HAZOP

Hazard And Operability Analysis

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INTRODUCTION

In 1963 a team of 3 persons was organizing 3 days meetings per week, during 4 months, to study the design of a new phenol plant.

They started with a technique called ”critical examination” asking for alternatives, but changed this to „look for deviations”.

The method was further refined within the company, under the name ”operability studies”, and became the third stage of its hazard analysis procedure (the first two were done at the conceptual and specification stages) when the first detailed design appeared.

HAZOP history

- Used widely in chemical industry after the Flixborough disaster in 1974 (28 killed).
- First guide: “A Guide to Hazard and Operability Studies”, ICI and Chemical Industries Associations Ltd. 1977.
- First main textbook: Kletz, T. A.: “Hazop and Hazan – Identifying and Assessing Process Industry Hazards”, Institution of Chemical Engineers.
- HAZOP methodology may be found within IEC International Standard 61882, Hazard and Operability Studies (HAZOP) Application Guide.

Overview

- Hazard and Operability Analysis (HAZOP) is a structured and systematic technique for system examination and risk management. In particular, HAZOP is often used as a technique for identifying potential hazards in a system and identifying operability problems likely leading to nonconforming products.
- HAZOP is based on a theory assuming that risk events are caused by deviations from design or operating intentions. Identification of such deviations is facilitated by using sets of “guide words” as a systematic list of deviation perspectives.

Overview

As a risk assessment tool, HAZOP is often described as:

- A brainstorming technique
- A qualitative risk assessment tool
- An inductive risk assessment tool, meaning that it is a “bottom-up” risk identification approach, where success relies on the ability of subject matter experts (SMEs) to predict deviations based on past experiences and general subject matter expertise

Definitions

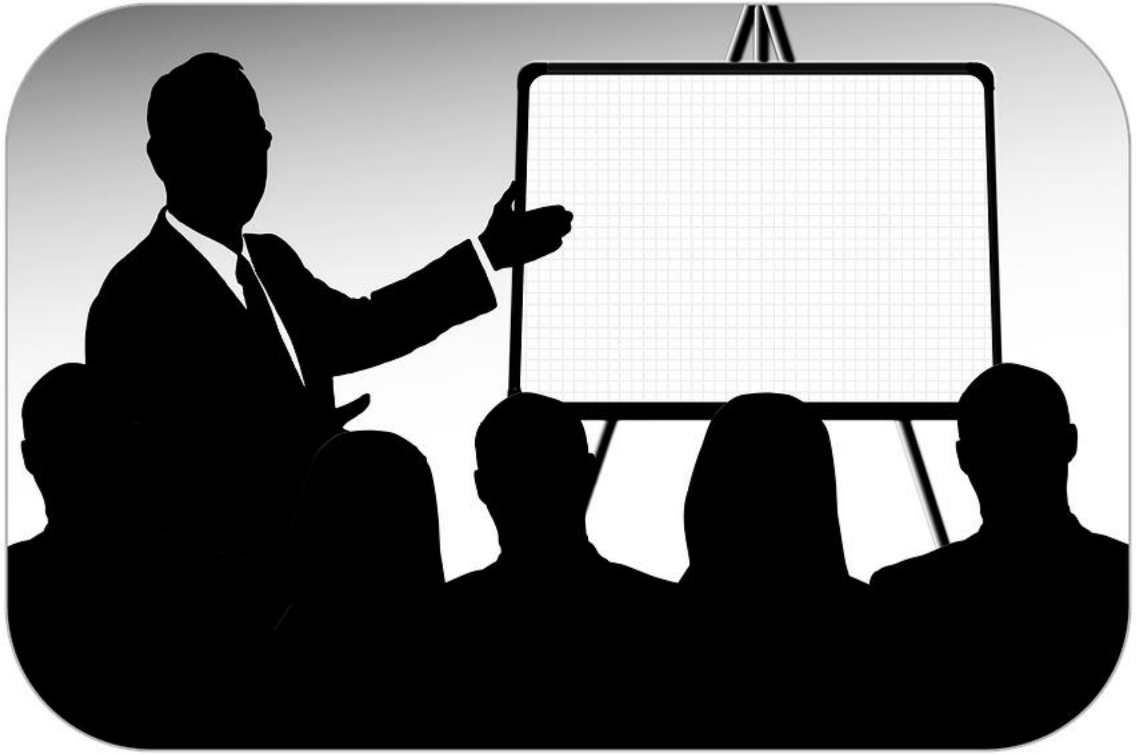
When describing the HAZOP methodology, the following definitions are useful:

