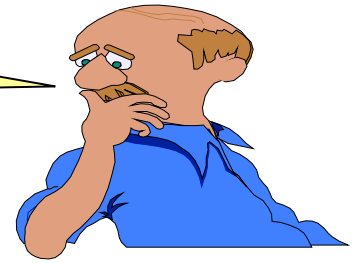
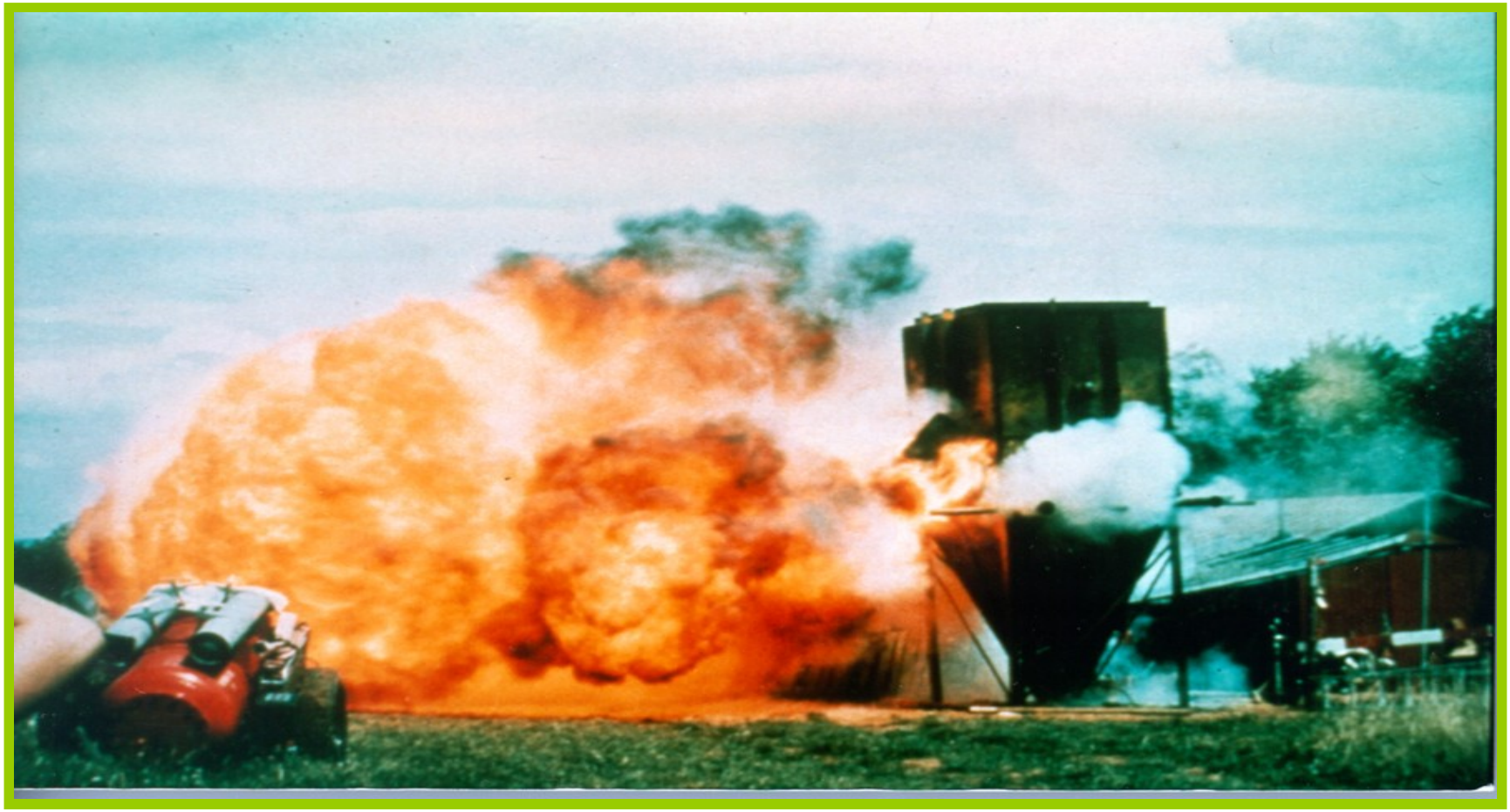
Hazard and Operability Study (HAZOP)

I suppose that I should have done that HAZOP Study!





Introduction to HAZOP - Content

- What is a HAZOP Study?
- Origin of HAZOP study
- Objectives of a HAZOP Study
- When to Perform a HAZOP Study
- Benefits of HAZOP Study
- Overall HAZOP Methodology
- A Conceptual Example of HAZOP Study
- HAZOP Terminologies
- References

A scenario…

You and your family are on a road trip by using a car in the middle of the night. You were replying a text message while driving at 100 km/h and it was raining heavily. The car hits a deep hole and one of your tire blows.

You hit the brake, but due to slippery road and your car tire thread was thin, the car skidded and was thrown off the road.

Points to ponder

What was the cause of the accident?

What was the consequence of the event?

What can we do to prevent all those things to happen in the first place?

What other possible accidents might happen on the road trip?

Can we be prepared before the accident occurs?

Can we make it more systematic?

Parameter	Guideword	Possible Causes	Consequences	Action	Safeguard
Car speed	Too fast Too slow	Rushing	Skidded when emergency brake	- Slow down - Speed up	-ABS brake system -Safety belt - Air bag
Tire	No thread Less thread	Tire too old, often speeding and emergency break	Car skidded		- Check frequently - Have spare tire
Window visibility	Low Very low	Rain	Cannot see the road		
Car light	Dim No light			-Stop car -Go to nearest garage -Use emergency signal	
Road	With holes Rocky		Breaks the car tire		- Put a signboard -Street lights
Travel time	Night Foggy	No street light			-Travel during daylight

What is a HAZOP study?

