Safety & Risk Management Services

Hazard Operability Studies (HAZOP)

Germanischer Lloyd – Service/Product Description
Hazard Operability Studies (HAZOP)

Service Title: Safety & Risk Management Services
Lead Practice: GL Safety & Risk (UK)

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Motivation
The hazard and operability study (HAZOP) is a creative technique for identifying hazards and operating problems in a process plant. Nowadays it is widely used in industry and is offered by Germanischer Lloyd (GL) for new and existing facilities.

Increasing demand by governments and public bodies for improved safety in addition to a strong awareness within the industry that safe operation can also be highly efficient and profitable, support the need for plant safety and effective safety management. Advances in technology and trends to highly complex and integrated plant designs have sensitised people for systematic and sustainable methods to identify hazards of which the HAZOP study is generally recognised as the foremost solution being able to cover standard and also new complex technology.

The operator of a technical installation by which health and safety, the environment, assets and the operator’s reputation could be affected is obliged e.g. by European legislation to:

- have an up-to-date knowledge about all safety relevant aspects of their operations,
- prevent accidents or to limit their impacts/escalations (acc. to Seveso II Directive),
- control hazards reliably and to minimise risks by identifying installations with risk potential regarding health and safety as well as the environment, evaluating their inherent risks and specifying risk mitigation measures (which is part of the risk management process),
- design, start up, operate and maintain workplaces in such a manner that the workforce can conduct work without putting their own safety and health or that of others at risk (§2 Abs.1 Allg. Bundesbergverordnung ABBergV, §3 ArbSchG).

Objectives
The primary objective of a HAZOP study is to identify potential hazards and operating problems on e.g. a process plant. Performed by a multi-disciplinary team which applies the HAZOP structured brainstorming technique all possible deviations from normal operating conditions are examined in detail and their reasons and consequences are assessed. The detailed insight into the plant is supported by dividing the plant into manageable sections, so called ‘nodes’. Specific ‘parameters’ and ‘guidewords’ are used to focus the team towards likely design issues in each section of the plant. Once identified, potential ‘deviations’ from the standard operating or design conditions may then be discussed and assessed by the team with respect to their effect on safety. Subsequently the implemented safeguards are identified and where considered necessary recommendations for action or further consideration are recorded and presented in the form of the HAZOP Report. The necessity of additional safeguards/recommendations can either be evaluated by the team on a qualitative basis or by means of a risk matrix.

HAZOP studies may be held at any time during the design and operation of a plant. Most effectively they are conducted during the conceptual design phase where recommendations affecting the general design may be made.

The analysis serves the operator as a proof to operate his installations such that hazards for employees, third parties, the environment and the surroundings can largely be excluded. The operator’s management gets an up-to-date picture of the present hazards, their possible effects and ways to solve these issues.

Frequency of Reviews
HAZOP analyses are usually to be revised when considerable modifications, upgrades or re-design of existing facilities are carried out or if events like accidents, critical situations or near misses call for this. In this context a change, upgrade or re-design is to be considered as essential if process modifications associated with consequences for safety or safety related equipment is involved. This also applies for utilities including buildings, machinery, equipment et al. that do not necessarily contribute to the operating objective directly but that are associated with the process facilities in terms of layout or operational-wise and that are safety relevant. Those being in charge of operations and those working in the facilities are obliged to indicate all identified possible changes. In principle operators are expected to repeat the analyses at least every 5 years in order to maintain the residual risk as low as reasonable practical.

Offered Service
The success of the HAZOP technique strongly depends on the skills and experience of the facilitator in preparing and running the study. A sufficient depth to derive all the potential hazards and safety related operability problems and on the other hand the avoidance of a time consuming design review which is out of scope for a HAZOP are essential for the effectiveness and quality of the sessions. The service offered in this matter is the provision of an experienced facilitator/chairman that leads through the HAZOP sessions supported by an experienced minute taker/scribe who notes down the relevant results into the prepared HAZOP spreadsheet. Depending on clients’ needs in house spreadsheets or a special HAZOP software tool will be used by the HAZOP management team. Subsequently upon completion of the sessions a report will be prepared by the HAZOP chairman and submitted to the client.