- **Hazard** - Potential source of harm. Deviations from design or operational intent may constitute or produce a hazard. Hazards are the focus of HAZOP studies, and it should be noted that a single hazard could potentially lead to multiple forms of harm.
- **Harm** - Physical injury or damage to the health of people or damage to property or the environment. Harm is the consequence of a hazard occurring and may take many forms: patient or user safety, employee safety, business risks, regulatory risks, environmental risks, etc.
- **Risk** - Combination of probability of occurrence of harm and the severity of that harm. In a strict sense, “risk” is not always explicitly identified in HAZOP studies since the core methodology does not require identification (also referred to as rating) of the probability or severity of harm. However, risk assessment teams may choose to rate these factors in order to further quantify and prioritize risks if needed.

HAZOP team

HAZOP requires a multidisciplinary team (maximum 6-10 members):

- HAZOP team leader
- HAZOP secretary
- HAZOP team members
  - Process Engineer
  - Design Engineer
  - Operation supervisor
  - Maintenance supervisor
  - Specialist(s)



Team member responsibilities

HAZOP team leader

- Define the scope for the analysis
- Select HAZOP team members
- Plan and prepare the study
- Chair the HAZOP meetings
  - Trigger the discussion using guide-words and parameters
  - Follow up progress according to schedule/agenda
  - Ensure completeness of the analysis

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

Team member responsibilities

HAZOP secretary

- Prepare HAZOP work-sheets
- Record the discussion in the HAZOP meetings
- Prepare draft report(s)

Team member responsibilities

HAZOP team members

- The basic team for a process plant may be:
  - Project engineer
  - Commissioning manager
  - Process engineer
  - Instrument/electrical engineer
  - Safety engineer
- Depending on the actual process the team may be enhanced by:
  - Operating team leader
  - Maintenance engineer
  - Suppliers representative
  - Other specialists as appropriate

Prerequisites

As a basis for the HAZOP study the following information should be available:

- Process flow diagrams
- Piping and instrumentation diagrams (P&IDs)
- Layout diagrams
- Material safety data sheets
- Provisional operating instructions
- Heat and material balances
- Equipment data sheets start-up and emergency shut-down procedures

