Hazard and Operability (HAZOP) Studies

Background.
A HAZOP study identifies hazards and operability problems. The concept involves investigating how the plant might deviate from the design intent. If, in the process of identifying problems during a HAZOP study, a solution becomes apparent, it is recorded as part of the HAZOP result; however, care must be taken to avoid trying to find solutions which are not so apparent, because the prime objective for the HAZOP is problem identification. Although the HAZOP study was developed to supplement experience based practices when a new design or technology is involved, its use has expanded to almost all phases of a plant's life. HAZOP is based on the principle that several experts with different backgrounds can interact and identify more problems when working together than when working separately and combining their results. The "Guide-Word" HAZOP is the most well known of the HAZOPs; however, several specialisations of this basic method have been developed.

Concept.
The HAZOP concept is to review the plant in a series of meetings, during which a multidisciplinary 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. Consequently the process requires that all team members participate (quantity breeds quality in this case), and team members must refrain from criticizing each other to the point that members hesitate to suggest ideas. The team focuses on specific points of the design (called "study nodes"), one at a time. At each of these study nodes, deviations in the process parameters are examined using the guide words. The guide words are used to ensure that the design is explored in every conceivable way. Thus the team must identify a fairly large number of deviations, each of which must then be considered so that their potential causes and consequences can be identified. The best time to conduct a HAZOP is when the design is fairly firm. At this point, the design is well enough defined to allow meaningful answers to the questions raised in the HAZOP process. Also, at this point it is still possible to change the design without a major cost. However, HAZOPs can be done at any stage after the design is nearly firm. For example, many older plants are upgrading their control and instrumentation systems.

The success or failure of the HAZOP depends on several factors:
- The completeness and accuracy of drawings and other data used as a basis for the study
- The technical skills and insights of the team
- The ability of the team to use the approach as an aid to their imagination in visualizing deviations, causes, and consequences
- The ability of the team to concentrate on the more serious hazards which are identified.

The process is systematic and it is helpful to define the terms that are used:
a. **STUDY NODES** - The locations (on piping and 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., flowsheets, line diagrams, P&IDS.
c. **DEVIATIONS** - These are departures from the 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. These causes can be hardware failures, human errors, an unanticipated process state (e.g., change of composition), external disruptions (e.g., loss of power), etc.
e. **CONSEQUENCES** - These are the results of the deviations should they occur (e.g., release of toxic materials). Trivial consequences, relative to the study objective, are dropped.
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 shown in the following table are the ones most often used in a HAZOP; some organisations have made this list specific to their operations, to guide the team more quickly to the areas where they have previously found problems. Each guide word is applied to the process variables at the point in the plant (study node) which is being examined.

HAZOP GUIDE WORDS AND MEANINGS

Guide Word	Meaning
No	Negation of the Design Intent
Less	Quantitative Decrease
More	Quantitative Increase
Part Of	Qualitative Decrease
As Well As	Qualitative Increase
Reverse	Logical Opposite of the Intent
Other Than	Complete Substitution

These guide words are applicable to both the more general parameters (e.g. react, transfer) and to the more specific parameters (e.g. pressure, temperature, flow). With the general parameters, meaningful deviations are usually generated for each guide word. Moreover, it is not unusual to have more than one deviation from the application of one

guide word. For example, "more reaction" could mean either that a reaction takes place at a faster rate, or that a greater quantity of product results.
With the specific parameters, some modification of the guide words may be necessary. In addition, it is not unusual to find that some potential deviations are eliminated by physical limitation. For example, if the design intention of a pressure or temperature is being considered, the guide words “more” or "less" may be the only possibilities.

Finally, when dealing with a design intention involving a complex set of interrelated plant parameters (e.g., temperatures, reaction rates, composition, or pressure), it may be better to apply the whole sequence of guide words to each parameter individually than to apply each guide word across all of the parameters as a group. Also, when applying the guide words to a sentence it may be more useful to apply the sequence of guide words to each word or phrase separately, starting with the key part which describes the activity (usually the verbs or adverbs). These parts of the sentence usually are related to some impact on the process parameters.

Guidelines for Using Procedure
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.
6. Follow up to ensure results are implemented.

It is important to recognize 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 continuously.
(Refer also to the diagrammatic representation of the HAZOP procedure attached).

