gives a complete description of the way the system is supposed to work
- The documentation must provide adequate definition of interface conditions. Often hazards arise from inconsistencies across battery limits

Whatever the system, the form of documentation chosen for the HAZOP has a subtle influence on the focus of attention of the team members

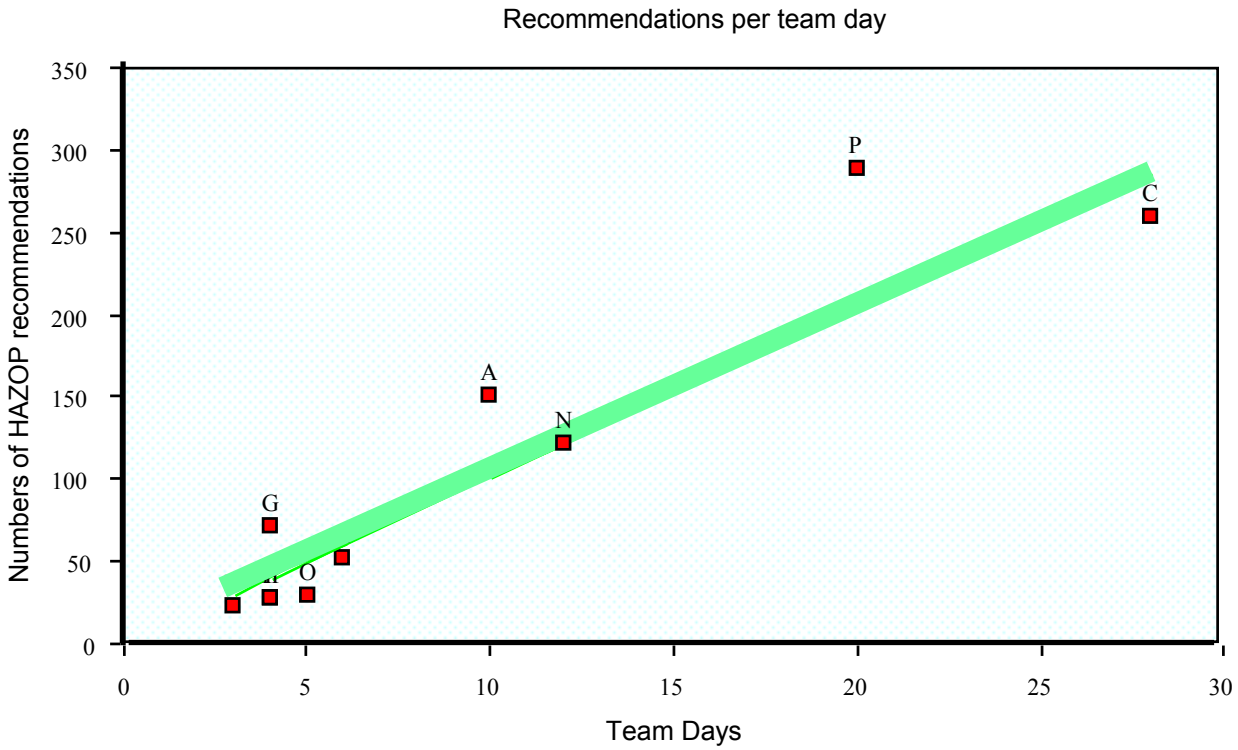
- Technical drawings of the facility such as Piping and Instrumentation Diagrams (P&ID) focus attention on the process design of the plant. This may be appropriate if the plant is under construction and the owners seek assurance that the design is safe and reliable to operate
- General arrangement drawings, one line drawings and so forth draw attention to the components of the system and may be suitable for an approach which is more like a Failure Mode and Effect analysis carried out as part of a system availability study.
- Operating or Emergency Manuals can also be used for HAZOP studies and the team concentrates then on human errors and their consequences in the operation of the system
- Whoever organises the study, needs to consider the main focus - for example is it design or human performance? - and to choose a documentary basis which is most appropriate

