Process Safety Management

Process Safety Management

- Introduction
  - What is process safety?
    - Process safety is a disciplined framework for managing the integrity of operating systems and process handling hazardous substances by applying good design principles, engineering and operating practices.

Process Safety Management

Process Safety is everyone's responsibility

Continuous improvement

A way of thinking and acting

It is a culture

Process Safety Management

- It deals with the prevention and control of incidents that have the potential to release hazardous materials or energy. Such incidents can cause toxic effects, fire or explosion and could ultimately result in serious injuries, property damage, lost production and environmental impact
- Process safety needs to be considered separately from occupational safety

Process Safety Management

- Process safety is a very common and used topic in the chemical industry.
- According to CCPS, an incident is reported as a process safety incident if it meets all four criteria (process involvement, above minimum reporting threshold, location and acute release)
- Although power plant industry doesn't handle hazardous chemicals as much as chemical, petrochemical or refining industry, it has the same equipment which can be the source of similar accidents such as:
- Boilers, Tanks, Cooling towers, Reactors, etc.

Applicable standards and guidelines

- American occupational health and safety Administration process safety management rule enacted in 1994.
- 14 Elements – CSChE – The Canadian Society for Chemical Engineering.
- 20 Elements – AIChE CCPS – The American Institute for chemical Engineers Centers or Chemicals process safety
- 14 Elements – OSHA 3132 – Process Safety Management

Cont……

- 14 Elements – OSHA 1910.119 – Process Safety Management of Highly Hazardous Chemicals
- 20 Elements – EU Energy Institute
- 12 Elements – Canadian Sociaty ChE Eng. Process Safety Management Guide
- 12 Elements – Operational Excellence Expectations CHEVRON
- 14 Elements – Dupont's Process Safety and Risk Management Model DUPONT

- Process Safety Information
- Process Hazard Analysis
- Operating Procedures
- Employee Participation
- Training
- Contractors
- Pre-Start up Safety Review
- Mechanical Integrity
- Hot – Work Permit
- Management of Change
- Incident investigation
- Emergency Planning and Response
- Compliance Audits

Process Safety Information

- To be assessed in process hazard analysis and management of change, following information should be considered.
- Process and Instrumentation diagrams (P&I)
- Block or simplified diagrams of the process, flow diagrams
- Diagrams of electrical installations
- A list of critical components
- Mass and energy balances

Process Safety Information

- Acceptable upper and lower limits for variables and any deviations from variables.
- A safety data sheet of the substances
- Classification of electrical areas
- Design and layout relied and ventilation systems
- Specifications for pipes and equipment
- A description of the interlock and shutdown systems

Components of Process Safety

Hazard Analysis

- Hazard identification and evaluation is contemplated at every stage of the plant's operations, from the initial project to the day is decommissioned. This includes identifying the potential dangers associated with
  - Operating conditions
  - Start-ups, stops, maintenance and special
  - Previous incidents
  - Process hazards

Components of Process Safety

Hazard Analysis

- Potential accidents and their consequences caused by
  - Failure of monitoring, controls alarms, interlocks, ESD
  - Human factors
  - External events
  - Failure of safety management system

Components of Process Safety

Operating Procedures

- Operating instructions must cover all possible operative stages
  - **Start-Up**
  - All phases of normal operations, including testing, maintenance and inspection
  - Detection of an response to, departures from normal operating conditions
  - Temporary or special operations
  - Operations under maintenance conditions
  - Normal shutdown
  - Emergency operations including shutdown
  - Decommissioning

Components of Process Safety

Operating Procedures

- Operating limits
  - Consequences of deviation
  - Steps required to correct or avoid deviation
- Safety and health considerations
  - Properties of and hazards presented by the chemicals used in the process
  - Precautions necessary to prevent exposure, including engineering controls, administrative controls and PPE
  - Control measures to be taken if physical contact or airborne exposure occurs
  - Quality control for raw materials and controls of hazardous chemical inventory levels
  - Any special or unique hazards
  - Safety Systems (interlocks, detection or suppression systems) and their functions

Components of Process Safety

Employee participation

- Consult with employee and their representatives on the development and conduct of hazard assessments and the development of chemical accidents prevention plans and provide access to these and other records required under the standard.
  - Develop a written participation plan
  - Consult with employees on PHA and PSM development
  - Provide to employees access to PSM information

