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GP 48-02

Hazard and Operability (HAZOP) Study

This Group Defined ETP has been approved by the GVP Safety and Operations for implementation across the BP Group.

BP GROUP
ENGINEERING TECHNICAL PRACTICES

EXHIBIT # 862
WIT:

Foreword

This revision of GP 48-02 includes greater clarity on the applicability of the HAZOP Process, relationship to the CVP, independence of the team leader, rigour and management of the HAZOP process, and reference of the risk matrix in GDP 31-00-01, the Group Defined Operating Practice for assessment, prioritization, and management of risk (issued 30 January 2008 as an implementation draft).

These changes were so extensive that revisions have not been indicated in the margin as is normal practice.

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1. Scope

a. The HAZOP technique is a structured, qualitative methodology that identifies potential safety and environmental hazards and major operability problems, assesses consequences, considers safeguards, and generates recommendations. It is applicable to both major projects and existing operations. This GP describes the expectations for leaders, deviations/guidewords, team composition, risk ranking, and proper recording of findings, and documentation requirements.

HAZOP is one of the techniques specifically mentioned in some regulations and is generally accepted as one of the preferred hazard identification methodologies in the chemical and petroleum industries.

HAZOP is a methodology used in Design and Operations to provide a rigorous design integrity assurance process.

HAZOP has been identified as a key hazard identification technique because with its systematic approach, it provides a thorough review and may identify potential hazards that the HAZOP team may have not considered before or that may have not previously resulted in incidents in industry.

b. The HAZOP technique is applicable to:

1. Continuous and batch processes,
2. Onshore and offshore facilities,
3. Control and computer systems,
4. Procedures.

c. The HAZOP technique is applicable to:

1. Major projects as defined by MPep (E&P) and Pep (R&M).
2. Major modifications to an operating facility,
3. Some changes being addressed in an MOC at operating facilities, and
4. Revalidation of previous HAZOPs.

d. HAZOP is not:

1. An occupied building analysis or facility siting study (but should include consideration of these risks).
2. A fire and explosion analysis.
3. A Quantitative Risk Assessment (QRA).
4. A means for defining engineering and procedural solutions for sources of hazards.

e. HAZOP does not normally consider independent double jeopardy events.

HAZOP does not normally consider double jeopardy events as being credible events. However close scrutiny often finds that these events may not be truly independent in which case the scenario should be considered. Refer to 10.6.e for a description of double jeopardy.

2. Normative references

The following referenced documents may, to the extent specified in subsequent clauses and normative annexes, be required for full compliance with this GP.

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- For dated references, only the edition cited applies.
- For undated references, the latest edition of the referenced document (including any amendments) applies.

BP

GDP 31-00-01	Assessment, prioritization and management of risk.
GP 48-03	Layers of Protection Analysis (LOPA).

3. Terms and definitions

For the purposes of this GP, the following terms and definitions apply:

BP Operations

BP Strategic Performance Units, Business Units, projects, facilities, sites, and operations.

Cause

Event, situation, or condition that results, or could result, directly or indirectly in an accident or incident.

Competent

Describes an individual with knowledge and skills deemed acceptable by the EA to perform a task. Appropriate knowledge and skill may be acquired through training, experience, qualifications, or some combination of these.

Consequences

Direct, undesirable result of an accident sequence usually involving a fire, explosion, or release of toxic material. Consequence descriptions may be qualitative or quantitative estimates of the effects of an accident in terms of factors such as health impacts, economic loss, and environmental damage.

Design intent

The way a process or system is intended to function.

Deviations

Departures from the design intent. A guideword plus a parameter equals a deviation.

Entity (BP entity or Operating entity)

Whilst these terms are not used in this GP they have a specific meaning in OMS. If this GP refers to BP Operation it should be interpreted as BP Entity or Operating Entity when working to OMS.

Guideword

Words such as "high", "low", and "no" that are applied to parameters to create a potential deviation from the design intent.

Hazard

Condition or practice with the potential to cause harm to people, the environment, property, or BP's reputation.

Hazard identification (HAZID)

Brainstorming approach used to identify possible hazards. HAZID studies are very broad in their scope. The HAZID is sometimes called a Preliminary Hazard Analysis.

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Hazard and operability (HAZOP)

Systematic qualitative technique to identify and evaluate process hazards and potential operating problems, using a series of guidewords to examine deviations from normal process conditions.

Independent protection layer (IPL)

Device, system, or action that is capable of preventing a postulated accident sequence from proceeding to a defined, undesirable endpoint. An IPL is (1) independent of the event that initiated the accident sequence and (2) independent of any other IPLs. IPLs are normally identified during layer of protection analyses.

Layer of protection analysis (LOPA)

Method for evaluating the effectiveness of protection layers in reducing the frequency and/or consequence severity of hazardous events.

Major operability problem

Operating condition that, while not presenting an immediate hazard, is not desired. "Major" differentiates between those smaller problems that merely require parameter adjustments vs. those bigger problems, e.g., those that could result in a significant amount of lost production or damage to catalyst.

Modification

Changes to existing facilities.

Operability

Ability to operate a facility inside the design envelope and meet business expectations.

Parameters

Conditions used to define a process, including flow, pressure, temperature, and level.

Process safety information (PSI)

Compilation of chemical hazard, technology, and equipment documentation needed to manage process safety.

Risk

A measure of loss / harm to people, the environment, compliance status, Group reputation, assets or business performance in terms of the product of the probability of an event occurring and the magnitude of its impact. Throughout this Practice the term "risk" is used to describe health, safety, security, environmental, and operational (HSSE&O) undesired events.

Safeguard

Device, system, or action that would likely interrupt the chain of events following an initiating cause or that would mitigate loss event impacts.

Safety instrumented function (SIF)

Safety function with specified integrity level that is necessary to achieve functional safety by putting process to a safe state or maintaining it in a safe state under predefined conditions. SIF is implemented using SIS.

Safety instrumented system (SIS)

Instrumented system used to implement one or more SIF. SIS is composed of sensors, logic solvers, and final control elements. An emergency shutdown system (ESD) is a specific example of an SIS.

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What if analysis

Scenario based hazard evaluation procedure using a brainstorming approach in which typically a team that includes one or more persons familiar with the subject process asks questions or voices concerns about what could go wrong, what consequences could ensue, and whether the existing safeguards are adequate.

4. Symbols and abbreviations

For the purpose of this GP, the following symbols and abbreviations apply:

CHAZOP	Control (or computer) HAZOP.
CRR	Continuous risk reduction.
CV	Control valve.
CVP	Capital value process
DCS	Distributed control system.
EA	Engineering authority.
EDP	Emergency depressuring.
ESD	Emergency shutdown.
FEL	Front end loading.
HAZID	Hazard identification.
HAZOP	Hazard and operability (study).
HHC	Highly hazardous chemical.
HIPO	High potential (incident).
HP	High pressure.
HRVOC	Highly reactive volatile organic compound (VOC).
HSSE	Health, safety, security, and environment.
HVAC	Heating, ventilation, and air conditioning.
IM	Integrity management.
IPL	Independent protection layer.
LDAR	Leak detection and repair.
LEL	Lower explosive limit.
LOPA	Layers of protection analysis.
LOTO	Lockout, tagout.