If the intention is to focus on human error, the HAZOP approach can help to identify how operating procedures and equipment design can be improved

- The HAZOP method is used to identify deviations from intent and in the case of human error this means deviations from the intended mode of operation
- A diagrammatic representation of the intended mode of operation involves showing the sequence of tasks necessary to carry out the operation in question. One option is a Hierarchical Task Analysis (HTA) diagram
- The HTA diagram is drawn by analysis of the description of each operation in the operating manual and should show the full sequence of activities. It will need to be supplemented by supporting data such as layout panels, mimic diagrams, isometrics which provide the details of the control arrangements
- HAZOP proceeds in the same way as for a conventional process system but the guidewords are different because the intention is to focus on operator actions

Those sponsoring a HAZOP study should take into account the large amount of work involved in implementing the main findings

- The following graph illustrates the relationship between numbers of recommendations and study duration in past work



The aim of assessment is to focus resources on key recommendations

Activity Name and Identification number	3.4 Assess the HAZOP recommendations	Essential ☐
Activity Description:	The team reassembles to assess the impact of the HAZOP recommendations	Useful ☐
Objective of Activity	Determination of the critical recommendations	Optional ☒

How to conduct the Activity

1. The leader explains matrix ranking to the HAZOP team
2. The team reviews each recommendation considering how likely the hazard is to occur and what loss might be incurred if it does
3. The assessments are made using a range in a matrix based on the experience of the team.
4. The HAZOP leader and Recorder facilitate the process by reference to other study information they have such as Fault Trees for frequency and QRA studies for consequence

What to avoid during this Activity

1. Hurrying the introduction and explanation of the method. Team members need to accept it before they can make effective use of the approach
2. Unreasonable estimates of frequency or consequence (but step 3.5 provides a cross check)
3. Avoid treating the assessment as integral to the HAZOP. It is an option as far as HAZOP technique is concerned (but adds great value)

Assessment can be a low cost and effective HAZOP team activity which gets participants to share views on risks and their management

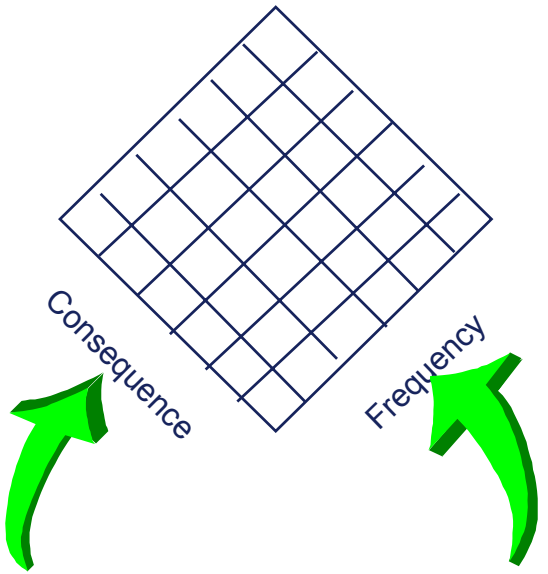
The Team has formed two groups each with their own PC with independent evaluations

The team is engaged in active debate on a ranking issue

Each hazard identified during the HAZOP can be assessed according to the frequency and consequence should the risk occur

