CS ENERGY PROCEDURE FOR

ASSET MANAGEMENT – HAZOPS GUIDE
CS-AM-024

Responsible Officer: Specialist Engineer Asset Management
Responsible Executive: Executive General Manager Operations

DOCUMENT HISTORY

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1 DEFINITIONS

For the purposes of this procedure, the following key definitions apply

Term	Definition
Asset Integrity	The ability of an asset to perform its required function reliably while safeguarding personnel health and safety and the environment.
Asset management	Coordinated activity of an organisation to realise value from physical assets. Realisation of value will normally involve a balancing of costs, risks, opportunities and performance benefits. Includes all activities within the Operations Division.
Asset management system	A management system for asset management.
Cause	If it is considered that a deviation could occur, then the possible cause(s) that would allow the deviation to occur should be identified.
Characteristic	Qualitative or quantitative property of an element. Examples of characteristics are pressure, temperature, voltage.
Competent person	Means a person who has acquired through training, qualification or experience the knowledge and skills to carry out the task.
Consequence	Having identified a possible cause(s) for a deviation, the possible consequences should be assessed.
Design Intent	Designer's desired, or specified range of behaviour for elements and characteristics of a process. Can be quantitatively described in process parameters as pressure, temperature, and flow rate. Can be qualitatively described as an activity e.g. feed, transfer, reaction, heating, etc.
Deviation	Departure from the design intent as suggested by each guide word
Element	Constituent of a part which serves to identify the part's essential features
Guide word	Word or phrase which expresses and defines a specific type of deviation from an element's design intent. Each identified guide word must be individually considered by the HAZOP team for each system. When each guide word for a particular system has been reviewed the process is repeated for the next system.

Term	Definition
Hazard	Potential source of harm, any operation that could possibly cause a catastrophic release of toxic, flammable, or explosive chemical or any action that could result in injury to personnel
Integrity	See Asset Integrity
Must	Indicates that compliance with the requirement is mandatory
Node	Section of the system which is the subject of immediate study
Operability	Any operation inside the design envelope that would cause a shutdown that could possible lead to a violation of environmental, health or safety regulation or negatively impact profitability
Plant	Includes any machinery, equipment, structure, appliance, container, implement and tool, and includes any component or anything fitted or connected to any of those things. Plant includes items as diverse as lifts, cranes, computers, machinery, conveyors, forklifts, vehicles, power tools and amusement devices. Certain kinds of plant, such as forklifts, cranes and some pressure equipment, require a licence from the WHS regulator to operate and some high-risk plant must also be registered with the WHS regulator.
Shall	Indicates that compliance with the requirement is mandatory
Significant asset	Meant to refer to large asset systems/equipment that has a significant relationship with or affect on, the total plant. An example is the Solar Boost asset. Can include major changes to an existing asset system/ plant area such as “Fuel Supply”, or “Turbine”.
System	A specific location or logical part of the process or operation in which possible deviations from the design intent are to be evaluated. Systems should be progressively identified on the P&ID as the HAZOP study proceeds.
Top management	Person or group of people who directs and controls an organisation at the highest level. Top management has the power to delegate authority and provide resources. In CS Energy top management refers to the Executive Leadership Team (ELT).

2 PURPOSE

An important element of any system for the prevention of major incidents is conducting a hazard and operability study (HAZOP) to identify hazards, operability and safety control systems problems associated with normal and transient operation of asset systems. Accordingly, CS Energy has developed this Guide as part of the system for managing asset management risks.

This procedure aims to provide guidance for personnel associated with the design and operation of a facility to appreciate the need for a HAZOP and also the general process that is followed in carrying out a HAZOP and reporting the study results. It provides a broad indication of what is required in undertaking a HAZOP with a list of references for further information.

3 SCOPE AND RESPONSIBILITY

This standard applies to all employees and contractors working for CS Energy and its associated activities.