Potential Clients
a. Operators in the oil, gas and (petro-, bio-) chemical business carrying out green-field and brown-field projects. The service can be rendered beginning in the FEED stage of a project.
b. Investors, insurers of above named enterprises.
The success of the HAZOP study depends upon an effective system for working through the items of the study. Germanischer Lloyd provides this effective system through the experience gained from several HAZOP studies and the theoretical and practical departmental expertise.

As a first step, the definition of scope is considered with respect to the special requirements of the client before the required data are collected by the HAZOP team and/or HAZOP facilitator. The plant or process under investigation is divided into a number of suitable units, the HAZOP nodes. Each node is the topic of a HAZOP session, conducted under the supervision of a GL team leader/facilitator who is an expert in the HAZOP technique. GL will also provide an experienced minute taker/scribe to assist the facilitator by entering the team’s brain-storming outcomes into the spreadsheets/software during the ongoing discussions. Each HAZOP session takes 1 ½ … 3 hours, depending on the scope of the item under discussion and on the plant or process itself – new or existing. A HAZOP on a large project may consist of a large number of nodes and respectively require several weeks to be performed.

HAZOP technique assumes that the plant management is competent and that the plant or process under investigation will be operated and maintained as intended by the design team and in accordance with good management and engineering practice.

The HAZOP study starts with a systematic examination of the plant or process with a depth depending on the level of detail required.

A list of guide words is applied to each part of the plant or process, thereby generating deviations from normal operating conditions with respect to all conceivable eventualities. Apart from normal operations the following deviations are considered and listed for all guidewords of each HAZOP: foreseeable changes to start-up and shut-down procedures, maintenance, etc. Each deviation is checked for possible causes and consequences; potential problems are identified and noted, and the need for action is decided by taking into account both the significance of the consequence(s) and the probability of the event occurring.

If necessary, a team member explains the function of the item under investigation, including normal process conditions and specifications if available, to ensure that all team members have the background knowledge of the item examined.

In general to search for possible deviations each HAZOP item is examined by applying the guide words

- **NONE**
- **REVERSE**
- **MORE OF**
- **LESS OF**
- **PART OF**
- **MORE THAN**
- **OTHER THAN**

Depending on the item, the following deviations may be considered.

<table>
<thead>
<tr>
<th>Guide Word</th>
<th>Deviation from design intention</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONE</td>
<td>No part of the intended result is achieved and nothing else happens</td>
<td>No operation, damage, wrong process routing, other failures</td>
</tr>
<tr>
<td>REVERSE</td>
<td>Opposite (logical) operation</td>
<td>Backflow</td>
</tr>
<tr>
<td>MORE OF</td>
<td>Quantitative increase</td>
<td>Flow, pressure, temperature, concentration</td>
</tr>
<tr>
<td>LESS OF</td>
<td>Quantitative decrease</td>
<td>See MORE OF</td>
</tr>
<tr>
<td>PART OF</td>
<td>Qualitative decrease</td>
<td>Number of components in a mixture, phase change, specifications</td>
</tr>
<tr>
<td>MORE THAN</td>
<td>Increase of components present in the system</td>
<td>Extra phase impurities, air ingress</td>
</tr>
<tr>
<td>OTHER THAN</td>
<td>Something completely different happens</td>
<td>Emergency shut-down alternative operation, made (service maintenance, etc.)</td>
</tr>
</tbody>
</table>

The item under investigation, e.g. a flow, is examined by applying the guide words, e.g. MORE OF. As a first step, possible causes for ‘more flow’ (deviation from normal forward flow) are considered. If ‘more flow’ is not possible, the team leader/HAZOP team moves on to the next deviation. If ‘more flow’ is possible, but does not prevent efficient operation (and is considered not to affect safety), other causes of ‘more flow’ are to be considered. If a possible cause can lead to hazardous situation(s), further consequences (detection of the deviation, change in plant or method to prevent ‘more flow’, etc.) are discussed and action(s) required are noted and/or suggested to the client. Protection against the consequences can be achieved by changing the plant design and/or operation method.
By defining appropriate nodes, each system or equipment is divided into sub-systems by consensus of the review team. The selected system is identified by a study node number and for easy reference a colour code can also be applied on the related P&IDs prior to the review and worksheet during the review.