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LP	Low pressure.
MAWP	Maximum allowable working pressure.
MIA	Major incident announcement.
MOC	Management of change.
MSDS	Material safety data sheet.
MPcp	Major projects common process (E&P).
NPSH	Net positive suction head.
P&ID	Piping and instrumentation diagrams.
Pcp	Projects common process (R&M).
PFD	Process flow diagrams.
PHA	Process hazard analysis.
PHSSER	Project HSSE review.
PLC	Programmable logic controller.
PM	Preventive maintenance.
PMI	Positive materials identification.
PPE	Personal protective equipment.
PSI	Process safety information.
PSSR	Pre start-up safety review.
QA/QC	Quality assurance/Quality control.
QRA	Quantitative Risk Assessment.
RBI	Risk based inspection.
RMP	Risk management programme.
RV	Relief valve
SCBA	Self contained breathing apparatus.
SIF	Safety instrumented function
SIL	Safety integrity level.
SIMOP	Simultaneous operation.
SIS	Safety instrumented systems.
TLV	Threshold limit value.

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TOR Terms of reference.

VOC Volatile organic compound.

WWT Wastewater treatment.

5. General

5.1. HAZOP purpose

The purpose of a HAZOP study is to:

a. Identify the causes of potential safety and environmental hazards and major operability problems.

b. Consider the consequences of these hazards and major operability problems.

c. Identify the safeguards provided as hazard prevention or mitigation.

d. Propose recommendations, as needed, to prevent, control, or mitigate hazards.

e. Provide assistance to facility management in their efforts to manage risks.

5.2. Management responsibilities

Responsibilities for projects and operating facilities shall be as follows:

a. BP Operation Leader ensures that organization and priorities have been established to ensure that HAZOP studies have:

1. Appropriate priority and, attention.

2. Commitment of competent resources.

3. Time for proper execution.

b. BP Operations EA or Project EA is responsible for execution of HAZOP for projects and major modifications to operating facilities.

c. BP Operations EA or Project EA ensures that studies for operating facilities comply with this GP and local regulations, if applicable.

d. BP Operations EA or Project EA ensures that HAZOP is included and functioning as a key aspect of hazard and risk management processes.

e. BP Operations leader or Project manager ensures that recommendations are resolved and closed out in a timely manner.

6. Timing

6.1. Projects

a. CVP stage activity describes the timing and intentions for hazard identification studies including HAZOP.

Design Safety Guidelines in MPcp should be used for selection of proper timing and types of reviews for E&P projects.

Design Safety Guidelines in Pcp should be used for selection of proper timing and types of reviews for R&M projects.

b. Hazard identification studies during project development include:

1. First, a high level review, perhaps HAZID, very early in the design development.

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The study focuses on inherently safer design issues. It takes place when there may be little or no design detail and may take approximately 1 d. The results of this early review could directly influence the basis of design.

2. Second review follows as design details are developed. This may be a HAZID, What If, or HAZOP.

This review takes place when P&IDs are available but not near completion. It should be early enough to allow any major issues to be identified, changes to be incorporated into the design, and cost impact of recommendations to be included in the project estimate. This also allows LOPA to be held soon enough for the SIS design to be sufficiently developed so that its cost can also be included in the project estimate.

3. A HAZOP shall be conducted when the design stage is nearing completion. For the purposes of this document, it is referred to as the 'final design HAZOP'.

This provides assurance on the process or system design.

This review is performed at the end of Define or in the Execute stage.

The design and P&IDs for vendor packages that are typically available later during detailed design and depending on timing, are likely to be subject to a separate HAZOP review.

A consideration for the project team is whether the HAZOP should be one long continuous HAZOP session or if the study should be conducted in smaller sessions. There may be benefits in phasing the HAZOP sessions to match the issue timing for P&IDs. If the study is conducted in phases interactions between sections should be addressed even if the sections are examined separately.

Recommendations developed in previous reviews should be actioned, tracked, and if incomplete, added to the recommendations in subsequent reviews. For projects, this ensures completion before startup, and for operations, it ensures recommendations continue to receive focus.

c. A detailed P&ID review should be conducted before issuing the drawings as "Approved for HAZOP." This should include the following.

1. Review of regulatory requirements.
2. Drawing titles, numbers, tag numbers for equipment, design conditions, etc.
3. Operations review.

In a project, the key to a successful project HAZOP is strong emphasis by the project on planning, development, and finalisation of design and P&IDs before executing the project HAZOP. This can be achieved by application of inherently safer design principles, engagement of operations expertise early in FEL, applying value engineering processes early-on, and conducting thorough P&ID reviews as a part of P&ID development.

d. When the final design HAZOP has been completed, a MOC process shall be used to consider any changes made to the design on which the HAZOP was based.

This minimises the effort required in implementing a project MOC.

e. Subsequent changes to the project as tracked by the MOC process should be the subject of a HAZOP review.

This is also an opportunity to review changes to the design resulting from completed recommendations in earlier HAZOPs.

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6.2. Existing facilities

a. Modifications to existing facilities

1. The use of HAZID, What If, or HAZOP earlier in a modification should be based on the size and complexity of the modification.
2. A HAZOP shall be used to provide assurance on final designs.
3. Consideration should be given to whether the HAZOP review should cover only the changes being made to the facility or the entire process.

A review of the entire process is more thorough and there are opportunities to introduce issues from the operating facility that are outside of the scope of the project that need to be managed.

b. Operating facilities shall establish a schedule for completing or revalidating their HAZOP based on potential risk and age of the facility, consistent with BP Operation requirements.

In some countries, regulations may dictate this frequency and the required PHA methodology. The generally accepted process industry practice is a 5 yr cycle for revalidating the HAZOP. Further details on revalidation are available in clause 14.

c. A HAZOP or other process hazard analysis technique should be considered as part of the MOC process so that the hazards associated with those changes can be understood, documented, mitigated, and communicated.

The level of process hazard analysis should be appropriate to the complexity and potential hazards of the change. Not all changes warrant a HAZOP review.

Changes to process units or facilities for which a HAZOP has been completed may choose to conduct a HAZOP on all changes, thus keeping the HAZOP study evergreen and leading to an efficient revalidation.

7. Terms of reference for HAZOP

7.1. General

a. A TOR shall be:

1. Developed for each study.
2. Subject to formal agreement between the BP Operations leader or delegate and the HAZOP study leader before the study commences.

b. A typical HAZOP TOR document should include:

1. Objectives.
2. Scope.
3. Methodology including parameters and deviations to be used.
4. Personnel required to attend the meeting.
5. Schedule and deliverables.
6. Report recipient.
7. Distribution list.
8. Reference documents (e.g., HAZID, P&IDs, etc.).

c. The TOR should also identify and be forwarded to the BP Operations EA or Project EA responsible for the hazard and risk management at that facility or on that project.

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The formality of the TOR should be appropriate to the HAZOP. For a project, it may be a detailed plan. For a minor change, it could be a brief statement addressing the above points.

d. The principal recipient of the study report should be identified as part of the scope and objectives in the TOR.