The assessment can be done off line
as an extra to the HAZOP proceedings

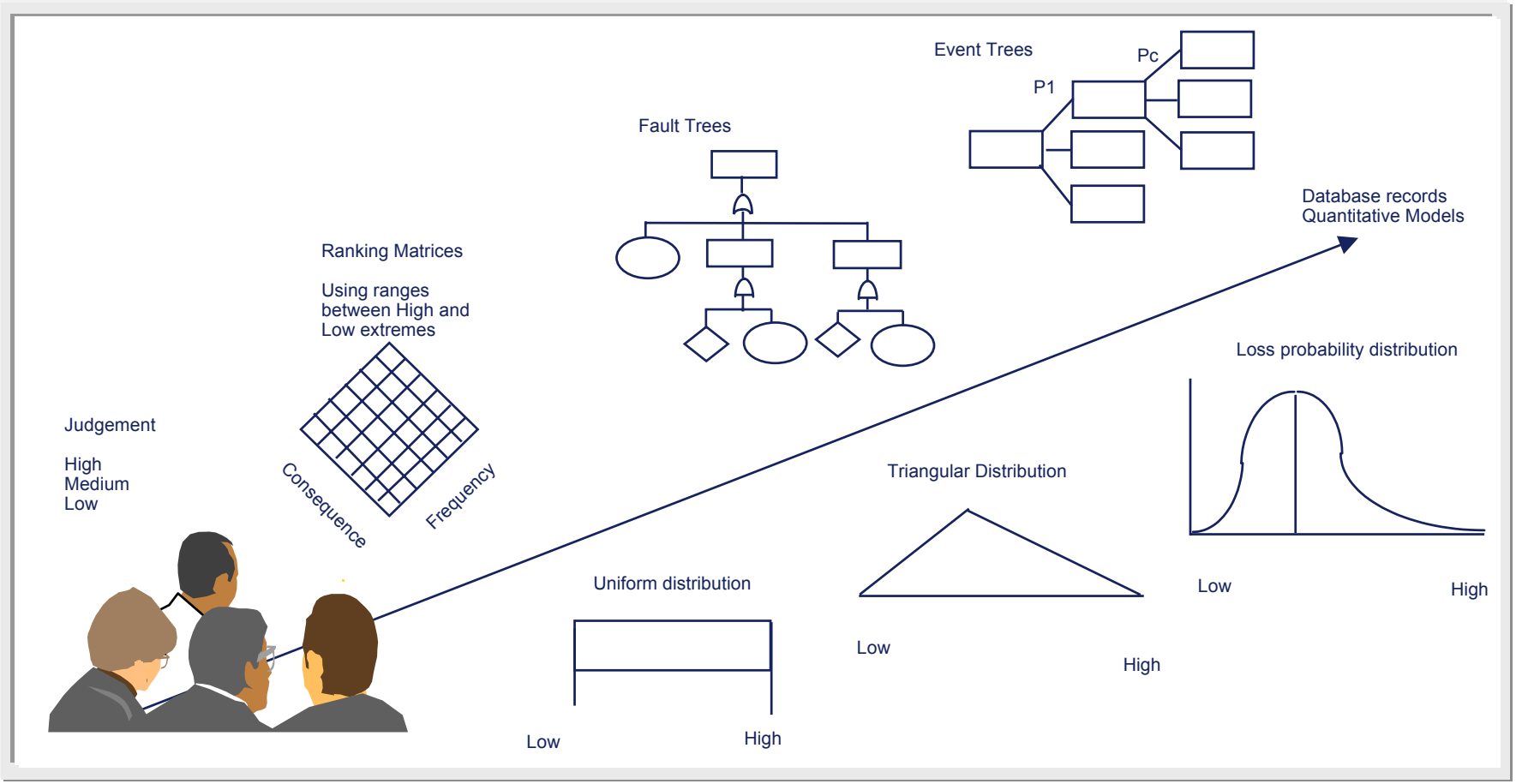
The output can be put into a matrix of
Frequency and
Consequence
where each range is quantified



Range of Loss per event

How often events occur

The assessment done after the HAZOP is preliminary and the approach can be supplemented later by more sophisticated quantified risk analysis



A better assessment can be obtained using matrices to indicate ranges of frequency, probability and consequence

Risk = Stage 1 (Typical size of Loss) X Stage 2 (Frequency of Failure) X Stage 3 (Probability of Loss)

	Stage 1: Typical size of Loss
1.	< $50K
2.	$50K to $ 250 K
3.	$250 K - 1 million
4.	$1 - 10 million
5.	> $10 million