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

What is a HAZOP study?

- A HAZOP study is an examination procedure.
- Its purpose is to identify all possible deviation from the way in which a design is expected to work and to identify all the hazards associated with these deviations.
- When deviation arise that results in hazards, action are generated that require design engineers to review and suggest solutions to remove the hazard or to reduce its risk to an acceptable level.

Origin of HAZOP study

- HAZOP were initially 'invented' by ICI in the United Kingdom, but the technique only started to be more widely used within the chemical process industry after the Flixborough disaster in 1974.
- This chemical plant explosion killed twenty eight people and injured scores of others, many of those being members of the public living nearby.
- Through the general exchange of ideas and personnel, the system was then adopted by the petroleum industry, which has a similar potential for major disasters.
- This was then followed by the food and water industries, where the hazard potential is as great, but of a different nature, the concerns being more to do with contamination rather than explosions or chemical releases.

Potential Hazard AND Operability Problems

Why the big AND ?

Potential Hazard AND Operability Problems

Because of the high profile of production plant accidents, emphasis is too often placed upon the identification of hazards to the neglect of potential operability problems.

Yet it is in the latter area that benefits of a HAZOP Study are usually the greatest.

Example

- A study was commissioned for a new plant.
- Some two years previously, and for the first time, a similar study had been carried out on different plant at the same site which was then in the process of being designed.
- Before the latest review commenced, the Production Manager expressed the hope that the same benefits would accrue as before, stating that

"In his twenty years of experience, never had a new plant been commissioned with so few problems, and no other plant had ever achieved its production targets and break-even position in so short a time".

Objectives of a HAZOP study

Safety Issues:

- **To identify scenarios that would lead to the release of hazardous or flammable material into the atmosphere, thus exposing workers to injury**
- **To check the safety of the design**
- **To improve the safety of an existing and or modified facility**

Operability Issues:

- **To decide whether and where to build**
- **To check operating and safety procedures**
- **To verify that safety instrumentation is working optimally**
- **To facilitate smooth, safe prompt start-up**
- **To minimize extensive last minute modifications**
- **To ensure trouble-free long-term operation**

"Prevention is better than control"

Philosophy – Hazard vs Operability

- HAZOPs concentrate on identifying both hazards as well as operability problems. While the HAZOP study is designed to identify hazards through a systematic approach, more than 80% of study recommendations are operability problems and are not, of themselves, hazards.
- Although hazard identification is the main focus, operability problems should be identified to the extent that they have the potential to lead to process hazards, result in an environmental violation or have a negative impact on profitability.

Definition of Hazard & Operability

- **Hazard** - any operation that could possibly cause a catastrophic release of toxic, flammable or explosive chemicals or any action that could result in injury to personnel.
- **Operability** - any operation inside the design envelope that would cause a shutdown that could possibly lead to a violation of environmental, health or safety regulations or negatively impact profitability.

Benefits

- **The circumstances when HAZOPs are likely to produce benefits are:**
  - **during the design or installation of any new plant or process, or major modification to an existing one;**
  - **when there are unique hazards such as environmental hazards and quality or cost issues associated with the operation;**
  - **following a major incident involving fire, explosion, toxic release etc; and**
  - **to justify why a particular code of practice, guidance note or industry code is not to be followed.**

When should a HAZOP be held

- During various stages of plant design
  - At the beginning of the project as a ‘safety and environmental specification’
  - Towards the end of process definition, when the Process Flow sheets are available as a Safety and Environmental Review
  - When P&IDs are at ‘Approved for Design’ stage (Final design HAZOP)
- During construction site inspections ensure that recommendations arising from the HAZOP or other safety and environmental reviews are being implemented.
- A pre-commissioning study reviews plant procedures and perform a conventional safety audit
- Once operational, an audit of plant and procedures at regular interval ensures ongoing safety awareness