Developing the TOR helps ensure a consistent understanding of the HAZOP technique, and its application will be established among HAZOP leader, project site management, and HAZOP team.

7.2. Study scope

a. The study scope shall be clearly stated in the TOR.

This is important so that necessary information can be gathered and an accurate prediction of the study time can be made.

b. The scope of the HAZOP study for projects and existing operations shall include:

1. Process and utility systems including Vendor packages. If Vendor packages are not available at the time of the HAZOP, they should be the subject of a later HAZOP when details are available.
2. Normal and abnormal operational modes, e.g., startup, shutdown, emergency shutdown, and special or abnormal operations, e.g., pigging, regeneration, flushing.
3. Safety/health and environmental hazard consequences.

The study may also include privilege to operate and equipment damage/business value lost consequences.

4. Major operability problems.
5. The boundaries of the review, particularly if the overall HAZOP program involves multiple reviews and interfaces.
6. Consideration of human factors.

If issues are identified, a follow up human factors analysis may provide greater definition of hazards.

7. Consideration of facility siting issues.

A separate facility siting study should be conducted to evaluate occupied building hazards.

8. A review of applicable process safety incidents that have occurred in the subject facility and in the facilities that have the same process design in BP and industry, if information is available.

c. When modifications to an operating facility are being studied, the TOR shall clearly indicate whether the HAZOP is to be limited to the modifications only or applied to the whole facility.

d. Interfaces (process/utilities) between operating facility and modifications should be identified and reviewed.

Particular attention should be paid to tie-ins to operating facility and recognize that the impact could extend upstream and downstream of the tie-in.

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8. Team composition

8.1. HAZOP study leader

a. Each HAZOP study shall have a leader (also referred to as facilitator or chairman) who is independent.

b. The HAZOP leader shall be approved by the BP Operations EA or Project EA.

The HAZOP leader may be selected by a contractor on a project; however, approval of the HAZOP leader is a BP responsibility.

c. The nature of independence should be as follows.

1. For projects, the leader should be independent of the project.
2. For major modifications, the leader should be independent of the modification project team.
3. For operating facilities, the leader should be independent of the subject process unit.
4. For a HAZOP in support of an MOC, the leader should be independent of the subject process unit or plant area impacted by the change.

d. The leader shall meet the requirements of 8.1.g and be able to plan and lead the HAZOP study through its various stages consistent with BP expectations.

The BP Operation should consider maintaining a list of competent HAZOP leaders.

e. If possible, the HAZOP leader should have experience in the type of facility being reviewed.

f. The Leader shall implement the methodology and the requirements of this GP.

g. A HAZOP leader shall have:

1. Attended a HAZOP leadership training course (BP internal HAZOP leader course or recognised industry available and accredited HAZOP leader training course) that provides instruction on preparing, leading, and documenting a HAZOP, as well as on the HAZOP technique itself.
2. Participated as a HAZOP team member on previous HAZOPs.
3. Acted as scribe for HAZOP sessions under the leadership of a competent HAZOP leader.
4. Co-lead HAZOP sessions under the supervision of a competent HAZOP leader either acting as scribe or participating as a team member.

h. HAZOP leader should be responsible for:

1. Advising project/site leadership of issues that could affect the integrity of the study and working with leadership to ensure an effective resolution.
2. Being alert to time pressures and ensure that the quality, thoroughness, or integrity of the review is not compromised.
3. Advising project/site leadership of the need to delay/postpone the study until issues affecting the integrity of the HAZOP can be resolved. Such issues can include:
   a) Inadequate experience/expertise or makeup of the HAZOP team for an effective review.
   b) Core HAZOP team member roles as agreed in the TOR are not in attendance.
   c) Team fatigue.
   d) Required PSI is inaccurate or not available.

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The authority of the HAZOP leader should be defined in the TOR and agreed to before initiating the HAZOP.

i. The HAZOP leader should have experience in other PHA or risk assessment techniques such as consequences analysis, reliability analysis, and QRA, that may be recommended to further address hazards identified by the HAZOP team.

j. The HAZOP leader should be familiar with LOPA requirements and should ensure that information required to perform a LOPA is discussed and captured in the HAZOP worksheets.

8.2. HAZOP study scribe

a. HAZOP working sessions for studies taking more than a few hours should be documented by a scribe (also referred to as recorder or secretary).

This leaves the other team members free to concentrate on the details of the study without the added burden of completing the log sheets.

b. The scribe should be trained in the use of the software used to record the study, have good typing and summarisation skills, and be familiar with HAZOP process and terminologies used.

A scribe who is lacking skills in these areas causes the process to be less efficient and leads to poor documentation of the study. An inadequate scribe could be the bottleneck for the study, slowing down pace of the team to the speed of recording.

Successful and efficient scribes are often engineers early in their career. The scribe position can also be used as a development opportunity for future HAZOP leaders and to provide an appreciation for process safety engineering.

A scribe who is not familiar with the design of the chemical and petroleum industry or does not have good skills in scribing causes an inefficient study as the leader and team are distracted by providing much direction to the scribe.

c. The scribe should be capable of structuring recommendations/actions in a clear and understandable way.

d. The scribe should work with the leader to ensure all parameters and deviations are addressed, unmitigated consequences are fully documented, and recommendations are clearly worded.

8.3. Selection of the HAZOP study team

The quality of the HAZOP is dependent upon the knowledge and the experience of team members involved. Therefore, selection of team members is critical for successful HAZOP.

a. The HAZOP leader shall select and appoint competent HAZOP team members based on their experience of the type and scale of the HAZOP being conducted.

b. The TOR for the HAZOP shall identify the team members and define those that are considered the core HAZOP team members who will be present for the HAZOP sessions to be held.

c. Adequate BP representation shall be included on the HAZOP team.

This varies between HAZOPs. Contractors are typically used to supplement the HAZOP team. It is a BP accountability to provide a quality HAZOP.

d. Technical expertise of the HAZOP team includes the following.

1. Core HAZOP team shall include with the following engineering and operating expertise:

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a) Understanding of and experience with the Process/facility design and process intent.

This should cover process safety and may be the process or facility engineer depending on the engineering contractor practices and terminology. For chemical processes, this would be someone familiar with process chemistry.

b) Understanding of and experience with the equipment, design limits, materials of construction, and condition of equipment being reviewed.

For existing operations, this may be the unit mechanical or process engineer or both. For projects, this may be the mechanical engineer depending on the BP project team and the engineering contractor's practices and terminology.

c) Understanding of and experience with the day to day operations.

For existing operations, this may be the unit process engineer, operating engineer, or an operations technician. For projects, this may be the project operations representative or a senior operating person who is familiar with the process being considered.

2. Other technical expertise should include, as warranted:

a) Instrument or controls - control and shutdown hardware and logic.

For most projects, the safety shutdown system knowledge is critical to the HAZOP and this individual should be present. Typically the lead instrument engineer is the most knowledgeable in this area. This is also important as the HAZOP feeds into the OPA SIL determination.

b) Corrosion and materials.

c) Maintenance - instrumentation and/or mechanical.

d) Mechanical.

e) Inspection.

f) Technical representative for licensed technologies and/or Vendor package.

g) Other disciplines as required.

e. Affiliations (representation) should be considered:

1. Representative from the project team (projects).

2. Representative familiar with the site operations.

3. Cold eyes - Representative of senior level with significant experience in similar process/facility that is not familiar with the specific process/facility to be studied.