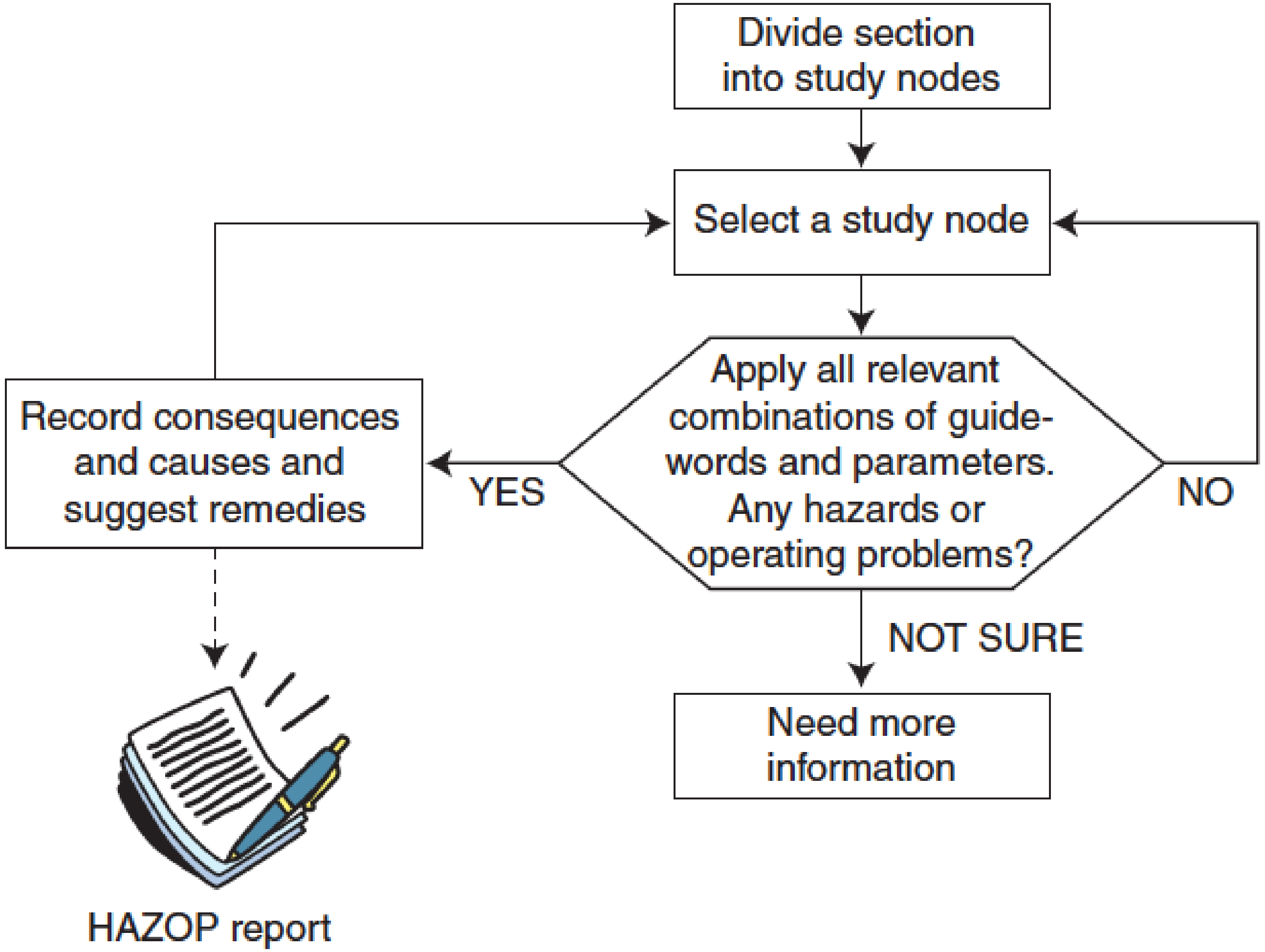
HAZOP procedure

1. Divide the system into sections (i.e., reactor, storage)
2. Choose a study node (i.e., line, vessel, pump, operating instruction)
3. Describe the design intent
4. Select a process parameter
5. Apply a guide-word
6. Determine cause(s)
7. Evaluate consequences/problems
8. Recommend action: What? When? Who?
9. Record information
10. Repeat procedure (from step 2)

HAZOP procedure

The HAZOP procedure

may be illustrated as follows:



HAZOP work-sheet

The HAZOP work-sheets may be different depending on the scope of the study – generally the following entries (columns) are included:

- Ref. no.
- Guide-word
- Deviation
- Possible causes
- Consequences
- Safeguards
- Actions required (or, recommendations)
- Actions allocated to (follow-up responsibility)

Work-sheet entries

Node

A node is a specific location in the process in which (the deviations of) the design/process intent are evaluated. Examples might be: separators, heat exchangers, scrubbers, pumps, compressors, and interconnecting pipes with equipment.

Design intent

The design intent is a description of how the process is expected to behave at the node: 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.

Work-sheet entries

Deviation

A deviation is a way in which the process conditions may depart from their design/process intent.

Parameter

The relevant parameter for the condition(s) of the process (e.g. pressure, temperature, composition).

Guideword

A short word to create the imagination of a deviation of the design/process intent.

Work-sheet entries

Guideword

The most commonly used guide-words are:

- no,
- more,
- less,
- as well as,
- part of,
- other than,
- and reverse.