- The Group Manager Asset Management is the owner of this procedure and is responsible for periodic reviews.
- The EGM Operations is responsible for approving the outcomes from HAZOP studies of major projects (e.g. Solar Boost).
- The Group Manager Asset Management is responsible for approving the outcomes from HAZOP studies on new or modified assets / systems where the risk is assessed as high or significant.
- All managers are responsible for the application of this procedure in relation to new and modified assets or asset systems.

4 INTRODUCTION

A process hazard analysis is a thorough, orderly, systematic approach for identifying, evaluating, and controlling the hazards of processes in order to identify and evaluate problems that may represent a risk to personnel, equipment or operation.

- An initial process hazard analysis (hazard evaluation) shall be performed on all *significant* new or modified assets.
- The process hazard analysis methodology selected must be appropriate to the complexity of the process and must identify, evaluate, and control the hazards involved in the process.
- One or more of the following methods can be used, as appropriate, to determine and evaluate the hazards of the process being analysed:
    - Hazard and operability study (HAZOP),
    - Failure mode and effects analysis (FMEA),
    - Fault tree analysis, or
    - Another appropriate and equivalent methodology.
- Whichever method(s) are used, the process hazard analysis must address the following:
    - The hazards of the process;
    - The identification of any previous incident that had a potential for catastrophic consequences in the workplace;

- Engineering and administrative controls applicable to the hazards and their interrelationships, such as appropriate application of detection methodologies to provide early warning. Acceptable detection methods might include process monitoring and control instrumentation with alarms, and detection sensors;
- Consequences of failure of engineering and administrative controls;
- Facility siting;
- Human factors; and
- A qualitative evaluation of a range of the possible safety and health effects on employees in the workplace if there is a failure of controls.

Process hazard analysis is best performed by a team with expertise in engineering and process operations, and that the team should include at least one employee who has experience with and knowledge of the process being evaluated. Also, one member of the team must be knowledgeable in the specific analysis methods being used.

The team leader must ensure that the recommendations are resolved in a timely manner and that the resolutions are documented; document what actions are to be taken; develop a written schedule of when these actions are to be completed; complete actions as soon as possible; and communicate the actions to operating, maintenance, and other employees whose work assignments are in the process and who may be affected by the recommendations or actions.

The Guide is specifically focussed on the HAZOP method.

This guide is not designed to provide detailed guidance on how to conduct a HAZOP study; rather it provides a set of broad guidelines into the technique and a set of minimum standards. **For detailed guidance refer to AS IEC 61882-2003 Hazard and Operability Studies – Application Guide**.

5 HAZOP METHOD

5.1 Overview

A HAZOP study is a systematic and structured risk management process used to identify both potential hazards and operability problems in terms of plant design and human error.

A HAZOP is a design verification process, not a design development process. A HAZOP study is normally conducted during the final design stage for asset systems however can be applied when plant modifications or extensions are made, or applied to an existing asset system.

Hazop studies seek to minimise the effect of an atypical situation in the operation / process by ensuring that control and other safety systems (such as emergency shutdown) are in place and work with a high level of reliability. It identifies possible deviations from the system design intent or operating intentions which could lead to hazardous situations, utilising a core set of guide words.

Hazop may be used in conjunction with other analysis methods such as Failure Mode and Effects Analysis (FMEA) and Fault tree Analysis (FTA).

A HAZOP workshop template and study report format is suggested for submission and approval of the study outcomes.

The basis of HAZOP is a “guide word examination” which is a deliberate search for deviations from the design intent. To facilitate the study, a system is divided into parts in such a way that the design intent for each part can be adequately defined. The size of the part chosen is likely to depend on the complexity of the system and the severity of the hazard. The design intent for a given part of a system is

expressed in terms of elements which convey the essential features of the part and which represent natural divisions of the part. Elements can be further defined in terms of characteristics, e.g. the element "material" may be further defined in terms of characteristics such as temperature, pressure, etc.