The inclusion of senior level persons, with significant experience, from outside of the facility has been found to add value by highlighting different design and operating practices and assist in identifying potential damage or deterioration modes during equipment integrity reviews.

4. Representative for Vendor design (includes package units and external supplied technology Vendors).

Vendor representation may be required to address intellectual property or other specific issues related to the Vendor design. For projects, it is also advantageous to bring expertise from other similar facilities. This allows HAZOP team to capture problems that can occur during various stages of process operations.

f. The team should be as small as possible for each review session, preferably no larger than 10 people.

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Selecting team members that represent more than one technical expertise or affiliation helps to limit team size.

If contractors are used as team members, care should be taken to ensure that adequate BP operational expertise is included in the study. The contractor should not be totally responsible for providing the BP expertise.

One way to limit the size of the HAZOP team on a large project is to restrict the specialist or Vendor representatives to only those days and or sessions that require their participation.

g. The core team should not be changed during the HAZOP study and the other team members should not be changed frequently during the study.

9. Implementation

9.1. Planning and preparation

a. HAZOP cost and schedule should be included in project planning and existing plant budgeting.

b. Availability of information and key team members required should be considered in development of HAZOP schedule.

c. Before commencing the study, the HAZOP leader and BP Operation leader or delegate should plan and prepare for the study, which should include the following.

1. Development of a formal schedule showing times and durations of the study sessions and dates on which draft and final reports are to be submitted to the various recipients. The schedule should take into account the time required for a comprehensive review and the needs of the HAZOP team.

The HAZOP meeting should not last more than 6 hr per day to maintain the quality of the HAZOP and avoid team fatigue. If the HAZOP lasts more than 6 hr per day, the team may get tired, and effective brainstorming may not be possible. Additionally, the leader may have daily followup and preparation work for the next day to accomplish.

2. List of documents to be included in the review, including drawing and document numbers and revision numbers and dates. A list of typical documents required for a HAZOP study is given in clause 9.2.

3. Identification of materials and supplies for an effective review.

It is best to provide every person in the HAZOP team with a copy of the drawings to be reviewed. The leader or scribe maintains the master set for inclusion in the report.

It is also helpful to provide a copy of the risk matrix from GDP 31-00-01 to each team member.

This also includes required drawings and documentation, record sheets, computer aids for recording, projection screens, stationery, highlight markers, and checklists.

It is preferable for the study leader to identify study nodes before the session to allow for the most productive use of the team's time.

4. If different operational modes are being covered, the corresponding operating procedures should be available and referenced. In some cases, the different operational modes may be defined in design documentation, P&IDs, or supplemented by simplified PFDs.

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For project, operating procedures may have not yet been developed. Recommendations from the HAZOP can reference items that may be developed in future operating procedures.

5. For operating facilities not undergoing major modifications, documentation should reflect the "as built" facility before the HAZOP commences.

6. Study location should be selected based on location of design information, team members, or the facility to be reviewed.

   If practical, a site tour should be arranged for operating facilities.

   If the study involves a review of an existing facility or one being modified by a project, the study can be located near the site to provide easy access to the site for addressing questions that may arise during the study.

   Consideration can be given to locate the study offsite so that the HAZOP team can focus its full attention on the review and not be subject to the distractions and disturbances of an operating facility or engineering office.

7. The study room should be of sufficient size to comfortably accommodate the study team and any specialist advisors with enough working table space for placing copies of P&IDs for each team member.

9.2. Drawings and information required

a. BP Operations EA or Project EA shall ensure that PSI is accurate and up to date before starting the HAZOP on an operating facility.

   HAZOP quality is affected by the accuracy of PSI. Inaccurate P&IDs, information on process equipment, materials of construction, etc will result in additional time required and could lead the HAZOP team to flawed conclusions.

b. BP Operations EA or Project EA shall ensure that P&IDs for project HAZOPs have been approved for HAZOP, confirming that the P&IDs have been sufficiently developed and reviewed and the design finalised for an effective review.

   P&IDs are the focal point of the HAZOP study. A single large set for a master and smaller individual sets (A3 or 11 x 17) for team members are recommended. HAZOP leader may use the large drawings in selecting a node (with colour marking) and hang them on the wall during the HAZOP for easy team viewing.

c. Documentation for a HAZOP study shall include the following as applicable:

   It is not necessary to supply each member of the HAZOP study team with all of the following documentation. These documents can instead be made easily available for reference.

   1. P&IDs
      a) Vendor packages if within the scope of the HAZOP.
      b) Piping class specifications.
      c) Materials of construction.
   2. PFDs
      a) Heat and material balances.
      b) Inventory.
      c) Safe upper and lower operating limits, operating envelopes.

      This includes process design and operating conditions and process contaminants (e.g., H_2S, water, chlorides, ammonia, etc.).

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3. Previous HAZID, What If, HAZOP, or LOPA reports.
4. Control, alarm, and trip information
   a) Alarm and trip settings.
   b) Control system philosophy and description.
   c) Interlock/trip activation and response descriptions.
   d) Shutdown matrices (cause and effect diagrams).
   e) ESD system functions.
5. Pressure relief, flare, vent, and depressuring information
   a) Relief valve data sheets.
   b) Scenarios considered for sizing of the devices.
   c) Flare/disposal systems design and sizing information, including comprehensive list of common failure scenarios (i.e., power failure) and effects on flare loadings and flare system backpressure.
6. Changes to design since the last HAZOP or PHA.
7. Operating procedures (startup, operating, shut down, emergency), (required for a procedural HAZOP).
8. Previous process safety accident/ incident/ near miss reports.
9. Process description and process chemistry.
10. Facility plot plan/Unit layout drawings.

d Additional documentation for a HAZOP study should include the following as applicable:

1. Corrosion control guidelines and corrosion & materials diagrams.
2. EDP system functions.
3. Pump and compressor operating curves and dead head pressures.
4. Instrumentation data sheets, including control valves, orifices, throttling valves and regulators.
5. Valve capacities - particularly important for gas breakthrough.
6. Fire protection design philosophy and basis.
7. Inspection and testing results, maintenance records, operational history, and current condition of process equipment.

   This may include inspection testing procedures and plans, inspection drawings/sketches, inspection database records, corrosion rate information.
8. General arrangement and elevation drawings, including electrical area classification and drainage.
9. Vessel inventories.
10. Operations and maintenance philosophy document.
11. Commissioning procedures.
12. Maintenance procedures.
13. MSDSs.

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14. Previous risk assessment. In particular, any consequence modelling that has been completed should be available to the HAZOP team to assess the consequences of identified causes.
15. Electrical loop diagrams.
16. Process sequence, for batch operations.
17. Ventilation system design.
18. Design codes and standards employed.