HAZOP study of existing plant

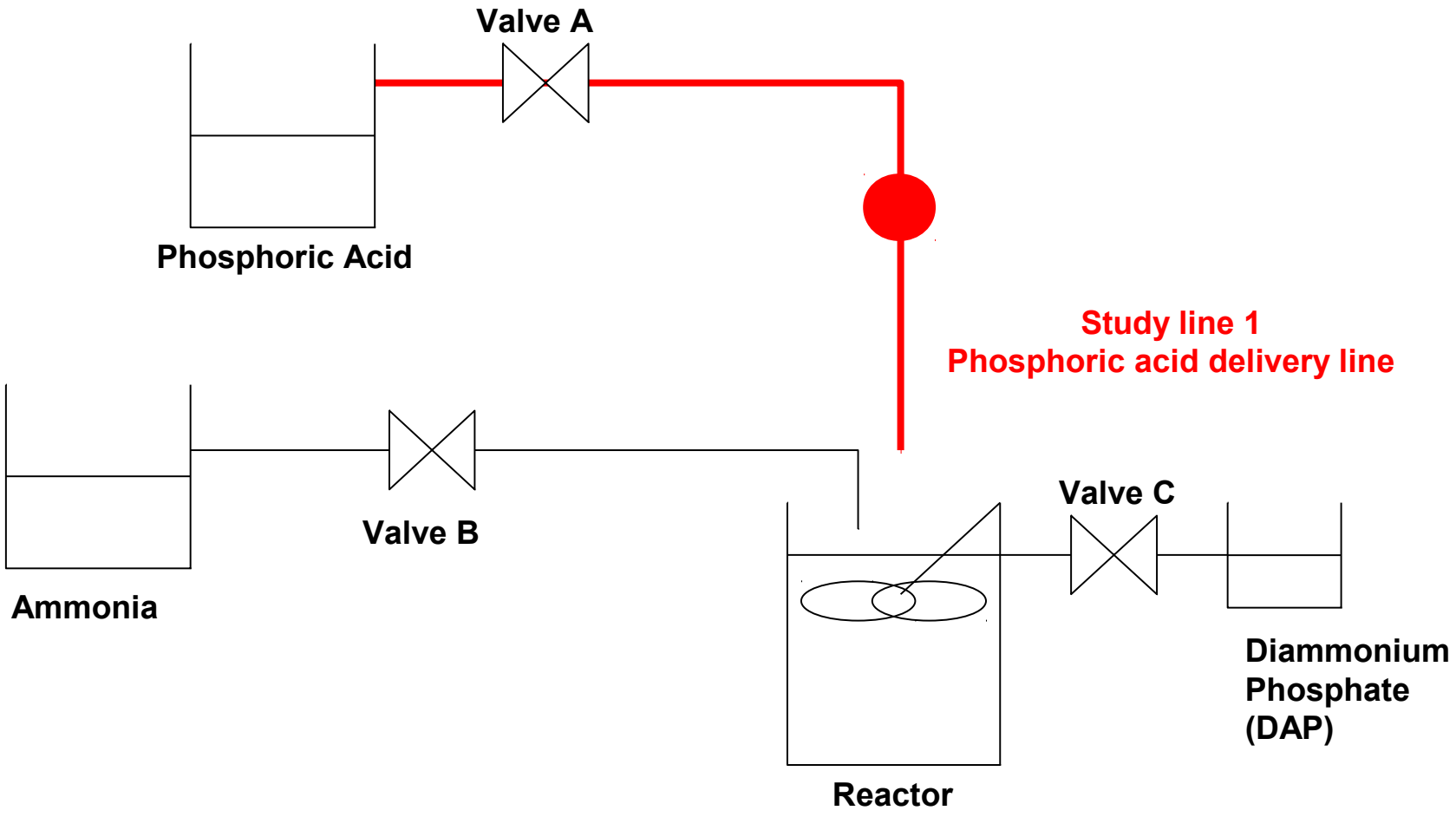
- Can be done at any time
- Mainly used to improve operating procedures or when modifying plant
- Sometimes used to identify possible improvements in plants where accident or incident rate is abnormally high
- Can be used in conjunction with plant safety audits
- Needs exceptional care to fully define the scope and aims of the study
- Despite detailed operation knowledge, much of the original design intent is often unknown

Simple Example of a HAZOP Study

Diammonium Phosphate (DAP) Production

- **Phosphoric acid and ammonia are mixed, and a non-hazardous product, diammonium phosphate (DAP), results if the reaction of ammonia is complete. If too little phosphoric acid is added, the reaction is incomplete, and ammonia is produced. Too little ammonia available to the reactor results in a safe but undesirable product.**
- **Both chemicals will be used in large quantities and in concentrated form. Due to the highly corrosive nature of both chemicals, the project team was assigned to investigate the hazards posed to staff from the reaction resulting from study line 1 (phosphoric acid delivery line).**

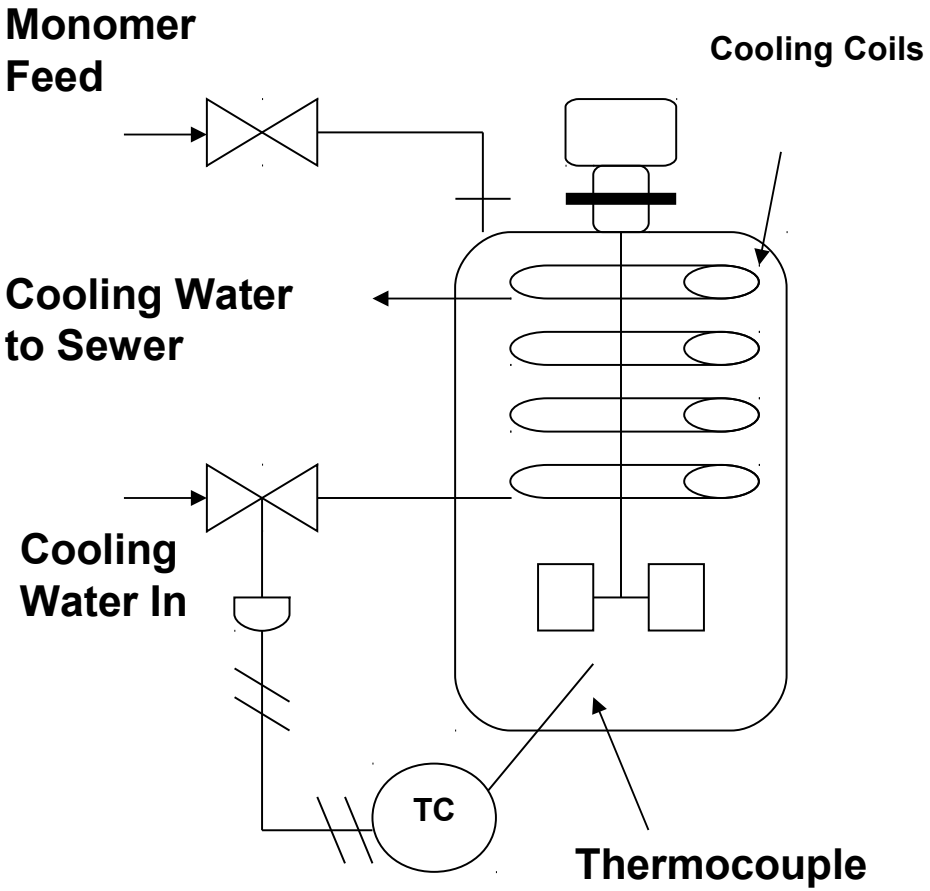
Production of DAP (continuous process)