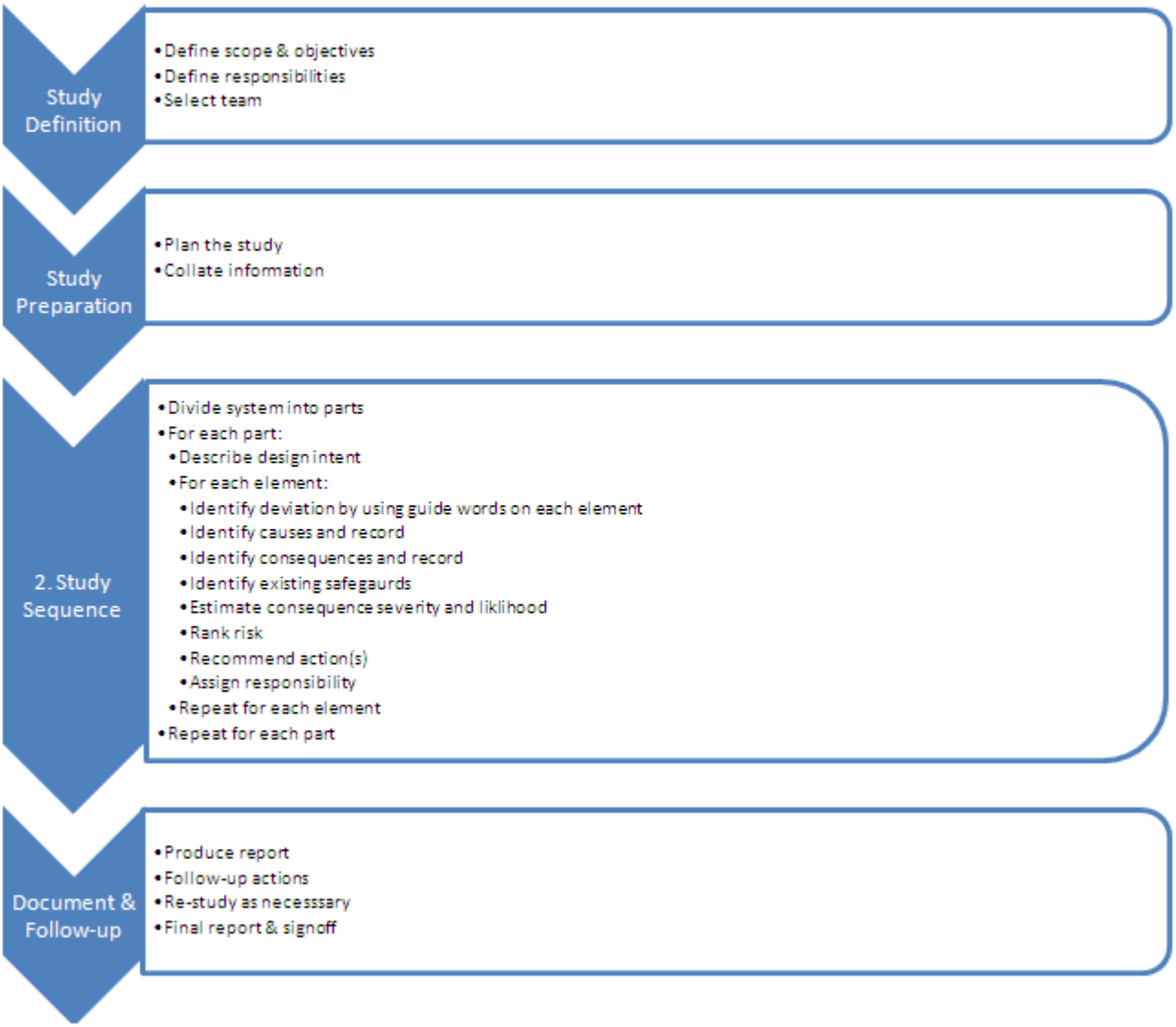
The HAZOP team examines each element and characteristic for deviation from the design intent which can lead to undesirable consequences. The identification of deviations from the design intent is achieved by a questioning process using predetermined "guide words".