	Stage 2: Frequency of Failure
1.	< Once in 5 yr.
2.	Once in 3 - 5 yr.
3.	Once in 1 - 3 yr.
4.	One failure a year
5.	Several failures a year

	Stage 3: Probability of Loss
1.	< 1 in 100
2.	1 in 100 to 1 in 10
3.	1 in 10 to 1 in 3
4.	0.3 - 0.6
5.	> 0.6

The "top event" which could be derived using a Fault Tree

Probability which could be derived using an event tree

The assessment can be cross-checked against Industry Loss Profiles

Activity Name and Identification number	3.5 Cross check against Industry Loss Profile	Essential ☐
Activity Description:	The ranking of Recommendations is used to generate a Plant Loss profile before recommendations are implemented and compared to industry losses	Useful ☐
Objective of Activity	Ensuring a balanced risk assessment	Optional X

How to conduct the Activity

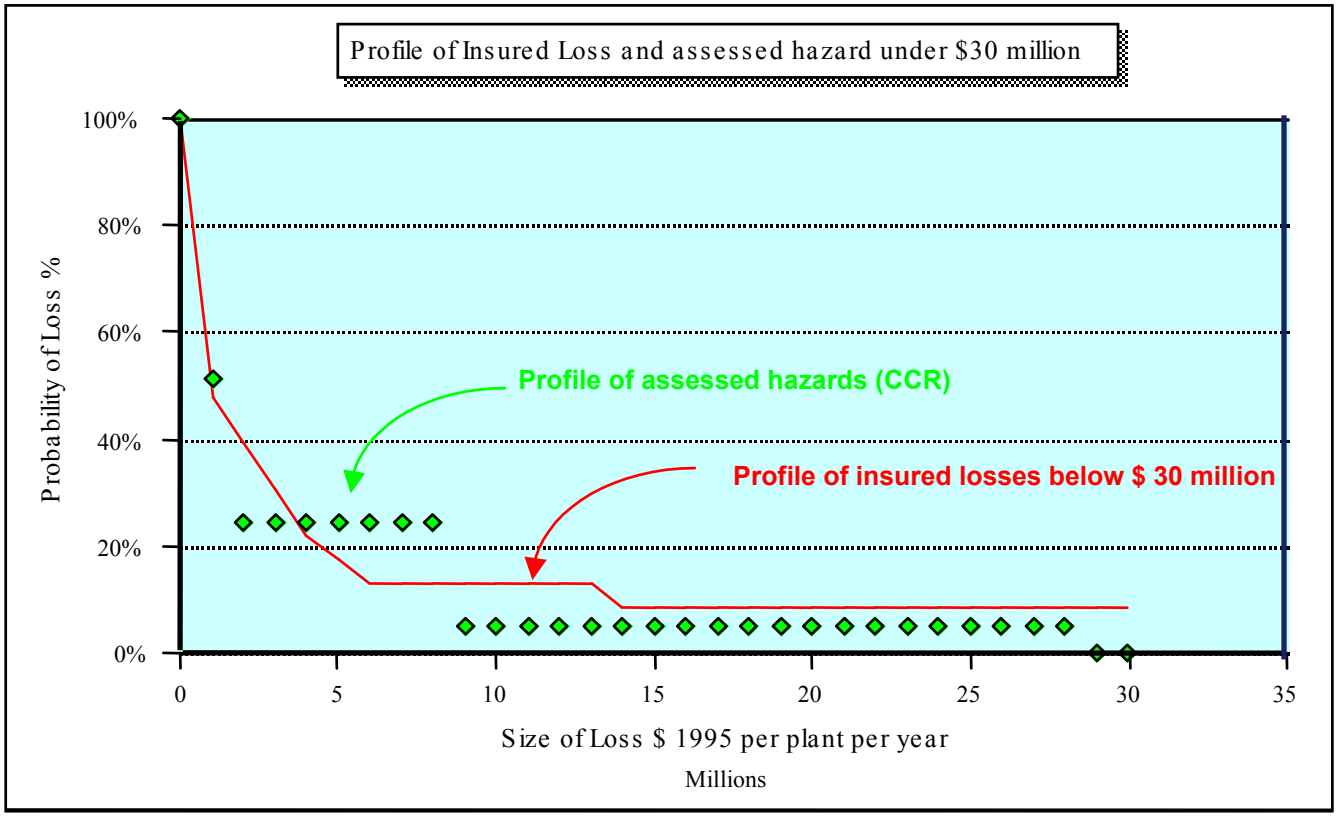
1. The leader or recorder, depending on their skills at Monte Carlo simulation, uses the risk assessment made by the HAZOP team to estimate the profile of loss from the plant before modification
2. The assessment is adjusted for insurance deductible and is adjusted to include only insured loss
3. The profile of loss from the plant which has been studied is compared to the average loss profile expected on the basis of known Loss History from the type of plant being studied
4. If the assessment has been soundly based, the estimated profile from the plant which has been studied will be broadly similar to the industry average but may be higher or lower depending on whether the plant is industry top quartile or not.

