HAZOP

Hazard and Operability

Definitions

- **Hazard**
  - Any action that could result in injury to personnel
- **Operability**
  - Any operation inside the design envelope that would cause a shutdown that could possible lead to a violation of environmental, health or safety regulations or negatively impact profitability

What is HAZOP?

- It is systematic way of identifying potential hazards in the system and identifying operability problems.
- ICI (UK Company) in 1963
- After Flixborough disaster – followed by chemical industries
- HAZOP – quality technique (based on guide words)
- To identify causes, consequences
- To safeguards before incident occurs
- Legal requirement – process safety

Fundamental principles of HAZOP study

- Obtain a full description of the process, including the intended design conditions.
- Systematically examine every part of the process to find out how deviations from those designed or specified can occur.
- Decide whether these deviations can give rise to hazards and/or operability problems.

Types of HAZOP

- Process HAZOP
- Human HAZOP
- Procedure HAZOP
- Software HAZOP

Where – HAZOP is USED?

- Chemical and Petrochemicals
- Oil and Gas including refining
- Power Generation
- Mining and Metals
- Pharmaceutical manufacturing

When - HAZOP study?

- **During installation**
  - New plant
  - New process
  - Major modification
- **Issues associated with operation**
  - Environmental hazard
  - Quality issues
  - Cost issues
  - Industry code

When – HAZOP study?

- **Major incidents**
  - Fire
  - Explosion
  - Toxic release
- **To justify**
  - codes of practice
  - Guidance
  - Industry code

How to conduct a HAZOP study?

- Objective study
- Formation of multi disciplinary team
- Collection of data
  - Process flow diagrams
  - Piping and Instrumentation diagrams (P&IDs)
  - Layout diagrams
  - Material safety data sheets
  - Heat and material balances
  - Equipment data sheets
  - Start up and Emergency shut down procedures

When – HAZOP study? (Cont……)

- Study of the plant – arranging necessary visits and through study
- Examinations by applying the guide words
- Record the result arrived

HAZOP Methodology

Definition

Preparation

Examination

Documentation and follow-up

HAZOP Methodology

Definition

- Define scope and objective
- Define responsibilities
- Select Team

HAZOP Methodology

Preparation

- Plan the study
- Collect Data
- Agree style of recording
- Estimate the time
- Arrange a schedule

HAZOP Methodology

Examination

- Divide the system into parts
- Select a part and define design intent
- Identify deviation by using guide words on each element
- Identify consequence and causes
- Identify whether a significant problems exists
- Identify protection, detection and indicating mechanism
- Identify possible remedial/mitigating measures
- Agree actions
- Repeat for each element and then each part

HAZOP Methodology

Documentation and follow-up

- Record examination
- Sign off the documentation
- Produce the report of the study
- Follow up that actions are implemented
- Re-study any parts of system if necessary
- Produce final output report

HAZOP
Some Important Terminologies

NODE

- Node is a specific location in the process
  - Example: Heat exchanger, Pumps, Compressors and interconnecting pipes

Intention / Design

- Description of - how the process is expected to behave at the study line
- Qualitative description
  - Feed
  - Reaction
  - Sedimentation
- Quantitative description
  - Temperature
  - Flow rate
  - Pressure

Deviation

- Departure from the design intention
- Found by guide word / parameter combinations

Deviation Matrix

Guide Words / Design Parameter	More Of	Less Of	None Of	Reverse	Part of	As Well As	Other Than
Flow	High Flow	Low Flow	No Flow	Back Flow	Wrong Concentrations	Contaminants	Wrong Material
Temperature	High Temp	Low Temp					
Pressure	High Press	Low Press					
Level	High Level	Low Level	No Level				