5.2 Standards

- A HAZOP study **shall be conducted** for all significant new / modified asset / asset systems during the design stage where the risk assessment is high or significant.
- A HAZOP study **should be considered** for all new / modified plant systems during the design stage regardless of risk assessment.
- The workshop(s) **shall be lead by a competent person** who is trained and experienced in HAZOP studies and is independent of the design team. For **major projects it is recommended** that an experienced external consultant be used.
- Identified risks are to be assessed on the basis of current safeguards being in place and ranked in accordance with the **CS Energy Risk Management Framework**.
- Responsible persons shall be assigned to investigate possible solutions for each problem identified.
- The HAZOP study should be based on the standard HAZOP method as described in AS IEC 61882-2003.

5.3 Process Flow

Identify the scope of the study and breakup into sections (nodes). For each section, follow the following process documenting on the standard worksheet as you go.



5.3.1 Study Definition

During this phase the study team members are selected, the scope is carefully defined in order to focus effort, and responsibilities are to be defined.

The scope of the study is to be defined including study boundaries and key interfaces and any assumptions that the study will be performed under.

The Hazop is intended to be a cross-functional effort which relies on specialists from various disciplines with appropriate experience and knowledge.

5.3.1.1 HAZOP Leader

- The HAZOP team leader or facilitator will be someone trained and experienced in the HAZOP method
- The HAZOP Team leader will be someone independent of the system being studied, i.e. no responsibility for the process or operations under review, but with sound knowledge of and experience in similar processes
- The team leader's responsibilities include:
  - Defining the scope of the analysis
  - Selection of team members
  - Provision of information required prior to workshops
  - Adequate design representation is available
  - Plans, schedules and coordinates the workshops
  - Providing a briefing to participants to enable them to familiarise themselves with the content and also to ensure an understanding of the HAZOP method
  - Facilitates the process and ensures all items in scope are analysed
  - Ensures information is recorded and suitable records produced
  - Writes the report and presents to management
  - Follows-up on actions, where authority for such is assigned

5.3.1.2 HAZOP Team Members

The study team will consist of a minimum of 4 members with a spread of knowledge and skill relevant to the study. The study team should include personnel representing operations, maintenance, health and safety, environmental, chemistry, mechanical engineering, electrical engineering, and instrumentation/ control engineering. Personnel familiar with the design of the facility should be included.

5.3.2 Study Preparation

The study needs to be planned including collating of relevant information, scheduling of meetings, template format to be used and consensus on "guide words" to be used.

5.3.2.1 Study Information Requirements

A full description of the process is needed to guide the HAZOP team. In the case of conventional plants, detailed P&IDs should be available for the plant under consideration. At least one member of the HAZOP team should be familiar with these diagrams and all instrumentation represented on them. If the

plant is too complex or large it may be split into a smaller number of units to be analysed at separate HAZOP meetings.

In addition to P&IDs, models (either physical or computer generated) of the plant or photographs of similar existing plants may also be utilised. Both greatly assist in visualising potential incidents, especially those caused by human error.

If the HAZOP is to be carried out on an existing plant, or the proposal is for a new plant but a similar plant is already operating, inspection of this facility before commencing the HAZOP by the team would be highly beneficial. In conducting a HAZOP on an existing or proposed plant where a similar one has been in operation elsewhere, past incidents could also be considered during the course of the HAZOP.

When carrying out a HAZOP on a facility for which traditional P&IDs are not appropriate, it may be more suitable to use alternative visualisation and diagrammatic techniques such as plan and section drawings, layout drawings or photographs. A decision as to which medium will be used should be made well before the HAZOP commences.