What to avoid during this Activity

1. Avoid spending a long time on this activity building complex models or indulging in intricate data manipulation. The aim is a cross check
2. While all losses affect the business, the cross check data from insurance sources will only be for allowed claims under the policy
3. Avoid dramatic differences between the industry loss profile and the assessed profile unless there is a specific and exceptional reason
4. Avoid basing decision making on a risk assessment which cannot be cross-checked

The ranges of potential loss assessed by the HAZOP team are compared with the historic record of losses on similar plant

- The curve (showing the profile for insured losses from reforming plant) follows the assessment of recommendations on the CCR



Forms are used for tabulating recommendations according to risk aversion

Safety Related Reccommendations

No.	Issue	Recommendation	Before Recommendation				After Recommendation				
			Severity	Likelihood	Risk Rank	Risk Matrix	Severity	Likelihood	Risk Rank	Risk Matrix	d RM
105	33	R952.5: Connect PSVs to Blow down and increase reliability of LT. Use one LT from control of Lv 1203 and a second independent LT for LAL. Consider variance alarm to give further warning of irregularity	5	4	20	Intolerable	1	4	4	Minor	16
122	33	R1040.2: Install silencers on PSVs or ear protection required for operators working near PSVs	5	3	15	Significant	2	3	6	Minor	9
125	33	R 1061.2 If vent close to platform then install noise suppression to PSV.	5	3	15	Significant	2	3	6	Minor	9
23	29	R214.1: Consider if emergency blowdown system is desirable	4	3	12	Moderate	4	1	4	Minor	8
107	29	R954.1:Install check valve on inlet to column or MOV or Blow Down protection for the column	4	3	12	Moderate	4	1	4	Minor	8
109	29	R954.3: Agip to discuss alternatives available for shut down systems in an emergency	4	3	12	Moderate	4	1	4	Minor	8
8	34	R65.2 To avoid problem when have two PSVs offset one PSV by .5 bar,	3	3	9	Moderate	3	1	3	Negligible	6

Benefit cost ratios can be used to prioritise recommendations

Activity Name and Identification number	3.6 Ranking of recommendations by benefit cost ratio	Essential ☐
Activity Description:	A comparison is made between the risk reduction offered by each recommendation and the costs of implementation	Useful ☐
Objective of Activity	Prioritising management attention on the higher benefit cost recommendations	Optional ☒

How to conduct the Activity

1. The assessment of risk before and after the recommendations are tabulated in a risk register
2. The cost of implementation of the recommendation is also assessed
3. Recommendations are tabulated according to the risk reduction they offer and the benefit-cost ratio
4. The tabulations and a discussion of the interpretation is prepared for inclusion in the HAZOP report

