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HAZARD AND OPERABILITY (HAZOP) STUDIES

17.1. INTRODUCTION

The HAZOP study has been developed to identify hazards in a process plant and to identify operability problems which, though not hazardous, could compromise the plant's ability to achieve design productivity. Thus, a HAZOP goes beyond hazard identification. Although, originally developed to anticipate hazards and operability problems for new and/or novel technology where past experience was limited, it has been found to be very effective at any stage in a plant's life from the final design onwards. The approach taken, is to form a multi-disciplinary team that works together (brainstorms) to identify hazards and operability problems by searching for deviations from the plants' design, intents. An experienced team leader systematically guides the team through the plant design using a fixed set of words, called "guide words", or using checklists. These guide words are applied at specific points or "Study Nodes" in the plant design to identify potential deviations of the plant process parameters at those nodes. Although the HAZOP study has been developed to supplement experience based practices when a new design of technology is involved, its use has expanded to all phase of a plant's life.

17.2. CONCEPT

This HAZOP concept reviews the plant in a series of meetings, during which a multi-disciplinary team methodically "brainstorms" the plant design, following the structure provided by the guide words and the team leader's experience. The primary advantage of this brainstorming is that it stimulates creativity and generates ideas. This creativity results from the interaction of the team and their diverse backgrounds.

When to Use: When applied to new plants at a point when the design is nearly firm and documented or to existing plants where a major redesign is planned, its use is optional from a cost viewpoint. It can also be used for existing facilities.

Type of Results: The results are the teams, findings, which include: identification of hazards and operating problems; recommendation changes in design, procedure, etc. to improve safety and recommendations for follow-on studies where no conclusion was possible due to lack of information.

Nature of Results: Qualitative

Data Requirements: A HAZOP study requires detailed plant descriptions, such as drawing procedures and flow-charts. A HAZOP also requires considerable knowledge of the process, instrumentation and operations.

The process is systematic and helpful towards defining the terms that are used:

(a) **Study Nodes:** These locations are on pipings, instrumentation drawings and procedures, at which the process parameters are investigated for deviations.

(b) **Intention:** The intention defines how the plant is expected to operate in the absence of deviations at the study nodes. This can take a number of forms and can either be descriptive or diagrammatic e.g., flow sheets, line diagrams, p & Ids.

(c) **Deviations:** These are departures from the original intention, which are discovered by systematically applying the guide words (e.g. "more pressure").

(d) **Causes:** These are the reasons why deviations might occur. Once a deviation has been shown to have a credible cause, it can be treated as a meaningful deviation.

(e) **Consequences:** These are the results of the deviations, should they occur (e.g., release of toxic materials).

(f) **Guide words:** These are simple words which are used to qualify or quantify the intention in order to guide and stimulate the brainstorming process and so discover deviations. The guide words are shown in the Table given below. Each guide word is applied to the process variables at the point in the plant (study node) which is being examined. For example

Guide Words		Parameter	Deviation
NO	&	FLOW	NO FLOW
MORE	&	PRESSURE	HIGH PRESSURE
AS WELL AS	&	ONE PHASE	TWO PHASE
OTHER THAN	&	OPERATION	MAINTENANCE

17.3. GUIDELINES FOR USING PROCEDURES

The concepts presented above are put into practice in the following steps:

1. Define the purpose, objectives and scope of the study
2. Select the team
3. Prepare for the study

4. Carry out the team review
5. Record the results

It is important to recognise that some of these steps can take place at the same time. For example, the team reviews the design, records the findings, and follows up on the findings, simultaneously. Nonetheless, each step is discussed below as a separate item.

17.3.1. Define the Purpose, Objectives and Scope of the Study

The purpose, objectives and scope of the study should be made as explicit as possible. These objectives are normally set by the person responsible for the plant or project, who is assisted by the HAZOP study leader, or perhaps the plant corporate safety officer. It is important that this interaction takes place to help the proper authority the hazards or plant study and to ensure that the study is focused. Also, even though the general objective is to identify hazards and operability problems, the team should focus on the underlying purpose or reasons for the study. Examples of reasons for a study might be to:

- Check the safety of the design
- Decide whether and where to build?
- Develop a list of questions to ask a supplier
- Check operating/safety procedures
- Improve the safety of an existing facility
- Verify that safety instrumentation is reacting to the best parameters