9.3. Execution of the study

9.3.1. Before the study

a. Before the study begins, the leader should provide an orientation to the team to ensure that everybody is at the same point of knowledge with respect to the study, including:
   1. Study objectives and expectations.
   2. HAZOP methodology.
   3. Ground rules for the study and expectations of team members.

b. A review of the facility layout should be included. This may be achieved using a model, plot plans, or a plant walk through.

9.3.2. HAZOP recording

a. Recording in full
   1. The HAZOP study shall be recorded in full.
   2. The log sheets shall include:
      a) Documentation of the nodes description.
      b) Node design intent.
      c) Deviation.
      d) Applicable causes.
      e) Consequences taken to the end-effect.
      f) Safeguards for significant consequences.
      g) Risk ranking.
      h) Recommendations.
      i) Relevant hazards identified by the team.

If a deviation is reviewed but the team does not identify any causes for the deviation, the "no feasible cause identified in this node" or "not applicable to this node" should be documented in the log sheet. Documenting this allows persons reviewing the study to identify that the deviation was considered.

As previous process safety incidents are reviewed the incidents and the team discussion should be fully recorded in the log sheets to provide documentation that a thorough review was conducted.

b. Recording by exception shall not be acceptable.

In the past, some teams have saved time by recording only those deviations that resulted in a recommendation. This is not acceptable because there is no documentation of the dependence of safeguards, and it is impossible to revalidate or

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review the discussions made by the HAZOP team. It does not provide an auditable trail of the HAZOP and a record of whether the deviation was considered.

c. HAZOP software

1. HAZOP software provides a systematic method for recording the study and generating log sheets and other information for the HAZOP report.

2. HAZOP software should provide capability to follow the formalised sequence detailed in 10.

Annex B shows typical HAZOP log sheets with the required information. Some leaders and scribes may prefer to use a spreadsheet or writing program for short studies.

d. For studies recorded using HAZOP software, an electronic copy of recordings should be retained with the project or facility hazard analysis documentation.

In some cases, it may be necessary to transfer the file into a Word or PDF format so that it is readily accessible to people without the HAZOP software.

e. The HAZOP leader shall be accountable for clearly marking up the nodes on the HAZOP master P&IDs and including these drawings with the HAZOP report.

Typically the node marking is done with coloured highlighters. It is very helpful for the leader or scribe to mark on the drawings the number of each recommendation close to the relevant point on the P&ID. This may be done outside review sessions. It is best to mark the recommendation numbers on the drawings at the end of the study since during the course of the study recommendations may be combined, added, or deleted.

f. The HAZOP leader shall ensure that names, expertise of team members and participants, and attendance for each HAZOP session are documented for the HAZOP record. The competency of the leader should also be documented.

Typically, the HAZOP scribe records the attendance for each session.

The HAZOP team is responsible for the quality, accuracy, and completeness of the HAZOP worksheets. After the final HAZOP review session, HAZOP log sheets should be issued in draft form to the Client Project Representative or operating site representative. It is advisable to print the log sheets at the end of every day to allow the entries to be checked over. It usually falls on the leader to do this and then any corrections (clarity, accuracy, and logic) can be discussed with the team before moving on to the next day's work.

Using software for recording HAZOPs provides capability to project the PC display so that all the team members (including the leader) can review the log sheets as they are recorded. However, it is important that the leader keep the team focused on the HAZOP as opposed to grammar, spelling, etc. Outside information is often used to complete the log sheets or answer team questions. This can include information from the results of detailed consequence analyses, PRD analyses, outside calculations from team members, etc. If appropriate, this outside information should be referenced within the log sheets for the benefit of future reviewers. This can be valuable for future MoC work or safety studies.

g. The leader should ensure that the HAZOP recommendations are clear and complete and that there is HAZOP team consensus on recommendations, including revisions made outside the review sessions, with the exception of minor grammatical corrections. Some considerations for writing recommendations are:

1. Written to be standalone (understandable without the benefit of the worksheets).

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Any well written recommendation contains the three Ws - What, Where, and Why (add a relief valve downstream of positive displacement pump P-101 to prevent casing overpressure in the event of accidental shut-in.).

2. Written so that recommendations are accomplishable and have a clear point of closure.

Some recommendations may be unresolved at the time of a particular review session, and a team member(s) may be given an action to follow up outside of the session. The whole team should review the final recommendation arising from these items at a later session.

h. If the team can not reach consensus on a recommendation, the HAZOP leader shall be the final arbiter.

9.4. HAZOP report

a. The HAZOP leader shall be responsible for issuing the HAZOP report.

The HAZOP report serves as the permanent record of the HAZOP study and is used by people that were not a part of the HAZOP team. Over time, the HAZOP report is the only indicator of the quality and completeness of the HAZOP study, and serves as a record of the team's diligence. It is important that the HAZOP Leader and team have the attention to detail to ensure clarity and accuracy of the log sheets and report.

b. Study documents, including master copies of colour marked P&IDs and the electronic HAZOP worksheets shall be collected and archived for future reference. The responsibility for doing this rests with:

1. The project team who should hand over study documents to client or asset, or
2. The person in an existing asset who coordinates HAZOP documentation.

In case the P&IDs are archived electronically, care should be taken to retain the colour mark up of the drawings.

c. HAZOP documentation (including initial and revised reports) shall be retained for the life of the process facility. This report should be prepared and filed in accordance with local document control procedures.

HAZOP documentation should be retained so that it is available for reference in MOC and revalidation.

The study should note or include in the file additional documents that were used in the study. This provides a basis for future review and an indication of which version of certain documents were reviewed.

d. At the conclusion of the study, the report should be formally issued by the HAZOP team leader and addressed to the principal recipient in TOR.

e. A HAZOP report should include following sections:

1. Main report
   a) BP Operations leader to receive the report.
   b) Executive summary.
   c) Introduction defining the scope of study.
   d) Process or system description and design intent.
   e) Methodology including guidewords used.
   f) HAZOP team members and their roles.

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g) Recommendation summary.

h) References (list of P&IDs and other data used).

i) Distribution list.

2. Appendices

a) TOR for the HAZOP study.

b) HAZOP log sheets.

c) List of recommendations from the study.

d) Team attendance for each session.

e) Colour marked P&IDs with node numbers.

f) Human factors and facility siting issues (checklists used or other related studies).

g) Risk matrix from Appendix 1, 2, and 3 of the GDP 31-00-01.

h) Any incidents considered.

i) MoCs reviewed or P&ID change logs.

j) Information that was referenced in the log sheets or used extensively by the team.

This can include calculations, detailed consequence analyses, or other useful information compiled for or during the HAZOP that would be useful reference material for future MoC or safety issues.

It may be beneficial to produce an annex to the full report that contains only those guidewords causes consequence discussions that resulted in recommendations. It may also be beneficial to sort the recommendations by risk ranking, if applicable, to give priorities on recommendations.

9.5. Follow-up

a. Recommendations shall be addressed in a timely manner and tracked until closure. To achieve this, each recommendation should be assigned to a responsible party with a target completion date for follow-up.

b. Technical reasons for recommendation resolution including suggestion of a different action, or rejection, shall be clearly stated in writing. A formal record should be kept of such decisions which can be accessed in the future if required.

c. If recommendation and actions cannot be agreed with the project or BP Operation to the satisfaction of the HAZOP leader then the Project EA or BP Operations EA shall be informed. The EA shall attempt to get resolution with the Project Manager or BP Operation leader but if this is not possible the EA shall raise the issue to a higher EA until agreement is reached with the BP Operation leader.

d. For projects, the Project manager shall ensure that agreed recommendations are addressed in an appropriate timescale as dictated by project schedule.