HAZOP Study Report on line 1 of DAP

HAZOP STUDY RECORD SHEET			PROJECT: AMMONIA PLANT			DATE: DD/MM/YY	
SYSTEM: DAP PRODUCTION PROCESS PARAMETER: FLOW (Primary keyword) LINE: STUDY LINE 1			PRESENT: HAZOP TEAM MEMBER LIST CHAIRED: HAZOP LEADER SECRETARY: TEAM MEMBER			PAGE: 1 TOTAL PAGES:1	
NO.	GUIDE WORD	DEVIATION	CONSEQUENCES	POSSIBLE CAUSES	ACTION REQUIRED	PERSON	DONE (sign off)
1	NO	NO FLOW	Excess ammonia in reactor and release to work area.	• Valve A fails closed. • Phosphoric acid supply exhausted. • Pipe ruptures	Automatic closure of valve B on loss of flow from phosphoric acid supply.		
2	LESS	LESS FLOW	Excess ammonia in reactor and release to work area. With amount released related to quantitative reduction in supply. Team member to calculate toxicity vs flow reduction.	• Valve a partially closed. • Partial plug or leak in pipe.	Team member to calculate toxicity vs flow reduction. Set point determined by toxicity vs flow calculation. Automatic closure of valve to reduce flow from phosphoric acid supply.		
3	MORE	MORE FLOW	Excess phosphoric acid degrades product. No hazard to work area.				
4	PART OF	Normal flow of decreased concentration of phosphoric acid.	Excess ammonia in reactor. release to work area, with amount released related to quantitative reduction in supply.	• Vendor delivers wrong material or concentration. • Error in charging phosphoric acid supply tank.	Check phosphoric acid supply tank concentration after charging.		
5	OTHER THAN	Material flow other than phosphoric acid in Line A.	Depends on substitution. Team member assigned to test availability of other materials.	• Wrong delivery from vendor. • Wrong material chosen.	Plant procedures to provide check on material chosen before charging phosphoric acid supply tank.		

Preliminary HAZOP Example



Refer to reactor system shown.

The reaction is exothermic. A cooling system is provided to remove the excess energy of reaction. In the event of cooling function is lost, the temperature of reactor would increase. This would lead to an increase in reaction rate leading to additional energy release.

The result could be a runaway reaction with pressures exceeding the bursting pressure of the reactor. The temperature within the reactor is measured and is used to control the cooling water flow rate by a valve.

Perform HAZOP Study

Preliminary HAZOP on Reactor - Example

Guide Word	Deviation	Causes	Consequences	Action
NO	No cooling		Temperature increase in reactor	
REVERSE	Reverse cooling flow	Failure of water source resulting in backward flow		
MORE	More cooling flow			Instruct operators on procedures
AS WELL AS	Reactor product in coils			Check maintenance procedures and schedules
OTHER THAN	Another material besides cooling water	Water source contaminated		

Preliminary HAZOP on Reactor – Answer

Guide Word	Deviation	Causes	Consequences	Action
NO	No cooling	Cooling water valve malfunction	Temperature increase in reactor	Install high temperature alarm (TAH)
REVERSE	Reverse cooling flow	Failure of water source resulting in backward flow	Less cooling, possible runaway reaction	Install check valve
MORE	More cooling flow	Control valve failure, operator fails to take action on alarm	Too much cooling, reactor cool	Instruct operators on procedures
AS WELL AS	Reactor product in coils	More pressure in reactor	Off-spec product	Check maintenance procedures and schedules
OTHER THAN	Another material besides cooling water	Water source contaminated	May be cooling inefffective and effect on the reaction	If less cooling, TAH will detect. If detected, isolate water source. Back up water source?

HAZOP – The Critical Success Factor

- The HAZOP process is based on the principle that a team approach to hazard analysis will identify more problems than when individuals working separately combine results. The HAZOP
- team is made up of individuals with varying backgrounds and expertise.
- The expertise is brought together during HAZOP sessions and through a collective brainstorming effort that stimulates creativity and new ideas, a thorough review of the process under consideration is made.

HAZOP Terminology - 1

Term	Definition
Cause	**The reason(s) why the DEVIATION could occur. More CAUSES can be identified for one DEVIATION.**
Comments	**Any remarks to be given to the RECOMMENDATIONS or which, in another way, showed up during the HAZOP sessions.**
Consequence	**The results of the DEVIATION, in case it occurs. CONSEQUENCES may both comprise process hazards and operability problems, like plant shutdown. More CONSEQUENCES can follow from one cause and, in turn, one CONSEQUENCE can have several CAUSES.**

HAZOP Terminology - 2

Term	Definition
Deviation	A way in which the process conditions may depart from their INTENTION.
Intention / Design intent	Description of how the process is expected to behave at the Study Line. This is qualitatively described as an activity (e.g., feed, reaction, sedimentation) and/or quantitatively in the process parameters, like temperature, flow rate, pressure, composition, etc.
Keyword/ Guideword	A short word to create the imagination of a DEVIATION of the INTENTION. The mostly used set of Guidewords is: NO, MORE, LESS, AS WELL AS, PART OF, OTHER THAN and REVERSE. The GUIDEWORDS are applied, in turn, to all the PARAMETERS, in order to identify unexpected and yet credible DEVIATIONS from the INTENTION.

HAZOP Terminology - 3

Term	Definition
Parameter	**The relevant parameter for the condition(s) of the process, e.g., pressure, temperature, composition, etc.**
Study Line/ Node	**A specific location in the process in which (the deviations of) the process intention are evaluated. Examples might be: separators, heat exchangers, scrubbers, pumps, compressors, and interconnecting pipes with equipment**
Recommendation	**Activities identified during a HAZOP study for follow-up. These may comprise technical improvements in the design, modifications in the status of drawings and process descriptions, procedural measures to be developed or further in-depth studies to be carried out.**

HAZOP Terminology - 4

Term	Definition
Safeguard	**Facilities that help to reduce the occurrence frequency of the DEVIATION or to mitigate its CONSEQUENCES. There are, in principle, five types of SAFEGUARDS:** ❑ Facilities that **identify** the DEVIATION. These comprise, among others, alarm instrumentation and human operator detection. ❑ Facilities that **compensate** the DEVIATION, e.g., an automatic control system that reduces the feed to a vessel in case of overfilling it (increase of level). These usually are an integrated part of the process control. ❑ Facilities that **prevent** the DEVIATION to occur. An example is an inert blanket gas in storages of flammable substances. ❑ Facilities that **prevent a further escalation** of the DEVIATION, e.g., by (total) trip of the activity. These facilities are often interlocked with several units in the process, often controlled by logical computers. ❑ Facilities that **relieve the process from the hazardous** DEVIATION. These comprise for instance: pressure safety valves (PSV) and vent systems.