17.3.2. Select the Team

Ideally, the team consists of five to seven members, although a smaller team coul be sufficient for a smaller plant. For example, a team might include:

- Design Engineer
- Process Engineer
- Operations Supervisor
- Instrument Design Engineer
- Chemist
- Maintenance Supervisor
- Safety Engineer (if not HAZOP leader)

17.3.3. Prepare for the Study

The amount of preparation depends upon the size and complexity of the plar The preparatory work consists of three stages

- obtaining the necessary data
- converting the data to a suitable form

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17.3.3. Prepare for the Study

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- obtaining the necessary data
- converting the data to a suitable form

- planning the study sequence and
- arranging the meetings.

- **Obtaining the Necessary Data:** Typically, the data consists of various drawings in the form of the diagrams, flow sheets, plant layouts, isometrics and fabrication drawings. Additionally, there can be operating instructions, instrument sequence control charts, logic diagrams and computer programmes. Occasionally, there are plant manuals and equipment manufacturers' manuals. The data must be inspected to make sure that it pertains to the defined area of study and contains no discrepancies or ambiguities.
- **Convert the Data into a Suitable Form and Plan the Study Sequence:** The amount of work required in this stage depends on the type of plant. With continuous plants, the preparatory work is minimal. The study team starts at the beginning of the process and progressively works downstream, applying the guide words at specific study nodes.
  With batch plants, the preparatory work is usually more extensive, primarily because of the more extensive need for manual operations; thus, operation sequences are a larger part of the HAZOP. This operation information can be obtained from operating instructions, logic diagrams or instrument sequence diagrams.
- **Arrange the Necessary Meetings:** Once the data has been assembled and the equipment representations made (if necessary) the team leader is in a position to plan meetings.

17.3.4. Carry-out the Team Review

The HAZOP study requires that the plant system be divided into study nodes and that the process at these points be addressed with the guide words, as shown in the Figure given ahead.

- A suggested action is found for each hazard as it is detected before looking for the next hazard.
- No search for suggested actions is started, until all hazards have been detected.

In practice, there is a compromise. It may not be appropriate or even possible for a team to find a solution during the meeting. On the other hand, if the solution is straightforward, a decision can be made and the design and operating instructions modified immediately.

17.3.5. Record the Results

The recording process is an important part of the HAZOP study. It is impossible to manually record all that is said, yet it is very important that all ideas are kept. It is very useful to have the team members review the final report and then come together for a report review meeting.