Components of Process Safety

Training

- Ensure contactors and contract employees are provided with appropriate information and training
  - Identify the training needs of employees
  - Identify the training periods
  - Training plans
  - Evaluation of effectiveness of training

Components of Process Safety

Training

- Initial Training
  - PSM requires that each employee presently involved in operating a process or a newly assigned process must be trained in an overview of the process and in its operating procedures.
- Refresher training
  - Refresher training must be provided at least every three years, or more often if necessary, to each employee involved in operating a process to ensure that the employee understands and adheres to the current operating procedures of the process.

Components of Process Safety

Contractors

- When selecting a contractor, obtain and evaluate information regarding the contract employer's safety performance and programs.
- Inform contract employers of the known potential fire, explosion, or toxic release hazards related to the contractor’s work and the process
- Develop and implement safe work practices to control the presence, entrance and exit of contract employers and contract employees in covered process areas.
- Evaluate periodically the performance of contract employers in fulfilling their obligations; and maintain a contract employee injury and illness log related to the contractor’s work in the process areas

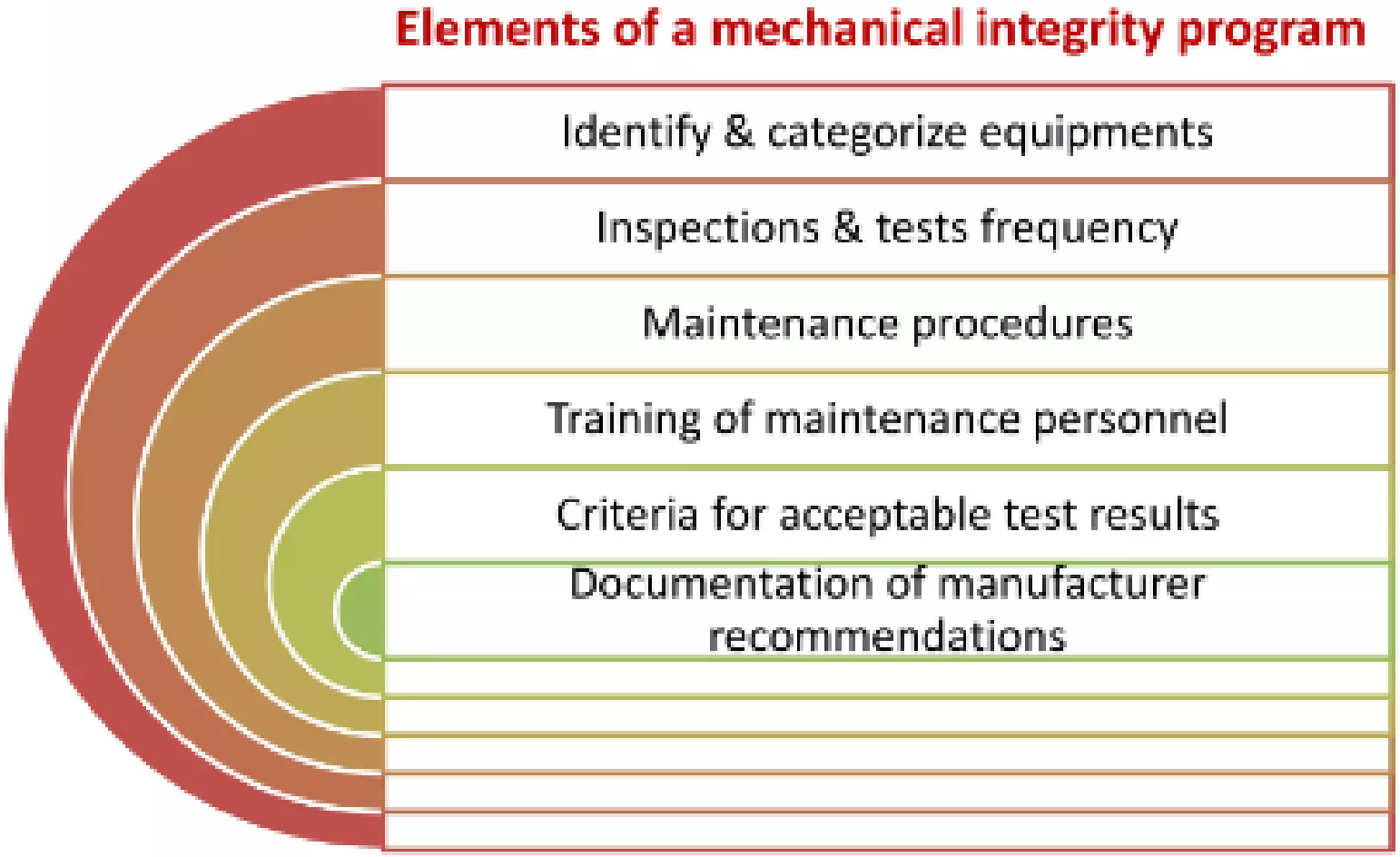
Components of Process Safety

Mechanical Integrity

- Written procedures to maintain ongoing integrity of process equipment
- Establish a quality assurance program to ensure that initial process-related equipment, maintenance materials, and spare parts are fabricated and installed consistent with design specifications

Components of Process Safety

Mechanical integrity



Components of Process Safety

Pre-Start Up Safety Review

- Prior to start-up or implementation of a significant change, following should checked:
  - Any documents which may be affected by the change must have been modified (procedures, instruction, etc)
  - Staff affected by the change must have been adequately informed / trained.
  - Modified procedures must have been made available to the staff affected
  - In the event of changes to the conditions of the activity, the relevant authorizations must have been issued and the staff affected informed.
  - There must be compliance with applicable laws and all the relevant authorizations and licenses must have been obtained.