What to avoid during this Activity

1. Avoid making a separate register entry for each recommendation. Cluster similar recommendations in process issues and record these
2. Avoid undue pretence at estimating accuracy… if the costs are then the benefit-cost ratio will have a corresponding high uncertainty
3. Avoid an overly mechanistic interpretation… the programme of upgrading must be coherent with company design standards and policy

Typical tabulation ranking recommendations by benefit – cost ratio

HAZOP Issue	Incident Description	Safety Benefit	Property and BI Benefit	Performance Benefit	Total Benefit	Cost of Implementation	Benefit Cost Ratio	Total Saving
34	PSV mechanical arrangements	L. 4,154,048	L. 131,622,814	L. 0	L. 135,776,862	L. 11,180,340	12.14	L. 124,596,522
40	Protection against seal failure	L. 0	L. 13,012,141	L. 0	L. 13,012,141	L. 2,236,068	5.82	L. 10,776,073
23	Materials selection	L. 0	L. 13,012,141	L. 0	L. 13,012,141	L. 2,236,068	5.82	L. 10,776,073
8	Making OM a better basis for safe operation	L. 9,675,780	L. 1,366,002	L. 0	L. 11,041,782	L. 2,236,068	4.94	L. 8,805,714
30	Positive isolation of utilities	L. 8,308,096	L. 1,301,214	L. 0	L. 9,609,310	L. 2,236,068	4.30	L. 7,373,242
33	Discharge from PSV	L. 1,287,542	L. 192,668,726	L. 0	L. 193,956,268	L. 50,000,000	3.88	L. 143,956,268
38	Autostart provisions	L. 0	L. 7,742,209	L. 520,670	L. 8,262,880	L. 2,236,068	3.70	L. 6,026,812
50	Improvements to pilot light	L. 0	L. 8,105,184	L. 0	L. 8,105,184	L. 2,236,068	3.62	L. 5,869,116
31	PSV design case and setting	L. 0	L. 38,225,538	L. 0	L. 38,225,538	L. 11,180,340	3.42	L. 27,045,198
27	Emmision reduction	L. 0	L. 6,743,572	L. 497,491	L. 7,241,063	L. 2,236,068	3.24	L. 5,004,995
29	Emergency blowdown systems	L. 12,351	L. 36,173,495	L. 0	L. 36,185,846	L. 11,180,340	3.24	L. 25,005,506
10	Improvement to reliability of equipment	L. 0	L. 33,430,800	L. 0	L. 33,430,800	L. 11,180,340	2.99	L. 22,250,460
17	Problems with small bore tubing	L. 0	L. 6,376,541	L. 0	L. 6,376,541	L. 2,236,068	2.85	L. 4,140,473
53	Protection against tube rupture in heat exchangers	L. 0	L. 6,374,621	L. 0	L. 6,374,621	L. 2,236,068	2.85	L. 4,138,553
69	Inappropriate failure modes	L. 0	L. 5,207,846	L. 0	L. 5,207,846	L. 2,236,068	2.33	L. 2,971,778
28	Isolation of large,toxic or flammable inventories	L. 0	L. 3,970,606	L. 0	L. 3,970,606	L. 2,236,068	1.78	L. 1,734,538
11	Improvements to maintenance of plant items of equipment	L. 0	L. 3,296,096	L. 47,513	L. 3,343,610	L. 2,236,068	1.50	L. 1,107,542
51	Tube rupture:Fin Fans	L. 0	L. 3,291,840	L. 0	L. 3,291,840	L. 2,236,068	1.47	L. 1,055,772
36	Protection against low flow	L. 0	L. 13,575,320	L. 0	L. 13,575,320	L. 11,180,340	1.21	L. 2,394,980
41	Additional trip protection	L. 0	L. 13,012,141	L. 0	L. 13,012,141	L. 11,180,340	1.16	L. 1,831,801
42	Protection against other relases	L. 0	L. 13,012,141	L. 0	L. 13,012,141	L. 11,180,340	1.16	L. 1,831,801
Totals		L. 23,437,816	L. 551,520,991	L. 1,065,674	L. 576,024,481	L. 157,331,263		L. 418,693,218