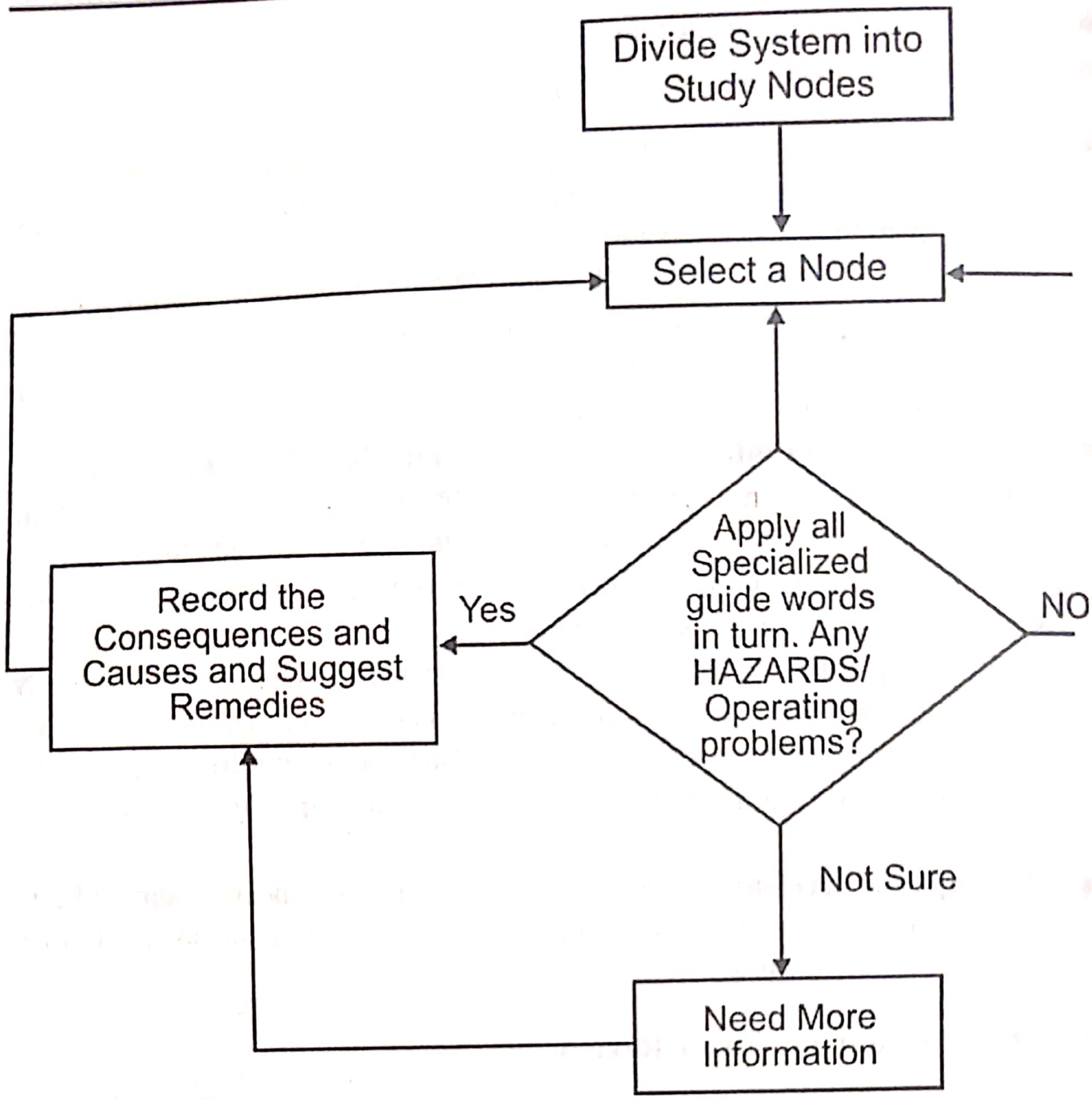

Figure - 1: HAZOP Method Flow diagram

17.4. HAZOP TECHNIQUES

A HAZOP form should be filled out during the meeting (a sample is given below)

Process Unit: DAP Production
Node: 1 Process Parameter: Flow

Guide	Deviation	Consequences	Causes	Suggested Action
No	No Flow	Excess ammonia in reactor. Release to work area	1. Valve A fails closed 2. Phosphoric acid supply exhausted 3. Plug in pipe; pipe ruptures	Automatic closure of valve B on loss of flow from phosphoric acid supply
Less	Less Flow	Excess ammonia in reactor. Release	1. Valve A partially closed	Automatic closure of valve B on loss of flow

		to work area, with amount released related to quantitative reduction in supply. Team member to calculate toxicity vs. flow reduction	2. Partial plug or leak in pipe	from phosphoric acid supply
More	More Flow	Excess phosphoric acid degrades product. No hazard to work area	———	———
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	1. Vendor delivers wrong material or concentration 2. Error in charging phosphoric acid supply tank	Check phosphoric acid supply tank concentra tion after charging.