Parameters

- Flow
- Pressure
- Temperature
- Level
- Quantity
- Time

Guide word / Keyword

- Short word to create the imagination of deviation of the intention

Guide Word	Meaning
NO	Negation of the design intent (e.g., no flow when there should be; no pressure when there should be
LESS	Less of a physical property than there should be —quantitative decrease (e.g., lower flow rate than there should be)
MORE	More of a physical property than there should be —quantitative increase
PART OF	Composition of the system (stream) is different than it should be —qualitative decrease (e.g., less of one component)
AS WELL AS	More components present than there should be—qualitative increase (e.g., extra phase or impurities present)
REVERSE	Logical opposite of the design intent (e.g., reverse flow)
OTHER THAN	Complete substitution (e.g., transfer of a material other than the material intended; transfer of a material to a location other than intended)

Cause

- Reason (s) why the deviation could occur
- More CAUSES can be identified for one deviation

Consequence

- Results of the deviation
- Consequence may both comprises
  - Process hazards
    - Example: high pressure
  - Operability problems
    - Example: Plant Shutdown
- Consequence may both comprises
  - process hazards and operability problems

Comments

- Any remarks to be given to the recommendations
- HAZOP session discussion topic

Risk Ranking

- Does not include any formal ranking of the hazards identified
- Difficult to prioritize the recommendations for implementation
- So it is beneficial to use a risk ranking scheme

HAZOP Team

- Consists of the representatives from the following discipline
  - Inspection
  - Instrumentation / Electrical
  - Loss prevention / Fire Prevention
  - Maintenance
  - Operations
  - Process Engineering
  - Other specialists (If required)

Responsibility of HAZOP Leader

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

- 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 Leaders

- 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 point focused.
- 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

- **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

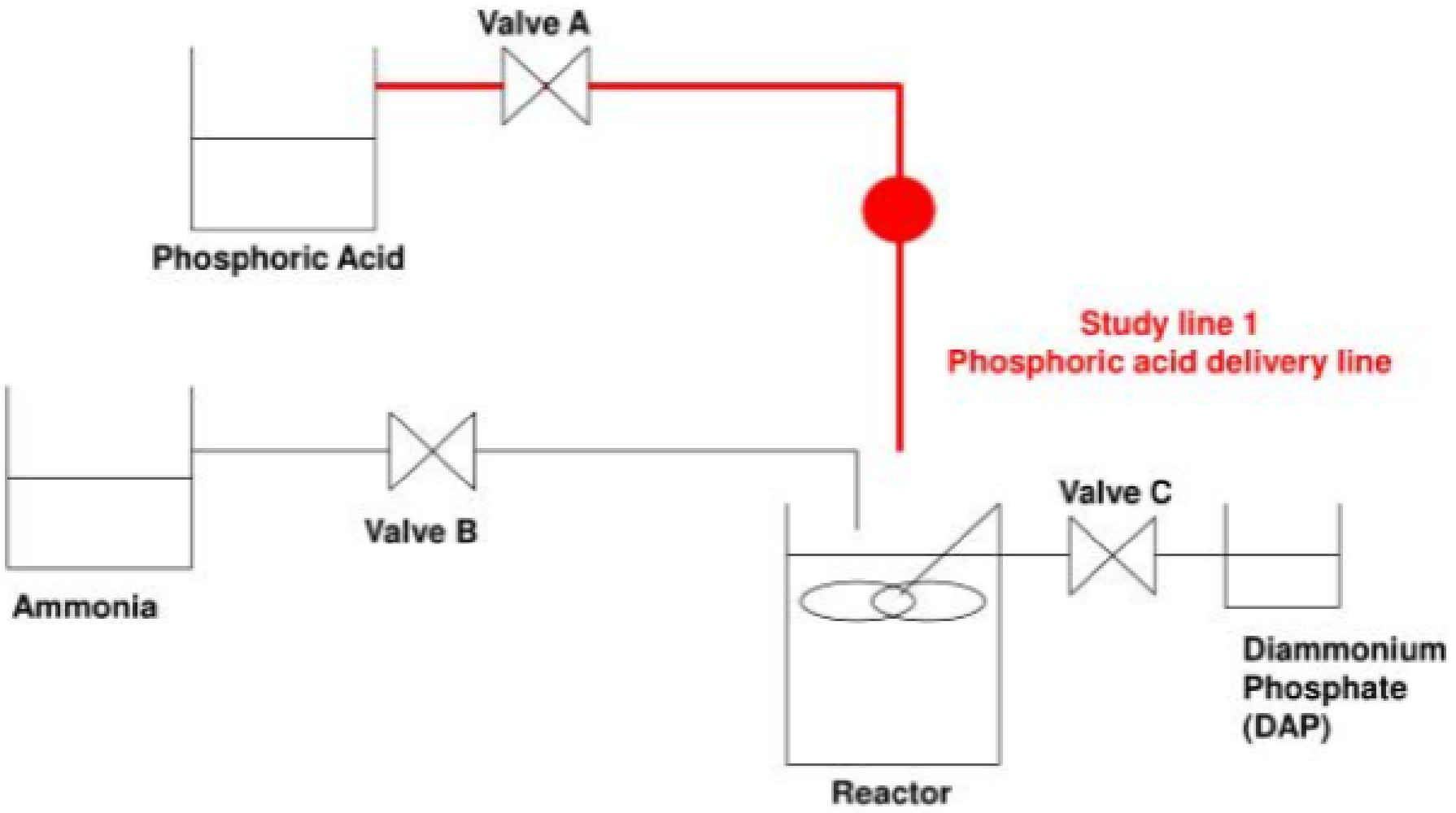
- **Plant Engineer or Manager**
  - Provide information on compatibility with any existing adjacent plant
  - Provide details of site utilities and services
  - Provide (for study on existing plant) any update on maintenance access and modifications
  - Shift Operating Engineer or Supervisor
  - Provide 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 parameter
  - 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 (polymerizations, byproducts, corrosion etc.)
- **Project Engineer**
  - Provide details of cost and time estimation and also budget constraints.
  - Ensure rapid approval if required