The PHSSER teams will review and audit action progress at various stages of CTP in accordance with GP 48-01, as well as the compliance of the HAZOP strategy and process with this GP.

Completion of recommendations should also consider the amount of work involved in completing the tasks. Administrative and documentation recommendations should be completed in a reasonably short period while recommendations requiring extensive engineering and installation during unit downtime may require years to complete.

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e. BP Operations leader shall ensure that agreed actions are followed through to an appropriate conclusion. A person should be nominated to do this and instructed to report formally at regular intervals while the action remains outstanding.

f. A full audit trail of responses and actions completed in respect of each recommendation shall be maintained for the life of the facility.

Report recommendations, Project or Asset Management responses, and supporting documentation should ideally be recorded in a records system, which will permit ready retrieval, status reporting, progress chasing, and independent audit. The supporting documentation should include appropriate reports, memos, drawings, and other communications demonstrating that the recommendations arising from the HAZOP have been carried out or otherwise resolved.

g. BP Operations EA or Project EA should ensure that an effective means of tracking recommendations is in place and accomplishes the following:

1. Tracks the status of open action items.
2. Records the action item closure and approval by project or site authority (approved action response sheets should be retained with the log sheets).
3. Includes or references documentation requirements.
4. Tracks the transfer of action items between delivery teams (e.g., project to commissioning).

To facilitate future reviews and use of material for training purposes, it is useful if the log sheets are updated to include the actual actions taken when the recommendations are closed out.

To assist in this activity, project teams or facility teams may choose to use a separate HAZOP Recommendation Action Tracking system.

5. Provides for a confirmation of completion including by field-verification for operating facilities.

h. Relevant recommendations and actions from HAZOP reports and related study documents shall be communicated to members of the BP workforce who may be affected by them.

Local law may impose additional communication requirements, including a requirement to make the risk assessment accessible to persons who work with or near the studied risk.

i. For operating facilities, an MOC process shall be followed for approved changes resulting from HAZOP recommendations.

MOC ensures that employees are advised on changes to procedures and or equipment and any relevant training provided at the time of change. It also guards against the resolution of the recommendation inadvertently introducing a new risk.

10. HAZOP methodology

10.1. General

The HAZOP study shall follow the sequence illustrated in Figure 1.

A HAZOP study is a structured methodology for hazard identification. It is an investigation technique that is designed to inspire imaginative thinking (or brainstorming) by a team of experts to identify hazards and major operational problems while examining a process or facility in a thorough and systematic manner.

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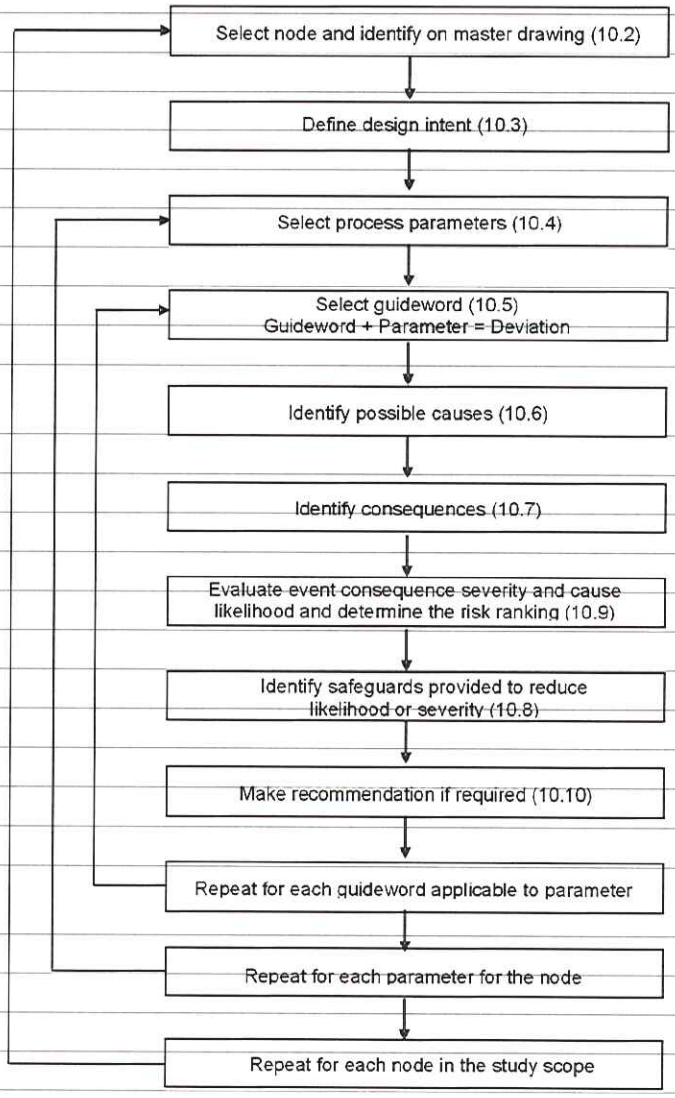
A HAZOP study involves a systematic, methodical examination of design documents that describe the facility. The study is performed by a multidiscipline team and the team focuses on potential deviations from design intent by using guidewords.

Figure 1 shows the sequence of a typical HAZOP study.

Figure 1 - HAZOP sequence



10.2. Selecting nodes

Node size and complexity is a topic of much debate. Nodes that are very small, such as a single process line, often lead to longer study times as each guide word combination should be recorded more times. Large nodes, such as multiple process lines and equipment items, confuse the application of the guidewords and if not

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properly managed, could lead to overlooking hazards. Selecting a proper node size and guiding the team through the node is crucial for success of HAZOP study.

a. Nodes should be selected by the HAZOP Leader, but team members may also provide their input.

b. To ensure that the design intentions of each node can be easily and clearly understood, the nodes should be selected by function.

This GP does not intend to prescribe exact node size. Such a decision is left up to the HAZOP leader and team members. Several factors influence size and complexity of a node including leader and team experience, hazards of the process, and complexity of the control system.

c. The following criteria should be considered in selecting the appropriate transition to the next node.

1. Change in design intent.
2. Change in state (e.g., from liquid to vapour).
3. Major pieces of equipment.
4. There could be confusion over which piece of process equipment is being discussed (e.g., if the deviation is more flow and there are multiple lines in the node, there may be confusion over which line is being discussed).

If nodes are selected with multiple lines, the leader should ensure that team members are together and thinking about the same line. This can be done by the leader systematically guiding the team to review one line at a time.

d. Different operating nodes

1. If a node has more than one design condition or operating mode (e.g., normal production and in-situ molecular sieve regeneration), each operating mode/operation condition shall be considered (i.e., each of the nodes should be repeated for the different operating modes/operating conditions).
2. The different operating modes should be clearly documented in the HAZOP log sheet and report.

e. Parallel trains

1. Parallel trains may be reviewed independently or one train may be reviewed and the next train may be reviewed based on the first.
2. If the later approach is taken, the trains shall be compared in detail to ensure that any differences in control, instrumentation, piping arrangement, and equipment design is identified and considered.