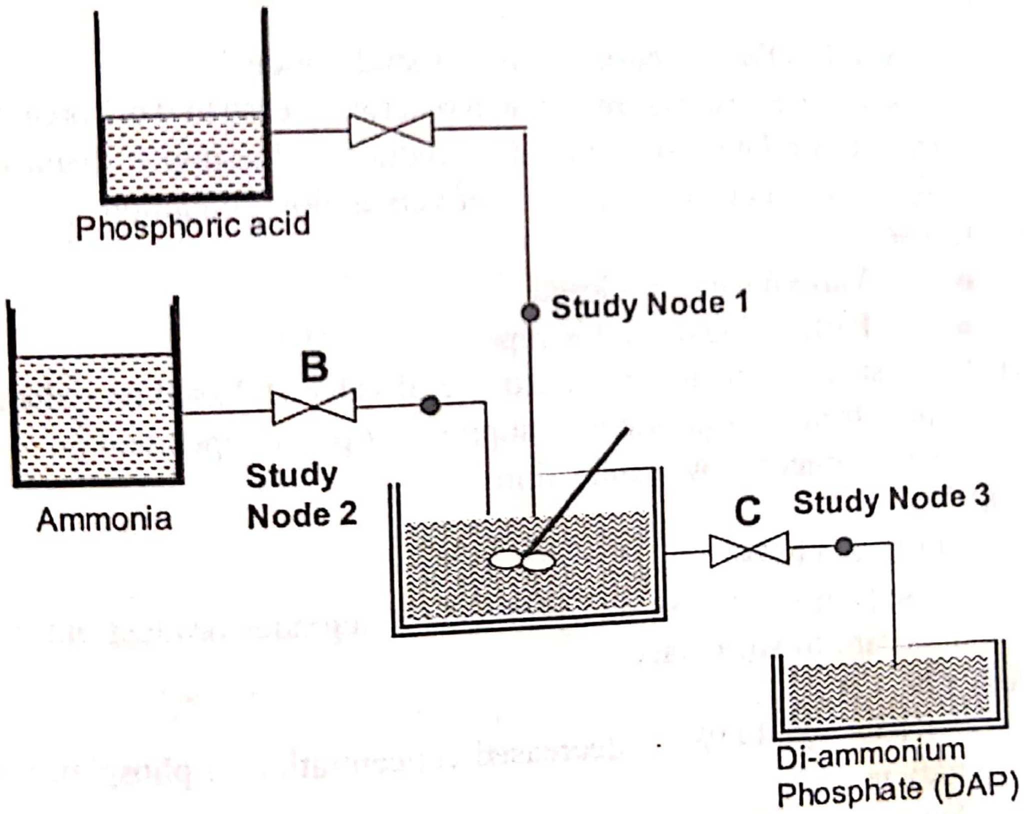

Figure 17.2. Continous Process Example for Hazop Technique

SAMPLE OF HAZOP WORKSHEET

Example – 1

Consider, as a simple example, the continuous process shown in Figure 2. In this process, the 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. The HAZOP team is assigned to investigate "Personal Hazards from the Reaction".

The team leader starts with a study node and applies the guide words to the process parameters. Thus, for study node 1:

I). NO

(a) NO & FLOW – no flow at study node 1

(b) Consequences : excess ammonia in reactor; and release to work area

(c) Causes

- Valve A fails, closed
- Phosphoric acid supply exhausted
- Plug in pipe, pipe ruptures

(d) Suggested action: automatic closure of valve B on loss of flow from phosphoric acid supply

II). LESS

(a) LESS & FLOW — reduced flow at study node 1

(b) Consequences: excess ammonia in reactor, release to work area. Amount released is related to quantitative reduction in supply. Team member assigned to calculate toxicity level versus flow reduction

(c) Causes :

- Valve A partially closed
- Partial plug or lead in pipe

(d) Suggested action: automatic closure of valve B, based on reduced flow in pipe from phosphoric acid supply. Set point dependent on toxicity versus reduced flow calculations.

III) MORE

(a) MORE & FLOW

(b) Consequences: excess phosphoric acid degrades product but, presents no hazard to workplace.

(IV) PART OF

(a). PART OF & FLOW — decreased concentration of phosphoric acid at study node 1

(b). Consequences: see II. B (low flow sequence)

(c). Causes

- Vendor delivers wrong material or concentration
- Error in charging phosphoric acid supply tank

(d). Suggested Action : check phosphoric acid supply tank concentration after charging procedures

V) AS WELL AS

(a). AS WELL AS & FLOW — increase concentration of phosphoric acid (not a realistic consideration, since the highest available concentration is used to charge supply).

VI) REVERSE

(a) REVERSE & FLOW — reverse flow at study node 1

(b) Consequences

(c) Causes: no reasonable mechanism for reverse flow

VII. OTHER THAN

(a) OTHER THAN & FLOW — material other than phosphoric acid in line A

(b) Consequences : Depends on substitution; team member assigned to test potential substitutions, based on availability of other materials at site and similarity in appearance

(c) Causes:

- wrong delivery from vendor
- wrong material chosen from plant warehouse

(d) Recommended Action: Plant procedures to provide check on material chosen, before charging phosphoric acid supply tank.