The following information is a guide to the type of information to be collated prior to the workshop:

- Overall process description / design philosophy / layout drawings of the process within the scope
- Full set of functionally complete P&ID's and a reduced sized copy for each team member
- Relevant codes or standards
- Operating, safety, emergency, shutdown, control and blowdown philosophy
- Process operating manual / procedures covering start-up, normal operation, shutdown and emergency operation
- Relevant material safety data sheets
- Incident reports from similar facilities
- Previous HAZOPs, process hazards analysis (PHA), or SIL reports
- Hazardous Area Classification documents / drawings
- Process control intent / philosophy / logic diagrams
- Emergency, interlock and safety shutdown system descriptions and philosophies
- Piping class specifications and materials of construction details
- Vessel schedules
- General arrangement drawings
- Equipment data sheets, including relief valve specifications

5.3.2.2 HAZOP Guidewords

Hazop guide words are a core part of the study. According to AS IEC 61882 *"the identification of deviations from the design intent is achieved by a questioning process using pre-determined "guide words". The role of the guide word is to stimulate imaginative thinking, to focus the study and elicit ideas and discussion."* The guide words work by providing a systematic and consistent means of brainstorming potential deviations to operations.

The study team is responsible for selecting the guide words that will best suit the scope and problem statement for the analysis. Sample guide words are provided in **Error! Reference source not found.**.

5.3.3 Study Workshop

5.3.3.1 Study Introduction

The team leader will introduce the project:

- Re-familiarise team members with HAZOP study process
- Overview of study scope and documentation
- Review process using P&ID's including breakup of process in logical *systems*
- Highlight key elements of process, e.g. process prone to two phase flow

5.3.3.2 Study Sequence

The analysis should follow the flow or sequence related to the subject of the analysis, tracing inputs to outputs in a logical sequence. Generally the process involves:

- Identification of discrete "nodes" within the drawing(s) included in the HAZOP scope.
  - Physical systems may be broken down into smaller parts as necessary
  - Processes may be broken down into discrete steps or phases
  - Similar parts or steps may be grouped together to facilitate assessment.
- Deviations from design (normal) operation (guidewords + elements) are systematically applied to each node of the system. As a general rule all reasonable deviations should be assessed, but only credible deviations need to be recorded.
- Possible "causes" and potential "consequences" resulting from the deviation are brainstormed and documented. A "cause" must be credible and generally needs to be one that will/can occur within the node being considered. In contrast the "consequences" should be global and look at what happens to upstream and downstream nodes, and even outside the HAZOP scope.
- After the "cause" and "consequence" are recorded the existing safeguards that mitigate or control the risk are identified and documented. The team assesses their effectiveness and allocates the risk ranking according the CS Energy Risk Matrix.
- List actions to further reduce the risk or improve the operability of the system are identified and persons responsible are allocated to each. Actions are required for all High or Significant risks that will reduce the overall risk to as low as reasonable practicable (ALARP).

There are two possible sequences of examination (refer to AS IEC 61882-2003 for more detail):

1. Element first, and
2. Guideword first.

The Element first process is described here.

Element first: The study leader starts by selecting a part of the design representation as a starting point. The design intent of the part is then explained and agreed, and the relevant elements / characteristics associated with these elements are identified. One of the elements is then chosen for examination and the first guide word chosen is applied and credible deviations identified and then examined for possible causes and consequences. The process is repeated for any other interpretation of that guide word, then for each other guide word. When all guide words have been applied, the

process is repeated for each characteristic of the element under examination, then again for each element until all elements have been examined.

It is sometimes useful to supplement the above analysis with a “what-if” approach to some of the more non-standard design parameters such as “maintenance”, start-up”, “corrosion-erosion”, utilities and services, etc. This method involves the team members brainstorming a series of questions prefixed with “what-if...” identifying the associated consequences, ranking the unmitigated risk, listing existing safeguards, ranking the mitigated risk, and finally identifying actions.

The following figure illustrates the process.