10.3. Design intention

HAZOP study addresses hazard and operability problems caused by deviation from design intent.

a. At the beginning of the HAZOP, a thorough briefing on design and operation should be provided as follows:

1. For a new facility - by someone knowledgeable about design.
2. For an operating facility - by someone knowledgeable about design and operations.

This intent can be reviewed as the study of each new system is started.

b. Normal and abnormal operating conditions, as well as transient conditions, and operating modes shall be assessed.

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c. The design intent defines how a component or system is expected to operate and the purpose of the system. This includes the design flow, temperature, pressure, level, and other relevant details.

d. The design intent of each parameter should be established, documented, and understood by team members.

The design intent (or design operating conditions) of the study node are usually available in the material balance sheet. The process engineer or other team member should be familiar with the design intent of the process.

Design intent includes the design flow, temperature, pressure, level, and other relevant details such as composition.

10.4. Process parameters

Process parameters should be selected and reviewed in turn for each node. Flow, temperature, pressure, level, and reaction (if applicable) should be considered. Additional parameters should be selected as applicable to the process.

The application of additional parameters depends on the type of process being considered (continuous, batch, procedure), the equipment in the process, and the process intent.

Using only the common process parameters may not fully identify all process hazards. Application of additional parameters is necessary to ensure that the full range of hazards is covered in the study. Some examples of other parameters are:

- *Viscosity*
- *Utility system failure*
- *Abnormal operation*
- *Instrumentation*
- *Composition*
- *Sampling*
- *Human factor*
- *Electricity*
- *Ignition*
- *Maintenance*
- *Safety*

10.5. Guidewords and deviation

HAZOP method considers deviations from the design intent by combining guidewords with parameters resulting in a possible deviation from design intent. For example if guideword "No" is combined with the parameter "Flow" the resulting deviation is "No Flow".

a. Guidewords should be selected and applied in turn to each parameter. At a minimum, more, less, no, reverse, part of, as well as, and other than shall be considered.

Table 1 shows how these guidewords should be applied to process parameters to develop deviations traditionally used in HAZOPs.

Table 1 - Example deviation matrix for continuous process

Parameters	Guideword						
	More	Less	No	Reverse	Part of	As well as	Other than
Flow	More flow	Less flow	No flow	Reverse flow	Wrong ratio	Contamination	Wrong direction (reverse flow)
Pressure	High pressure	Low pressure	Vacuum				
Temperature	High temperature	Low temperature					
Level	High level	Low level	No level				
Reaction	High reaction	Low reaction	No reaction	Reverse reaction		Side reaction	Wrong reaction

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The process for selection of the parameters and guidewords should be documented in the HAZOP report. The HAZOP leader and team should exercise caution in the selection of guideword and parameter combinations because it could set the scope of the HAZOP and place a limit on the types of hazards which could be identified.

A list of typical guidewords and descriptions applicable to continuous process HAZOP is available in Annex A, Table A.1. A more extensive list of deviations used in chemical and petroleum industry is also available in Annex a, Table A.2 with detail description.

A list of typical deviations and descriptions applicable to interlock and control system is available in Annex A, Table A.3. As interlocks are encountered in a HAZOP, these guidewords can supplement the review by providing a better analysis of the interlock function, its ability to achieve design intent, limitations, potential effects on the process and recovery from trip of the interlock.

b. Process parameters and guidewords (and hence deviations) should be applied to each process node, as appropriate. If no issues are found, it should be documented that the deviation was considered, but there were no issues of concern.

c. Different guideword/parameter deviations may be used for nonprocess facilities.

10.6. Causes

a. All potential causes should be established for each deviation from intention considered.

b. There may be multiple causes for each deviation. In such case, each cause should be listed separately.

c. Causes can be due to a range of events. Some examples are human error, equipment failure, process upset, or external event.

For example, a control valve could fail closed because of human error, loss of instrument air or electrical signal, actuator failure, etc. Similarly, a block valve adjacent to the control valve could be inadvertently closed due to human error. All of these causes have the same affect, blocked flow. The important point is that this information is included so that the correct initiating frequency can be used in subsequent analyses.

d. Causes should be specifically defined using the proper equipment, instrumentation, and piping tags.

e. Multiple-cause events shall be considered if they are the result of a common mode failure or a process dependency.

"Double jeopardy" events are not typically included in the HAZOP studies. Double jeopardy events are multiple independent events occurring at the same time and causing a hazardous situation (e.g., a level control failure on one tower that causes liquids overhead and a level control failure on another tower also causing liquids to the same overhead system if the system is not expected to handle liquids from both towers). If the causes are independent, they are considered double jeopardy. In determining if the causes are independent, careful consideration should be given to common mode failures and process dependencies.

When encountering potential cases of "double jeopardy", the team should consider the severity of the consequences. There may be cases in which the consequences are so severe and unacceptable that action is needed, even if the likelihood of the "double jeopardy" event is very low.

f. The cause is identified within the node being studied. However, the resulting consequence may occur throughout the process.

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Holding the cause to within the node and identifying consequences outside the node is the typical approach. An alternative HAZOP methodology is to identify consequences within the node and then to identify causes for each consequence inside and outside of the node. Both approaches can be acceptable and are driven by BP Operations practices. The leader and HAZOP team should ensure that the selected methodology is consistent with client expectations and, once adopted, is applied consistently throughout the study for thoroughness.

g. If the node starts from a battery limit, deviations from upstream and downstream shall also be considered.

For example, a node at the front end of the process boundary limits should consider upstream deviations, or a node at the back end of where the HAZOP ends for the process should consider downstream deviations. This approach is also applicable to deviations in process utilities to which a node is tied.

In the HAZOP review of major modifications and equipment changes, potential effects from deviations upstream and downstream of the change should be considered since causes outside the scope of the change may not be evaluated as a part of the study.

h. Same cause under multiple deviations

1. There are opportunities to identify the same cause under multiple deviations.
2. As long as the consequences and safeguards are fully defined and documented, there is no requirement to document details for the same cause in each of the deviations.
3. An example would be a valve closing could result in no flow or a change in pressure or level.

It is important that the HAZOP team documents the review of the deviation, however if recommendations are made under another deviation, the HAZOP team should state that "No new issues" are identified.

i. LOPA

1. HAZOP is typically used as the basis for LOPA.

There are other hazard identification and risk analysis techniques that may be used to feed into LOPA. In the majority of instances, HAZOP forms the basis. The remainder of the document is written from the point of view of using the HAZOP as the input.

2. Causes identified in the HAZOP can be used as an initiating event in LOPA.
3. All causes (including failure mode) shall be identified and clearly stated.

This saves effort in preparation of LOPA.

j. The cause should not be a restatement of deviations or consequences.

10.7. Consequences

a. The leader shall challenge HAZOP team members to identify all potential practical consequences of each cause, especially the potential for harm to people and the environment.