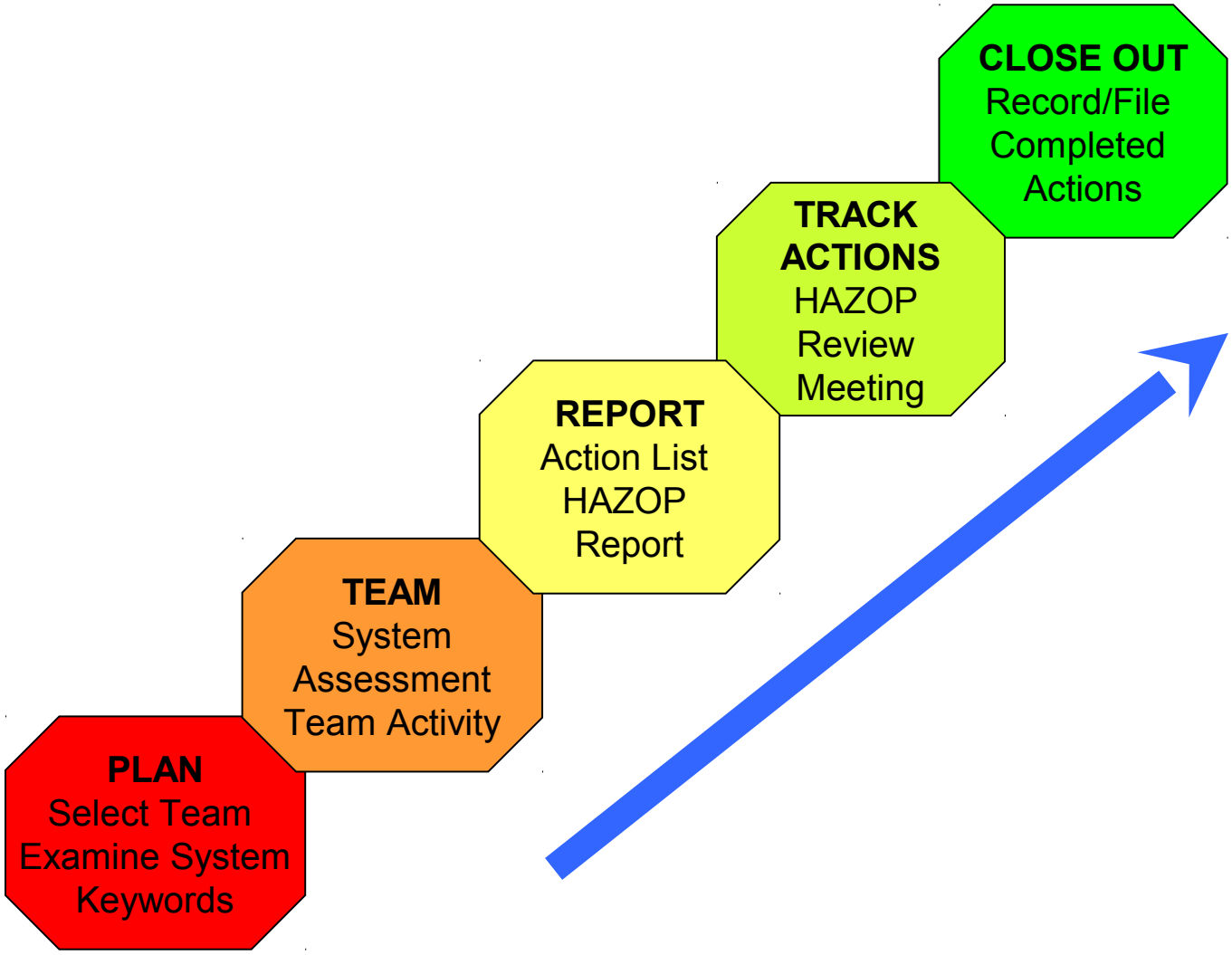
HAZOP Terminology - 4

Term	Definition
Action	**– Where a credible cause results in a negative consequence, it must be decided whether some action should be taken. It is at this stage that consequences and associated safeguards are considered. If it is deemed that the protective measures are adequate, then no action need be taken, and words to that effect are recorded in the Action column.** **– Actions fall into two groups:** • Actions that remove the cause. • Actions that mitigate or eliminate the consequences. **– Whereas the former is to be preferred, it is not always possible, especially when dealing with equipment malfunction. However, always investigate removing the cause first, and only where necessary mitigate the consequences.**

HAZOP Methodology - Content

- HAZOP Study Planning and Preparations
- HAZOP Study Team - Role and Responsibilities
- Meeting Arrangements
- Reporting and Follow-up
- HAZOP Guidewords;
- Possible Causes & Consequences
- Plant; Safeguards & Action Required
- Working Session 2: Chemical Plant

HAZOP Planning and Execution



HAZOP study team

- **Independent leader (e.g., not from plant studied)**
  - Preferred but complete independence not essential
- **Project engineer**
  - Provide engineering input
- **Operations representative**
  - Plant operation
- **Discipline engineers**
  - Process
  - Instrument/ electrical
  - Mechanical/ maintenance
- **HAZOP minute recorder**
  - One of the above

Responsibility of HAZOP Team Members

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

- Plan sessions and timetable
- Control discussion
- Limit discussion
- Encourage team to draw conclusion
- Ensure secretary has time for taking note
- Keep team in focus
- Encourage imagination of team members
- Motivate members
- Discourage recriminations
- Judge importance issues

Checklist for HAZOP Leader

- Always prepare study program in advance.
- Agree on the format or form to be used.
- Prepare follow up procedures.
- Brief members about HAZOP during first meeting.
- Stop the team trying to redesign the process.
- HAZOP is a team exercise. Do not let anybody (including the leader himself to dominate).