It is essential to implement HAZOP recommendations

Activity Name and Identification number:	3.8 Follow up HAZOP recommendation	**Essential**	X
Activity Description:	Appointed PE staff execute and monitor the implementation of HAZOP recommendations	**Useful**	
Objective of Activity:	Ensuring that all HAZOP recommendations are implemented according to plan	**Optional**	

How to conduct the Activity

1. Convert the recommendations in action plans, specifying for each one:
   - description of action
   - resources required (both human and financial)
   - PE staff in charge of implementation and verification
   - Schedule for implementation

2 Obtain approval of action plans from management

3. Train (when required) and communicate actions taken to operating, maintenance and other employees who may be affected by the actions

4. Retain documentation of the recommendations, action plans, schedule for implementation, status of action, training and communication for the life of the process

What to avoid during this Activity

1. Avoid writing action plans which are generic, vague and open to interpretation
   Don't create dangerous precedents by allowing start-up of plant to go ahead before all HAZOP recommendations have been resolved

A Risk Register assists the monitoring of progress to implementation

ID Number	Issue	Revision	G						
23	33	Date	22-Apr-99						
Issue		Discharge from PSV							
Cause		PSV on debutaniser not connected to blowdown. If failure of level control liquid could be released							
		6 HAZOP items eg 952.5							
Consequence		Potential for ignition of falling liquid and development of large fire							
Recommendation		Connect PSV on debutaniser to flare This is considered an intolerable risk							
Implementation					Action Summary				
Asigned to			Date Due						
			Date Done						
Verified by			Date Verified						
Assessment Notes		Frequency 1 in 100 years - requires loss of level control							
		Probability low -operator likely to detect problem							
		Consequence could be catastrophic in crowded process area							
Before/After Implement		Frequency	Probability	Consequence	Frequency	Probability	Consequence	Plant Benefit	Industry Benefit
Human Safety		1	3	4	1	1	4	1287541.675	540767503.4
Property Loss		3	3	5	3	3	1	96823465.62	40665855561
Business Interruption		3	3	5	3	3	1	95845260.38	40255009359
Catalyst life								0	0
Energy								0	0
Product Losses								0	0
Plant Utilisation								0	0
Plant Maintenance								0	0
Publicity									
Environmental Impact									
Cost of implementation		Total Benefit	Benefit/Cost	Total Saving					
3	50000000	193956267.7	3.88	143956267.7					

Imagine you receive the following memorandum

From the Plant Safety Manager:…..

‘Following the recent serious accident at Misfortune Pit, the Works Director has instructed me to ensure that similar plant in our facility are safe.

I propose we do this by conducting a HAZOP study.

You have been selected to lead the team.

Please make the necessary arrangements to start on Monday of next week with a view to reporting to management at the latest by the end of the week.

The plant is currently preparing for annual turnaround so it is important that undue demands are not made on operations during this busy time. Technical Department has also expressed concerns about the condition of the P&IDs but I am confident that by liaising with them you will be able to make progress with this urgent request.

It is imperative that the Director is able to provide the necessary assurances at the Main Board meeting scheduled in three weeks time.’

Please describe the actions you would take on receipt of the memorandum

- What are the main difficulties?
  - Our plant is not exactly the same as the one at Misfortune Pit.
  - HAZOP is the wrong technique for their needs.
  - I booked leave that day… I can't do it.
- Which parts of preparation for a HAZOP are unlikely to be followed:
  - Issuing the meeting notes
  - Preparing the nodes
  - Getting the P&IDs ready for HAZOP
- If a " what if " study based on a brainstorm workshop were proposed
- what would be your main concern?
  - Missing some sources of risk
  - Method has no formally recognised status
  - Not part of an overall approach to Risk Management