Work-sheet entries

Guideword

In addition, guidewords such as too early, too late, instead of, are used; the latter mainly for batch-like processes. The guidewords are applied, in turn, to all the parameters, in order to identify unexpected and yet credible deviations from the design/process intent.

Guide-word + Parameter → Deviation

Work-sheet entries

Cause

The reason(s) why the deviation could occur. Several causes may be identified for one deviation. It is often recommended to start with the causes that may result in the worst possible consequence.

Consequence

The results of the deviation, in case it occurs. Consequences may both comprise process hazards and operability problems, like plant shut-down or reduced quality of the product. Several consequences may follow from one cause and, in turn, one consequence can have several causes

Work-sheet entries

Safeguard

Facilities helping to reduce the occurrence frequency of the deviation or to mitigate its consequences.

Safeguard types (examples)

- Identify the deviation (e.g., detectors and alarms, and human operator detection)
- Compensate for the deviation (e.g., an automatic control system that reduces the feed to a vessel in case of overfilling it. These are usually an integrated part of the process control)
- Prevent the deviation from occurring (e.g., an inert gas blanket in storages of flammable substances)
- Prevent 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 computers)
- Relieve the process from the hazardous deviation (e.g., pressure safety valves (PSV) and vent systems)

Process parameters

Process parameters may be generally 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 tangible parameters related to batch type processes
- Parameters related to system operations

Process parameters

The parameters related to system operations are not necessarily used in conjunction with guide-words:

- Instrumentation
- Relief
- Start-up / shutdown
- Maintenance
- Safety / contingency
- Sampling

Examples of process parameters

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

Process HAZOP work-sheet

<table>
<tr><td colspan="7">Study title:</td><td colspan="3">Page: of</td></tr>
<tr><td colspan="3">Drawing no.:</td><td colspan="4">Rev no.:</td><td colspan="3">Date:</td></tr>
<tr><td colspan="7">HAZOP team:</td><td colspan="3">Meeting date:</td></tr>
<tr><td colspan="10">Part considered:</td></tr>
<tr><td colspan="3">Design intent:</td><td colspan="7">Material: Activity:
Source: Destination:</td></tr>
<tr><td>No.</td><td>Guide-word</td><td>Element</td><td>Deviation</td><td>Possible causes</td><td>Conse-quences</td><td>Safeguards</td><td>Comments</td><td>Actions required</td><td>Action allocated to</td></tr>
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– Source: IEC 61882

Report contents

- Introduction
- System definition and delimitation
- Documents (on which the analysis is based)
- Methodology
- Team members
- HAZOP results
  - Reporting principles
  - Classification of recordings
  - Main results

Appendix 1: HAZOP work-sheets

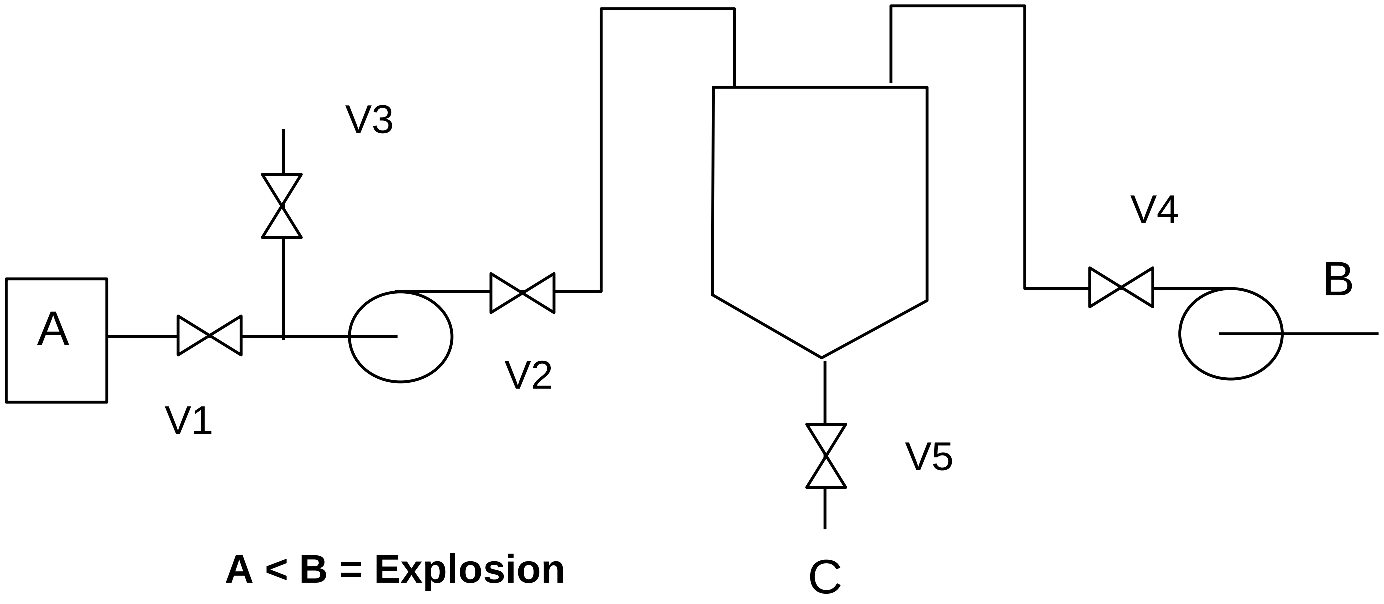
Appendix 2: P&IDs (marked)