Checklist for HAZOP Leader

- If conflict arises, handle with care.
- Avoid long discussions by recording areas which need to be resolved outside meeting.
- Leader must be strong, yet diplomatic.
- Speak clearly. Make you point.
- Better have experience working as team member previously.
- Do not skip anything….some time small things may cause big accident.

Responsibility of HAZOP Team Members

HAZOP Secretary

- Take adequate notes
- Record documentations
- Inform leader if more time required in taking notes
- If unclear, check wording before writing
- Produce interim lists of recommendations
- Produce draft report of study
- Check progress of chase action
- Produce final report

Responsibility of HAZOP Team Members

Process Engineer

- Provide a simple description
- Provide design intention for each process unit
- Provide information on process conditions and design conditions
- Provide a simple description
- Provide design intention for each process unit
- Provide information on process conditions and design conditions

Responsibility of HAZOP Team Members

Mechanical Design Engineer

- Provide specification details
- Provide vendor package details
- Provide equipment and piping layout information

Instrument Engineer

- Provide details of control philosophy
- Provide interlock and alarm details
- Provide info on shutdown, safety features

Responsibility of HAZOP Team Members

Plant Engineer or Manager

- Provide information on compatibility with any existing adjacent plant
- Provide details of site utilities and services
- Provide (for study on existing plant) any update on maintenance access and modifications

Shift Operating Engineer or Supervisor

- Provide guidance on control instrumentation integrity from an operating experience view point
- Provide (for study on existing plant) information on plant stability at the specified control parameters
- Provide information on experienced operability deviations of hazard potential

Responsibility of HAZOP Team Members

Chemist

- Provide details of process chemistry
- Provide details of process hazards (polymerisations, byproducts, corrosion etc)

Project Engineer

- Provide details of cost and time estimation and also budget constraints.
- Ensure rapid approval if required

Questioning Techniques

- **Open questions**
  - Help person being asked to think – use words how, what and why.
- **Closed questions**
  - To focus on an issue or problem. Start with words who, when, where.
  - Required answer yes or no only.
- **Question mix**
  - Mix between open and closed questions.

Questioning Techniques

- **Things to avoid**
  - Ambiguous or vague questions.
  - Double barelled/multiple questions.
  - Long complicated questions.
  - Interrogation type of questions.
  - A loaded questions – implied judgement.

Required information

- P & IDs
- Process flow diagrams
- Heat and Material Balances
- Layouts
- Logic Diagrams
- Equipment Data Sheets
- Material Hazard Data Sheets
- Hazardous area Layouts

Modes of operation to consider

- **The following modes of plant operation should be considered for each node:**
  - **Normal operation**
  - **Reduced throughput operation**
  - **Routine start-up**
  - **Routine shut-down**
  - **Emergency shutdown**
  - **Commissioning**
  - **Special operating modes**