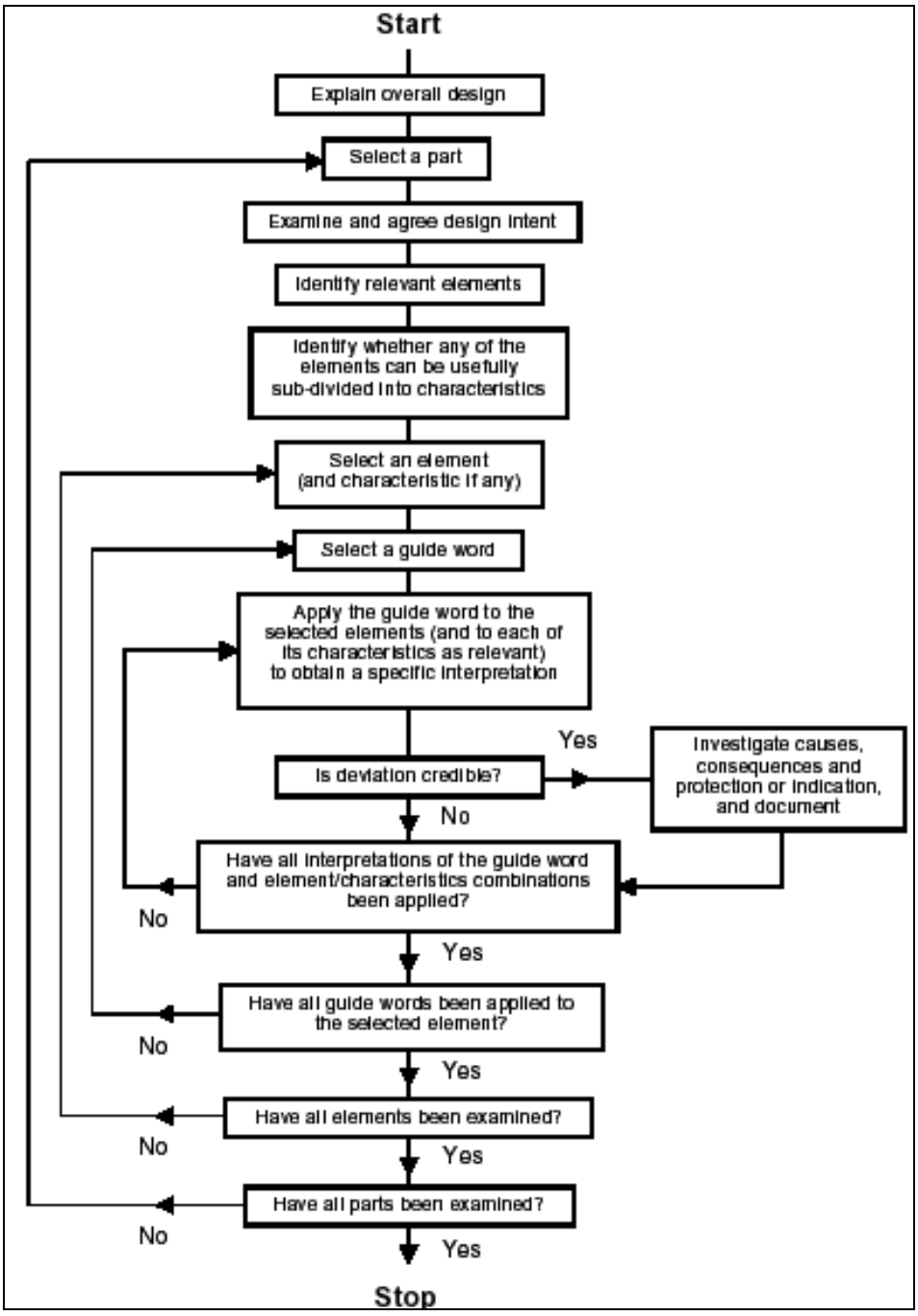


Figure 1: HAZOP Study Process

The following is a sample pattern for study of each section of plant:

- The process designer very briefly outlines the broad purpose of the area of design under study and displays the P&ID (or equivalent) where it can be readily seen by all team members. Any general questions about the scope and intent of the design are discussed.
- The first part for study is selected, usually one in which a major material flow enters that section of the plant. The section is highlighted on the P&ID with dotted lines.
- The process designer explains in detail its purpose, design features, operating conditions, fittings, instrumentation and protective systems, etc., and details of the plant immediately upstream or downstream of it. Any general questions about the relevant part are then discussed.
- The detailed 'line by line' study commences at this point. The leader takes the group through the guide words chosen as relevant. Each guide word / characteristic, such as HIGH FLOW, identifies a deviation from normal operating conditions. This is used to prompt discussion of the possible causes and effects of flow at an undesirably high rate. If, in the opinion of the study team, the combination of the consequences and the likelihood of occurrence are sufficient to warrant action, then the combination is regarded as a 'problem' and minuted as such. If the existing safeguards are deemed to be sufficient then no further action is required. For major risk areas the need for action may be assessed further using other techniques as Hazard Analysis (HAZAN) or Reliability Analysis. For less critical risks the assessment is usually based on experience and judgement. The person responsible for defining the corrective action is also nominated.
- It should always be remembered that the main aim of the meeting is to find problems needing solution, rather than the actual solution. The group should not be tied down by trying to resolve a problem; it is better to proceed with the study, deferring consideration of the unsolved problems to a later date.
- When the guide word requires no more consideration, the chairperson refers the team to the next guide word.
- Discussion of each guide word is confined to the part marked, the plant at each end and any equipment, such as pumps or heat exchangers, in between. Any changes agreed at the meeting are minuted, and where appropriate, marked on the P&ID or layout with red pen.
- When all guide words have been covered, the part is fully highlighted to show that it has been completed, and the next part is chosen.
- When all the parts in a plant sub-section have been reviewed, additional guide words can be used for review (overview) of the P&ID as a whole.

5.3.4 Document & Follow-up

To achieve the full benefits of the structured HAZOP approach, it has to be properly documented and followed-up. To facilitate this CS Energy has developed a standard template to be used. The study shall be documented using the CS Energy HAZOP template which includes the following information:

- Header with project, plant process / item, design intent, drawing / document being examined, date, page number
- Columns:
  - Reference number – assign each guide word / element entry a unique tracking number
  - Guide Word – insert deviation guide word used
  - Element – describe the element that the guide word pertains to (e.g. material A)

- Deviation – describe the deviation (may be > 1 deviation per guide word / element)
- Cause – describe how the deviation may occur
- Consequences – describe what may happen if the deviation occurs
- Current safeguards – list controls that reduce deviation likelihood or consequence
- Consequence, Likelihood and Risk ranking – list utilising the CS Energy Risk Matrix
- Further actions required – identify any hazard mitigations control actions required
- Actions to be Allocated to – record who is responsible for actions

A standard template for recording the workshop outputs is available. The template can be adapted as required. The template can be found here: "B/D/12/85989".

Depending on the agreed objectives of the study the study leader may or may not have the authority to follow-up on agreed actions from the study. Usually it falls to the project manager to ensure that actions are implemented. Either way, individual actions are to be assigned to personnel responsible for ensuring it is completed and either the project manager or the study leader must follow-up to ensure all actions are completed.

In some instances it may be that the process is revisited in part.