Simple Example – Scenario
Di-ammonium Phosphate Production

- Phosphoric acid and ammonia are mixed, and a non-hazardous product, di-ammonium 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)


Valve A
Phosphoric Acid
Study line 1
Phosphoric acid delivery line
Ammonia
Valve B
Valve C
Diammonium
Phosphate
(DAP)
Reactor

HAZOP Work Sheet

Some meaning related to guide word, parameter & cause

- 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

HAZOP Work Sheet (Cont……)

Some meaning related to guide word, parameter & cause

- More Temperature
  - Ambient conditions – Failed exchanger tubes – fire situation – cooling water failure – defective control – internal fires

Effectiveness of HAZOP

- Team approach
- Varying backgrounds and expertise
- Collective effort – stimulates creativity and new ideas
- Review

Advantages

- Systematic and through procedure
- Easy to Learn
- Stimulates creativity and generates ideas (Multidisciplinary Study)
- Participants gain valuable knowledge
- Readily acceptable to regulatory authorities (Statutory requirement)
- Utilizes operational experience
- Covers human errors also
- Accuracy of drawings and data used as a basis for the study
- Technical skills and insight of the team

Limitations

- The success of the review is highly dependent on the accuracy of drawings and data.
- It requires the right mix of team members with the proper technical experience and insight.
- It is tiring and difficult to perform over extended periods and leads to something we call “brain burnout.” (Time consuming)
- For a smooth, effective study, it requires the commitment of the team, and management, for the duration of the study.
- A HAZOP study is difficult to conduct when team members are changed or key team members don’t attend.

Limitations (Cont……)

- Focusing too much on solutions
- Team members allowed to divert into endless discussions of details
- A few of the team members dominate the discussion

Sample HAZOP Worksheet for reference

Study title:							Page: of		
Drawing no.:		Rev no.:					Date:		
HAZOP team:							Meeting date:		
Part considered:									
Design intent:		Material: Source:		Activity: Destination:					
No.	Guide-word	Element	Deviation	Possible causes	Conse-quences	Safeguards	Comments	Actions required	Action allocated to