HAZOP meeting

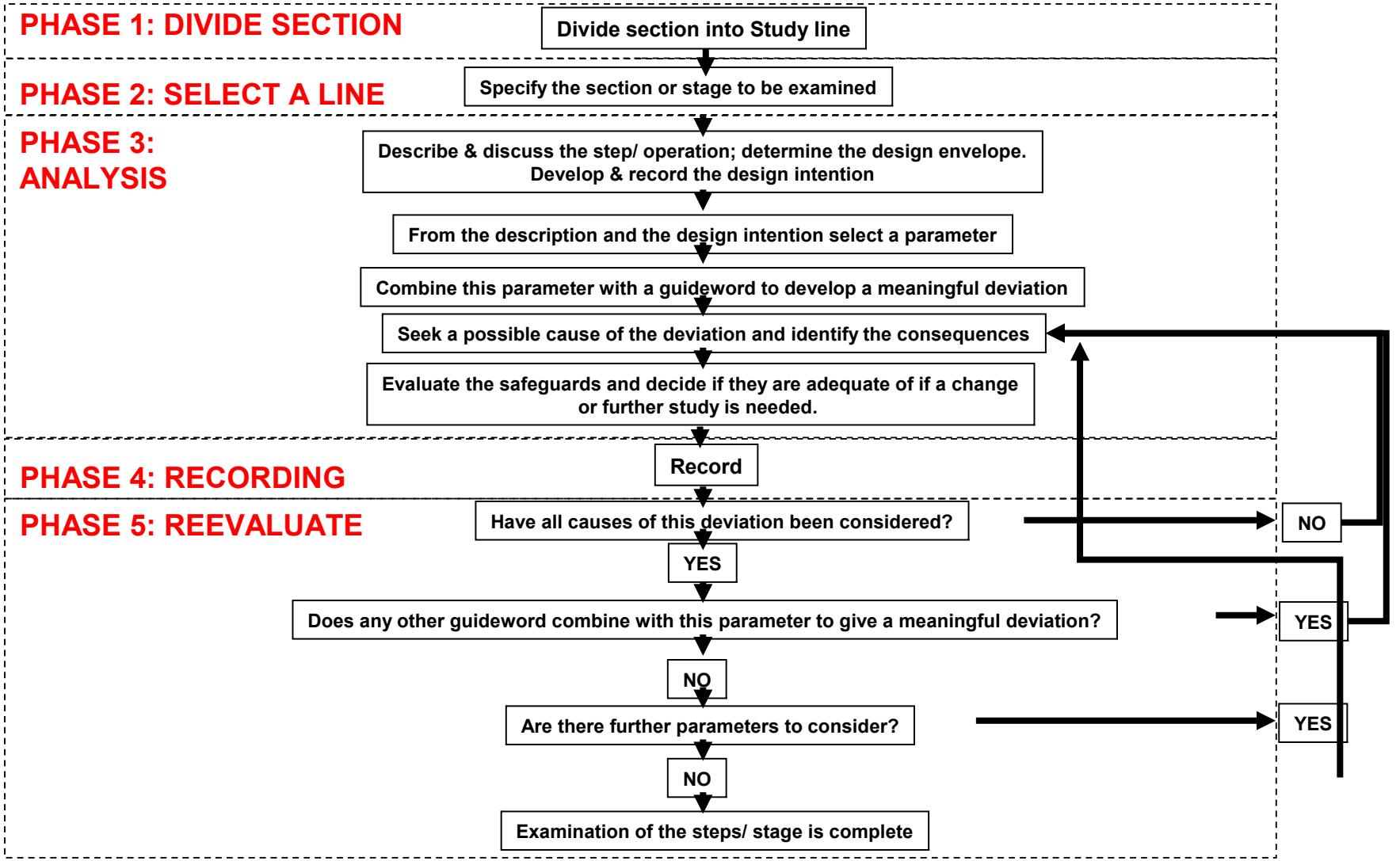
- **Proposed agenda:**

•Introduction & presentation of participation
•Overall presentation of the system/operation to be analyzed
•Description of the HAZOP approach
•Presentation of the first node or logical part of the operation
•Analyze the first node/ part using the guide-words and parameters
•Continue presentation and analysis (steps 4 & 5)
•Coarse summary of findings

Focus should be on potential hazards as well as potential operational problems.

Sequence for conducting a HAZOP Study

Flow diagram for the HAZOP analysis – The parameter-first approach



How to be a good HAZOP participant

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

HAZOP recording

- **The findings are recorded during the meeting(s) using a HAZOP work-sheet, either by filling in paper copies, or by using a computer connected to a projector (recommended).**

- **The HAZOP worksheet may be different depending on the scope of the study – generally the following entries (columns) are included**
  - **Ref. no.**
  - **Guidewords**
  - **Deviations**
  - **Possible causes**
  - **Consequences**
  - **Safeguards**
  - **Actions required (or, recommendations)**
  - **Actions allocated to (follow up responsibility)**

Process HAZOP worksheet

Hazards and Operability Review

Project Name: **Date:** **Page** **of**

Process :

Section: **Ref. Drawing:**

Item	Study node	Process Parameter	Deviations (guide words)	Possible causes	Possible consequences	Action Required

Guidewords/ Keywords

The basic HAZOP guide-words are:

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

Additional guidewords

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

Process parameter

- **Process parameter may generally be classified into the following groups:**
  - **Physical parameters related to input medium properties**
  - **Physical parameters related to input medium conditions**
  - **Physical parameters related to system dynamics**
  - **Non-physical parameters related to batch type process**
  - **Parameters related to system operations**

    These parameters are not necessarily used in conjunction with guide-words
    - Instrumentation
    - Relief
    - Startup/ shutdown
    - Maintenance
    - Safety/ contingency
    - Sampling

Examples of process parameter

Flow	Composition	pH
Pressure	Addition	Sequence
Temperature	Separation	Signal
Mixing	Time	Start/stop
Stirring	Phase	Operate
Transfer	Speed	Maintain
Level	Particle size	Service
Viscosity	Measure	Communication
Reaction	Control	Absorb

Examples of process parameter -2

Isolate	Corrode	Drain
Vent	Erode	Purge
Inspect	Separate (settle, filter, centrifuge	Maintain
Start-up	Reduce (grind, crush, etc)	Shut-down

Guidewords + Parameter

Some examples of combinations of guide-words and parameters:

- **NO FLOW**
  - Wrong flow path – blockage – incorrect slip plate – incorrectly fitted return valve – burst pipe – large leak – equipment failure – incorrect pressure differential – isolation in error
- **MORE FLOW**
  - Increase pumping capacity – increased suction pressure – reduced delivery head – greater fluid density – exchanger tube leaks – cross connection of systems – control faults
- **MORE TEMPERATURE**
  - Ambient conditions – failed exchanger tubes – fire situation – cooling water failure – defective control – internal fires

Causes of Deviations – 3 Types

- *Human error -* which are acts of omission or commission by an operator, designer, constructor or other person creating a hazard that could possibly result in a release of hazardous or flammable material.
- *Equipment failure -* in which a mechanical, structural or operating failure results in the release of hazardous or flammable material.
- *External Events -* in which items outside the unit being reviewed affect the operation of the unit to the extent that the release of hazardous or flammable material is possible. External events include upsets on adjacent units affecting the safe operation of the unit (or node) being studied, loss of utilities, and exposure from weather and seismic activity.

Consequences & Safeguards

- All **consequences** of any credible causes of a release that are identified by the group must be determined in order to:
  - help to determine a risk ranking in HAZOPs where multiple hazards are uncovered by the group so that priority can be established in addressing the hazard.
  - help make the determination as to whether a particular deviation results in an operability problem or hazard.
- If the team concludes from the consequences that a particular cause of a deviation results in an operability problem only, then the discussion should end and the team should move on to the next cause, deviation or node.
- If the team determines that the cause will result in the release of hazardous or flammable material, then safeguards should be identified.