  - That, where appropriate, findings from completed hazard assessments must be taken into consideration
  - That all safety systems must be fully operational

Components of Process Safety

Management of Change

- Management of change is key to safe design and maintaining the safe operations
- Following are considered as << Change>>

Components of Process Safety

Management of Change

- Written procedures addressing
  - Technical basis for the proposed change
  - Impact of the change on employee safety and health
  - Modifications to operating procedures
  - Necessary time period for the change
  - Authorization requirements for the proposed change

Components of Process Safety

Work Permit

- Non-Routine operations
- Sub-contractor activities
- Hot-work

Risk Assessment Prior to the Work

Components of Process Safety

Incident investigation

- Investigate every incident that results in or could have resulted in a major accident in the workplace, with any findings to the reviewed by operating personnel and modifications made, if appropriate.
- An investigation report must be prepared including at least;
  - Date of incident
  - Date investigation began
  - Description of the incident
  - Factors that contributed to the incident
  - Recommendations resulting from the investigation

Components of Process Safety

Emergency Planning and Response

- Develop and implementation and emergency action plan for the entire plant. Train and educate employees and contractors in emergency response
- Identify the emergencies
- Measures to prevent their negative consequences
- Identify the emergency response teams
- Specific tactical procedures defining how to response against the different kind of accidents
- Evacuation procedures
- Emergency drills
- Review emergency plans

Components of Process Safety

Compliance Audits

- To be certain process safety management is effective, employers must certify that they have evaluated compliance with the provisions of PSM at least every three years
- This will verify that the procedures and practices developed under the standard are adequate and are being followed
- The compliance audit must be conducted by at least one person knowledgeable in the process and a report of the findings of the audit must be developed and documented noting deficiencies that have been corrected.
- The two most recent compliance audit reports must be kept on file.

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

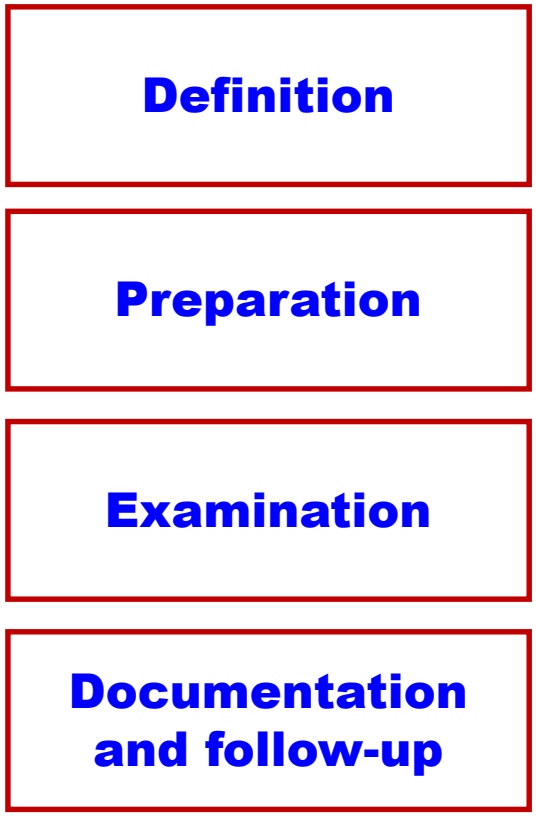
How to conduct a HAZOP study?