Detailed Listing of HAZOP guide words:

Guide Word (By Node)

High Flow , High level
Low Flow, Low level
Zero Flow, Empty
Reverse Flow
High pressure (venting, relief rate)
Low pressure (venting, relief rate)
High temperature
Low temperature
Impurities (Gaseous, Liquid, Solid)
Change in composition / Change in concentration / Two phase flow / Reactions
Testing (Equipment / Product)
Plant items (Operable / maintainable)
Electrical (Area Classification / Isolation / Earthing)
Instruments (Sufficient for control / Too many / Correct location)

Guide Word (Overview)

Toxicity
Services Required
Materials of Construction
Commissioning
Start-up
Shut-down (Isolation, Purging)
Breakdown (Power failure, Air, Steam, Water, Vacuum, Fuel, Vents, Computer, Other)
Effluent (Gaseous, Liquid, Solid
Noise (Sources, Problem, Control measures)
Fire / Explosion
Safety Equipment (Personal, Fire detection, Fire fighting, Means of escape)
Quality and Consistency
Output - Reliability and bottlenecks
Efficiency - Losses
Simplicity

The HAZOP Report

Aims
The report should provide sufficient information on each element so that, either read alone or together with available and clearly cross referenced documents, an assessment can be made of the adequacy of the HAZOP study carried out.

Title Page
The study title should be displayed both on the cover and on a separate title sheet. The title should clearly and unambiguously identify the facility covered by the Study. The title page should also show the type of operation, whether it is a proposed operation or an existing facility and its location.
The title sheet should specify on whose authority the report was prepared and the date it was authorised. The name/s/ of the chairperson and organisation she or he represents should be stated.

Table of Contents
A table of contents should be included at the beginning of the report. It should include a list of figures, tables and appendices.

Glossary and Abbreviations
A glossary of any special terms or titles and a list of abbreviations should be included to ensure that the report can be readily and clearly understood.

Summary of Main Findings and Recommendations
This Summary should briefly outline the nature of the proposal or existing facility and the scope of the report. A list of the main conclusions and recommendations arising from the HAZOP should be presented. An indicative implementation timetable is also useful.

Scope of Report
This section should give a brief description of the aims and purpose of the study and the reason for its preparation. For example, is the study being prepared to satisfy conditions of development consent or at the company's initiative as part of safety upgrading? Is it for an entirely new development or for the modification of, or extension to, an existing development? Reference should be made to any other relevant safety related studies completed or under preparation.

Description of the Facility
This section should give an overview of the site, plant and materials used/stored. Where this information is already available through an EIS, hazard analysis or other document, clear cross reference to these documents or inclusion in the form of appendices would suffice.
The description should include: a) Site locational sketch with identification of adjacent/surrounding land uses. b) A schematic diagram of the plant under study along with a brief description of each process step involved. The location and nature of raw materials and product storage should also be shown as well as loading/unloading facilities. The plant does not have to be described in detail, though some process conditions such as pressure in pressurised vessels may be necessary to gain an understanding of the plant. c) Clearly identified P&IDs with plant and line numbers as used in the HAZOP. Instrumentation and equipment symbols should be explained. Alternatives used (photographs, plans, etc.) should also carry appropriate identification. Where a large number of P&IDs are involved in the study, only those relevant to the recommendations need be appended to the report.

HAZOP Team Members
This section should list the HAZOP participants, together with their affiliations and positions. Their responsibility, qualifications, and relevant experience should also be given. The chairperson and the secretary of the group should also each be identified. The dates of the meetings and their duration should be provided. Where some members were not present at all meetings, the extent of their participation should be indicated. Special visitors and occasional members should be listed in a manner similar to the continuing members, with the reasons for their attendance detailed. For example, specialist instrumentation engineer/consultants may be required to overcome specific design problems.

HAZOP Methodology
The general approach used should be briefly outlined. Any changes to the accepted standard methodology used for a HAZOP should be detailed and explained.

Guide Words
The guide words used to identify possible deviations in this HAZOP should be listed. An explanation of any specialised words used for the facility should also be given.

Plant Overview
This section should outline what general conditions and situations likely to result in a potentially hazardous outcome were considered in the HAZOP (following line by line analysis) for the overall P&ID or section including overview issues, such as:
• first start-up procedures
• emergency shutdown procedures
• alarms and instrumentation trip testing
• pre-commissioning operator training
• plant protection systems
• failure of services
• breakdowns
• effluent (gas, liquid, solid/
• noise.
Any issues raised and considered necessary for review outside the HAZOP should be detailed.
A set of overview guide words is included in Appendix 1.

Analysis of Main Findings
An indication of the criteria used to determine whether or not action was chosen to be taken regarding the outcome of a deviation is required.
The results of the HAZOP, giving deviations, consequences and actions required, should be provided. Those events on which the decision of no action was made should also be listed, along with the events for which consequence or risk analysis was considered necessary. The decisions made after such further analyses should also be given. Any alternative actions generated and considered should be detailed.

Actions Arising from the HAZOP
This section should highlight those actions which are potentially hazardous to plant personnel, the public or the environment or have the potential to jeopardise the operability of the plant. Also included should be a clear statement of commitment to modify the design or operational procedures in accordance with the identified required actions and a timetable for implementation. Justification as to why no action was chosen for any actions identified should also be made. The current status of the recommended actions at the time of the report should also be given together with the names/designations of persons responsible for their implementation.