HAZOP Results

- Improvement of system or operations
  - Reduced risk and beer contingency
  - More efficient operations
- Improvement of procedures
  - Logical order
  - Completeness
- General awareness among involved parties
- Team building

HAZOP Example

Consider the simple process diagram below. It represents a plant where substances A and B react with each other to form a new substance C. If there is more B than A there may be an explosion.



HAZOP Example

The HAZOP sheet for the section of the plant from A to C will be as follows:

Guide Word	Deviation	Possible Causes	Consequences	Proposed Measures
NO, NOT	No A	Tank containing A is empty. V1 or V2 closed. Pump does not work. Pipe broken	Not enough A = Explosion	Indicator for low level. Monitoring of flow
MORE	Too much A	Pump too high capacity Opening of V1 or V2 is too large.	C contaminated by A. Tank overfilled.	Indicator for high level. Monitoring of flow
LESS	Not enough A	V1,V2 or pipe are partially blocked. Pump gives low flow or runs for too short a time.	Not enough A = Explosion	See above
AS WELL AS	Other substance	V3 open – air sucked in	Not enough A = Explosion	Flow monitoring based on weight
REVERSE	Liquid pumped backwards	Wrong connector to motor	Not enough A = Explosion A is contaminated	Flow monitoring
OTHER THAN	A boils in pump	Temperature too high	Not enough A = Explosion	Temperature (and flow) monitoring.

Types of HAZOP

- Process HAZOP
  - The HAZOP technique was originally developed to assess plants and process systems
- Human HAZOP
  - A “family” of specialized HAZOPs. More focused on human errors than technical failures
- Procedure HAZOP
  - Review of procedures or operational sequences sometimes denoted SAFOP – SAFe OPeration study
- Software HAZOP
  - Identification of possible errors in the development of software

HAZOP - Advantages

- Systematic examination
- Multidisciplinary study
- Utilizes operational experience
- Covers safety as well as operational aspects
- Solutions to the problems identified may be indicated
- Considers operational procedures
- Covers human errors
- Study led by independent person
- Results are recorded

Success factors

- Accuracy of drawings and data used as a basis for the study
- Experience and skills of the HAZOP team leader
- Technical skills and insights of the team
- Ability of the team to use the HAZOP approach as an aid to identify deviations, causes, and consequences
- Ability of the team to maintain a sense of proportion, especially when assessing the severity of the potential consequences.

Pitfalls and objections

- Time consuming
- Focusing too much on solutions
- Team members allowed to divert into endless discussions of details
- A few of the team members dominate the discussion
  - “This is my design/procedure”
  - Defending a design/procedure
  - HAZOP is not an audit
- “No problem”
- “Wasted time”

MANHAZ

Thank You for attention