5.4 Reporting

A final report of the HAZOP study shall be prepared, agreed by the team and signed off by the team leader. The report should demonstrate the adequacy of the Hazop study carried out, clearly describe the scope, and contain sufficient background information to allow the reviewer to appreciate the significance of the findings and recommendations. It should describe the Hazop team, the method used, focus on the main findings, recommendations and action plan. The report should contain the following:

- Title
- Contents
- Glossary and abbreviations
- Executive summary
- Summary of main findings and recommendations
- Scope and objectives
- Hazop study:
  - Description of facility
  - Team members
  - Hazop method
  - Guide words used
  - Plant overview
  - Analysis of main findings
  - Actions arising from the study
- HAZOP worksheets
- List of drawings, documentation, etc used in the study

5.5 Training & competency

The following table defines the minimum training requirements and competency recognition for the roles within this process.

Role	Activity	Required Competency	Required Training
Team leader / facilitator	Refer Section 2 of this document	• Understand & apply HAZOP process • Understand & apply CS Energy Risk Matrix • Document HAZOP worksheet • Perform duties of HAZOP facilitator • Report writing	• Read AS IEC 61882-2003 • Read this guide • CS Energy Risk Framework and Matrix • Participation in HAZOP workshop • For major project – experience in study facilitation
Team member	Contribute as part of workshop	Knowledge of plant as applicable: design, engineering, maintenance, chemical, safety, process, environment, etc Basic knowledge in HAZOP process to enable effective participation	Experience in knowledge areas as applicable. Team leader to provide overview of process at beginning of study.

6 REFERENCE DOCUMENTATION

Reference No	Reference Title	Author
"B/D/12/85989"	Form - PLANT / ASSETS - S2121 - HAZOP Study Template	CS Energy

7 RECORDS MANAGEMENT

In order to maintain continual improvement, suitability, safety and effectiveness of the organisation, registered documents will be reviewed on a two yearly basis, or where it has been identified that there are changes in technology, legislation, standards, regulations or where experience identifies the need for alteration to the content. Registered documents should also be reviewed following an incident, change management process, modification or where directed as part of a risk assessment process.

CS Energy must ensure that records are retained according to accountability, legal, administrative, financial, commercial and operational requirements and expectations. In compliance with records retention and disposal, all documentation created in relation to CS Energy business must be retained in line with minimum retention periods as detailed in legal retention and disposal schedules.

8 ATTACHMENTS

8.1 Attachment 1 – Sample Deviations and Guide Words

The HAZOP process creates deviations from the process design intent by combining guide words with process parameters resulting in a possible deviation from design intent. For example, the deviation “no flow” results when the guide word “No” is combined with the parameter “flow”. A sample list of guide words is given in Table 1.

The application if parameters will depend on the type of process being considered, the equipment in the process and the process intent. Common parameters are given in Table 2.

Guide Word	Meaning	Comments
NO	Complete negation of the intention	NO forward flow when there should be
MORE	Quantitative increase	MORE of relevant physical property than there should be (e.g. higher flow, pressures, viscosity, etc)
LESS	Quantitative decrease	LESS of....(as above)
AS WELL AS	Quantitative increase	All design & operating ‘intentions’ are achieved together with some addition (e.g. impurities, extra phase)
PART OF	Quantitative decrease	Only some of ‘intentions’ are achieved, some are not
REVERSE	Opposite if ‘intention’	Reverse flow or chemical reaction (e.g. inject acid instead of alkali in pH control)
OTHER THAN	Complete substitution of miscellaneous	No part of original ‘intention achieved, something quite different occurs. Also start-up, shutdown, alternative mode of operation, catalyst change. Corrosion, etc.
LATE	Time – occurs too late	Something happens early relative to clock time
EARLY	Time – occurs too early	Something happens late relative to clock time
BEFORE	Out of order / sequence – early	Something happens too early in a sequence
AFTER	Out of order / sequence – late	Something happens too late in a sequence

Table 1: Typical guide words for HAZOP study

Typical Parameters		
Flow	Relief	Maintenance
Temperature	Instrumentation	Addition
Pressure	Sampling	Safety
Composition	Startup	Reaction
Phase	Corrosion / Erosion	Inserting / Purging
Level	Service / Utilities	Contamination

Table 2: Typical parameters