The HAZOP process should proceed as follows:

1. Select the appropriate node
2. Apply the first or next parameter
3. Apply the first or next guideword, which in combination with the parameter gives the deviation
4. Determine deviation
5. Identify all potential causes of the deviation
6. Appraise the consequences of the deviation
7. Appraise the safeguards preventing or mitigating the deviation and its consequences
8. Agree a recommendation for action or further consideration of the problem where required
9. Once all causes and consequences for a given deviation have been identified and the requirement for action discussed, the procedure returns to step 3. This process iterates until all guidewords have been combined with a selected parameter.
10. Once all guidewords have been considered the next the next parameter will be selected (step 2) and the process will be repeated until all parameters have been applied
11. Then the discussion moves to the next node and the process will be repeated until all nodes are applied.

As mentioned above the HAZOP also includes the division of the plant into sections/nodes.

The method consists of a systematic study of all process and utility lines and equipment included in the project. The study will primarily be performed based on the piping and instrumentation diagrams (P&IDs) developed for the project. The study will be confined within the new and modified facilities only, along with tie-ins with the existing.

Each line will be studied as a whole from battery limit to battery limit or to the equipment connected to the end of the line, whichever applicable.

For each line, the study will look at the appropriate process parameters and the key word as listed on the following table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Key Word</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>No / one</td>
<td>No flow</td>
</tr>
<tr>
<td></td>
<td>More</td>
<td>Quantitative increase</td>
</tr>
<tr>
<td></td>
<td>Less</td>
<td>Quantitative decrease</td>
</tr>
<tr>
<td></td>
<td>Reserve</td>
<td>Opposite direction</td>
</tr>
<tr>
<td>Pressure</td>
<td>More</td>
<td>More than normal</td>
</tr>
<tr>
<td></td>
<td>Less</td>
<td>Less than normal</td>
</tr>
<tr>
<td>Temperature</td>
<td>More</td>
<td>More than normal</td>
</tr>
<tr>
<td></td>
<td>Less</td>
<td>Less than normal</td>
</tr>
<tr>
<td>Level</td>
<td>More</td>
<td>More than normal</td>
</tr>
<tr>
<td></td>
<td>Less</td>
<td>Less than normal</td>
</tr>
<tr>
<td>Composition</td>
<td>Different from,</td>
<td>Solids instead of liquid</td>
</tr>
<tr>
<td></td>
<td>as well as</td>
<td>(if applicable)</td>
</tr>
<tr>
<td></td>
<td>Corrosive</td>
<td>Corrosive</td>
</tr>
<tr>
<td></td>
<td>Explosive</td>
<td>Explosive</td>
</tr>
<tr>
<td></td>
<td>Out of specifications</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Contamination,</td>
<td>Leakage of release to</td>
</tr>
<tr>
<td></td>
<td>leakage</td>
<td>atmosphere</td>
</tr>
<tr>
<td></td>
<td>and spillage,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>maintenance,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>erosion,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>corrosion,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>toxicity</td>
<td></td>
</tr>
<tr>
<td>Start-up / Shut-down</td>
<td>Issues</td>
<td></td>
</tr>
</tbody>
</table>

As mentioned above the HAZOP also includes the division of the plant into sections/nodes.
For each key word, the HAZOP team will list the possible causes and the consequences regarding the operating procedures and the safety aspects from both personnel and material point of view. If the consequences are considered as being out of the normal operating range, the HAZOP team will investigate the installed safeguards:

a) The detection devices, to ensure that the operator will be aware that something abnormal is happening.

b) The safety devices installed, to limit the consequences of the process upset. If the P&ID shows devices which are considered adequate for the considered risk, the next key word will be reviewed, then the next parameter, then the next process lines or equipment.