Consequences & Safeguards

- **Safeguards should be included whenever the team determines that a combination of cause and consequence presents a credible process hazard.**

- **What constitutes a safeguard can be summarized based on the following general criteria:**
  - **Those systems, engineered designs and written procedures that are designed to prevent a catastrophic release of hazardous or flammable material.**
  - **Those systems that are designed to detect and give early warning following the initiating cause of a release of hazardous or flammable material.**
  - **Those systems or written procedures that mitigate the consequences of a release of hazardous or flammable material.**

HAZOP Study Reporting

- **The report must be placed with the HSE Assessment and Control of Work and will largely consist of the record sheet(s), however, the following information should be included:**
  - **An outline of the terms of reference and scope of the study.**
  - **A very brief description of the process which was studied**
  - **The procedures and protocol employed. The Keyword combinations applied should be listed, together with the explanatory meanings given to the team at the start of the study. Also the fact that Action Sheets have been produced and responses will be recorded should be explained. A brief description of the Action File (described in the following section) should be included.**
  - **General comments. If, for example, the team were assured that high point vents and low point drains would be universally provided, mention that statement and its source. If certain details of vendor packages were not available, explain and list the items which were not reviewed.**
  - **Results. This usually states the number of recommended actions.**
  - **Appendices:**
    - Master copies of the drawings studied.
    - Copies of technical data used.
    - Cause and Effect charts (i.e. matrices showing the executive action of safety related instruments and trips).
    - Any calculations produced.
    - Relevant correspondence between departments, from contractor to vendor, or client to contractor.
  - **HAZOP study record sheets**

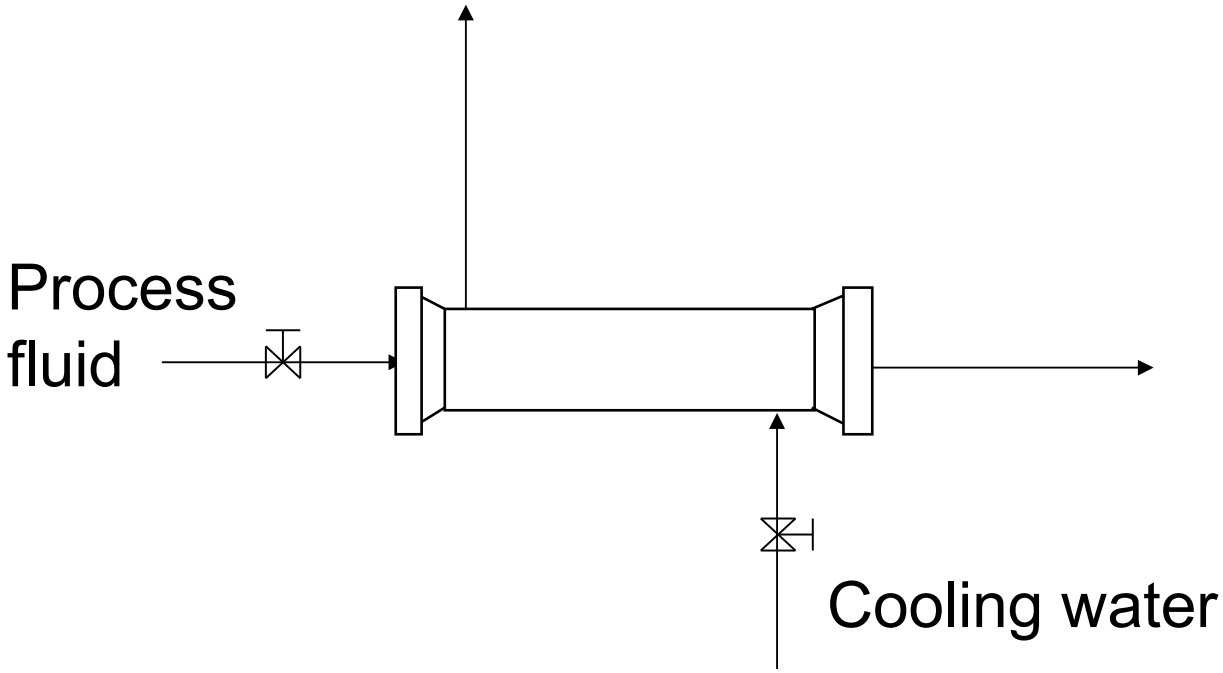
HAZOP Study Action Follow-up

- An addendum to the HAZOP report, to be issued when the actions have been completed
- Deviations from the original intent should be noted
- Major changes may require a follow-up HAZOP study

HAZOP Exercise

Case Study – Shell & Tube Heat Exchanger

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



HAZOP on Heat Exchanger – Answer 1

Guide Word	Deviation	Causes	Consequences	Action
Less	Less flow of cooling water	Pipe blockage	Temperature of process fluid remains constant	High Temperature Alarm
More	More cooling flow	Failure of cooling water valve	Temperature of process fluid decrease	Low Temperature Alarm
More of	More pressure on tube side	Failure of process fluid valve	Bursting of tube	Install high pressure alarm
Contamination	Contamination of process fluid line	Leakage of tube and cooling water goes in	Contamination of process fluid	Proper maintainance and operator alert
Corrosion	Corrosion of tube	Hardness of cooling water	Less cooling and crack of tube	Proper maintainence

HAZOP on Heat Exchanger – Answer 2

Guide Word	Deviation	Causes	Consequences	Action
NONE	No cooling water flow	Failure of inlet cooling water valve to open	Process fluid temperature is not lowered accordingly	Install Temperature indicator before and after the process fluid line Install TAH
MORE	More cooling water flow	Failure of inlet cooling water valve to close	Output of Process fluid temperature too low	Install Temperature indicator before and after process fluid line Install TAL
LESS	Less cooling water	Pipe leakage	Process fluid temperature too low	Installation of flow meter
REVERSE	Reverse process fluid flow	Failure of process fluid inlet valve	Product off set	Install check valve (whether it is crucial have to check?)
CONTAMINATION	Process fluid contamination	Contamination in cooling water	Outlet temperature too low	Proper maintenance and operator alert

Some References

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