- 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



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).

Check list 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

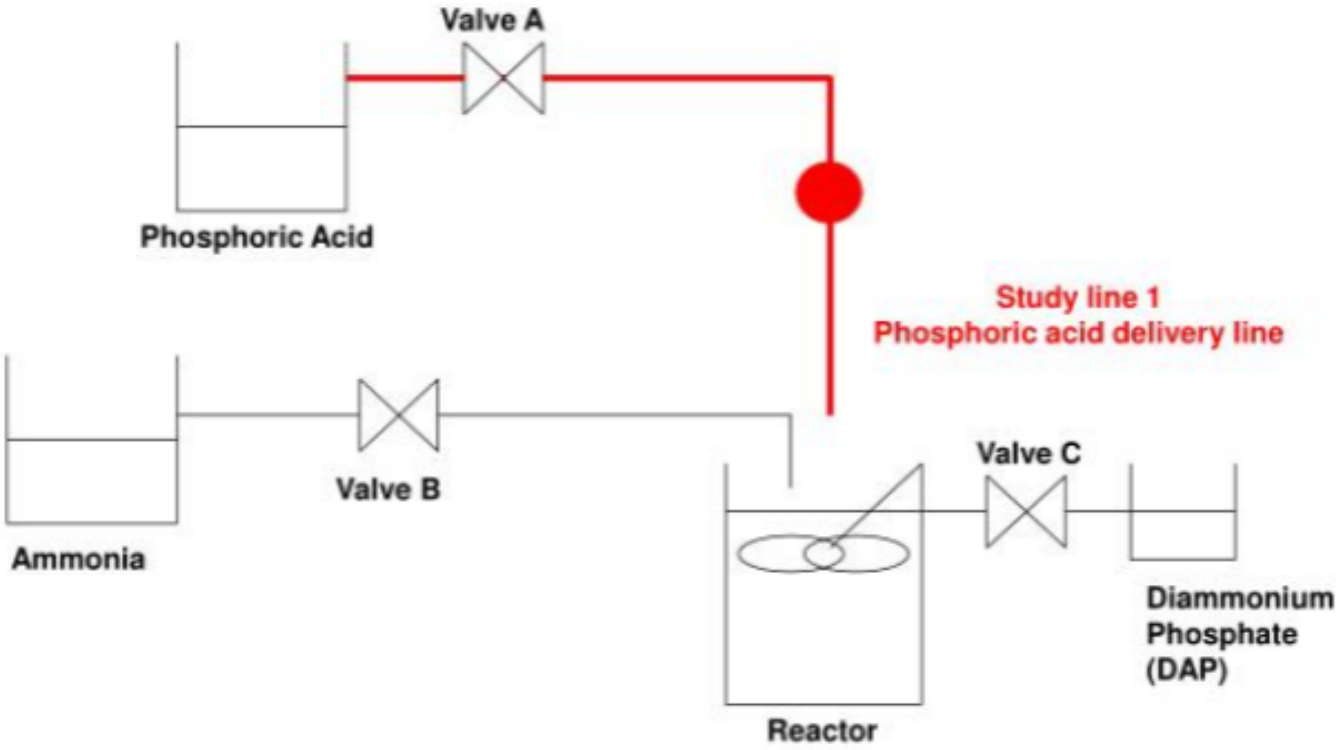
Responsibility of HAZOP Team Members

- **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: Activity: Source: Destination:						
No.	Guide-word	Element	Deviation	Possible causes	Conse-quences	Safeguards	Comments	Actions required	Action allocated to