Key aspects may include:

a) A detailed systematic study of the design and outline operating and maintenance philosophy to identify the consequences from design intent.

b) Consideration of transient operating conditions during start-up, shut-down, plant upsets and emergencies.

c) Consideration of potential exposure of employees to chemicals during routine operations including maintenance, de-contamination, etc. If the protection by so called safeguards indicated on the P&IDs are considered unsafe, the HAZOP team may make recommendations that are numbered and propose alternative designs elaborated to satisfy all the operation and safety requirements. These requirements will be recorded and classified in the HAZOP Report (see below).

Final report

When the HAZOP study is completed, a final report will be prepared. The minimum requirements for the report are as follows:

- Description of applied procedures and HAZOP technique
- Summary and description of approved HAZOP recommendations
- Summary of operational recommendations and limitations
- List and description of drawings and related documents studies
- Finalised HAZOP study work sheets together with reports from each study session including a list of participants
- Annotated copies of drawings together with supporting documentation which were used during the examination

- Recommended revisions of drawings and documents (or part thereof if more convenient) which show modifications, identified as necessary as a result of the HAZOP study
- Changes proposed by the HAZOP team, but not accepted, and the reasons why the proposed changes were rejected

Team composition

The HAZOP study team shall neither be over-nor undersized. Ideally the study is carried out by a team of 4 to 6 people plus a facilitator and scribe. The team should be composed of the following participants:

- the design engineer in charge for the respective facility
- the project manager (for new installations)
- the plant engineer in charge
- the maintenance engineer
- the HSE representative
- the foreman/ technician
- the facilitator and scribe

Execution of the HAZOP sessions

HAZOP Session Preparation

Prior to the HAZOP session itself the facility in question will be divided into manageable, logical sections (nodes). Section limits can be identified for example where there is a significant change in the process conditions, a change in location or in material phase and composition. Sections will preferably be identified in a way that one section contains either gas or liquid, not both at the same time. Reasonable divisions of a complex facility can be processing units, less comprehensive facilities could also be sub-divided into functional groups. The identified sections will be written in the GL section division document. This preparatory sectioning work including the compilation of the work sheets for each defined unit as well as the HAZOP section division document is generally carried out by the facilitator. Subsequent to completion the prepared documents are subject to discussion with the operator’s representative.
a. Natural Gas Storage Facility - Underground Cavern

**Date:** 2008  
**Customer:** Medium Size German Oil and Gas Producer  
**Savings:** Savings not directly quantifiable

**Issue:**

A medium size German oil and gas producer and supplier, owned by a major European gas exploring and producing company, requested a process hazard analysis for its gas cavern storage facility expansion project. GL offered the independent leadership of a HAZOP study in order to support the company in their effort to get an early as possible first appraisal of the integrity of the planned facilities.

**Methodology & Results:**

The existing and newly planned facilities were sectioned into logical units and scrutinised in consideration of potential hazards originating from or affecting the unit in question. Amongst the total number of identified scenarios the majority of scenarios were classified as non-critical. However, a significant number of recommendations representing safety and operability issues were established.

**Savings:**

Savings due to this assessment can not be comprehended monetarily. But the identification of hazards and operability issues at an early stage of the project enabled the designer to account for this in the consecutive planning. The obvious benefit is the reduction of the possibility of increased expenses for potentially required corrective measures in the course of the proceeding project.
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Safety & Risk Management Services

- Safety Case and Compliance Consultancy
- Hazard Identification Studies (HAZID)
- Hazard Operability Studies (HAZOP)
  - SIL Studies (Safety Integrity Level)
  - Consequence Evaluation (Fire, Release, Explosion, Dispersion), Including CFD
  - EER Analysis (Escape, Evacuation, Rescue) (GL-Aeneas)
  - Quantitative Risk Analysis (QRA)
  - Decision Support (Risk Based Layout Studies)
  - Performance Standards
  - Large Scale Hazards Testing (Spadeadam)
  - Incident Investigation

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