In some cases, that might be considering the worst consequence and lower likelihood while in other cases, it might be the more likely but less consequential outcome.

b. The discussion should consider the unmitigated consequences - those consequences without giving any credit to the safeguards (assuming all safeguards fail). Safeguards are discussed and documented in the next step.

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It may be beneficial to consult any dispersion modelling or risk assessment, if available, to fully understand the range of potential consequences.

c. Consequences shall be taken to be anything that affects:

1. Health and safety of BP workers, contractors, and offsite populations.
2. The environment.
3. Privilege to operate.

and should be taken to be anything that affects equipment damage and business value lost.

GDP 31-00-01 provides additional guidance in this area.

d. LOPA

1. Consequences identified in the HAZOP are also important inputs for LOPA.

GP 48-03 recommends performing LOPA for the consequence categories D through F as shown on the risk matrix in GDP 31-00-01, Appendices 1, 2, and 3.

2. The HAZOP team should think through scenarios of events to final outcome assuming that safeguards fail and document them clearly in the log sheet including severity categories.

The HAZOP team should take care in estimating the consequence level. As this information will feed into LOPA, underestimation of the consequence may lead to inadequate layers of protection managing the risk. Overestimation can lead to more layers of protection being applied than are warranted which, over the lifecycle, results in increased cost, inspection, and maintenance requirements.

e. Consequence rankings shall not be modified by the HAZOP team after the team and leader have reached a consensus on the ranking, without the concurrence and authority of the HAZOP team.

10.8. Safeguards

a. In the next step the team should identify the engineered system (as defined in the P&IDs and other engineering information) and administrative controls (such as operator response to alarms) that can prevent or mitigate the hazard.

b. The team should also consider whether operability is impaired if any deviations occur or whether design could be improved to give the operator better information or facilities to prevent/control/mitigate the hazard.

c. Principal safeguards (engineering and administrative controls) shall be recorded in the HAZOP log sheet referencing the appropriate equipment tags.

d. Typical safeguards (or protection layers) that prevent or minimise consequences and likelihoods are described in Figure 2. This develops information required for a LOPA evaluation.

e. Relief valves should be listed as safeguards only after it has been confirmed that the relief valve size and set pressure are sufficient for the consequence being considered.

This can be accomplished either through review of data on the P&IDs or relief device data sheets.

f. If operating procedures are identified as the primary safeguard preventing/mitigating a safety consequence, the HAZOP team shall:

1. Ensure written procedures address the cause/consequence identified and the appropriate action described in the safeguard, and

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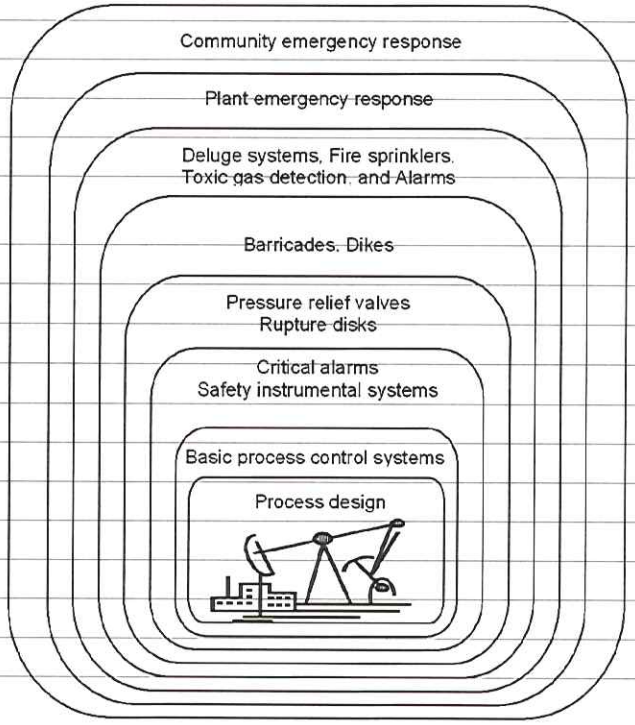
For example, operating procedures contain operating instructions about pressure limits, temperature ranges, flow rates, what to do when an upset condition occurs, what alarms and instruments are pertinent if an upset condition occurs, and other subjects.

This does not mean that the cause/consequence needs to be copied from the HAZOP to the operating procedures.

2. Determine whether the operators have time and capability to carry out the procedures, or
3. Make a recommendation in the HAZOP log sheet to conduct a review of the procedures prior to startup.

Figure 2 - Examples of safeguards (protection layers)



The safeguards shown in Figure 2 are also considered in LOPA. However, unlike HAZOP, LOPA considers only IPLs as safeguards in assessing capability to reduce risk.

10.9. Risk ranking

a. Risk ranking of safety/health, environmental, and privilege to operate risks shall be included in the HAZOP and use the risk matrix in GDP 31-00-01, Appendices 1, 2, and 3.

b. Risk ranking of equipment damage/business value lost risks may be included in the HAZOP. If they are included, the ranking should be based on the risk matrix in GDP 31-00-01, Appendices 1, 2, and 3.

Risk ranking allows the project team to screen identified hazards and assign priorities.

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c. Consequence severity of an event should be determined based on team experience/judgement or consequence analysis results available to the study team. The consequence severity should be determined without considering available safeguards.

In some cases, the consequences are estimated quantitatively by specialists outside of the HAZOP team meetings.

d. Event likelihood

1. Likelihood of event should be determined considering available safeguards.
2. Not all safeguards listed can be credited in determining the likelihood.
3. Approach suggested in GP 48-03 should be used in determining event likelihood.

e. The risks as plotted on the risk matrix shall be resolved in accordance with the associated endorsement levels as defined in GDP 31-00-01, Appendices 1, 2, and 3.

10.10. Recommendations

a. A recommendation shall be made if the team judges that any of the following are true:.

1. Engineered systems and administrative controls are unlikely to prevent or sufficiently mitigate a consequence.
2. An operability concern is sufficiently severe that it requires attention.
3. There is a shortfall in compliance with a regulation or BP standard.

Recommendations can be design changes, procedural changes, or issues requiring further study. The recommendation needs to be understandable, concise, and unambiguous, clearly address the identified hazard, and be effectively completed.

b. Recommendations should meet the following.

1. Stand alone, such that it is understandable without benefit of the log sheets.

Sometimes recommendations are placed on an action list, not accompanied by the appropriate deviation, cause, consequence information. The person responsible for closing the recommendation needs to fully understand the hazard.

2. Be able to be accomplished - have a clear point of closure.
3. Be understandable, concise, and unambiguous.

Including equipment piping instrumentation names or numbers can aid in the clarity of the recommendation.

4. Be clearly worded to address the identified hazard.
5. Be thorough (identifying the reason for the recommendation and clearly communicating the intentions of the HAZOP team).

Sometimes recommendations are placed on an action list, not accompanied by appropriate deviation, cause, consequence information. The person responsible for closing the recommendation needs to fully understand the hazard.

c. The HAZOP team should focus on addressing hazards and not try to design the solution to problems identified. If the team is not certain how to prevent or mitigate the hazards, the team should recommend a further study to determine the resolution.

The purpose of the HAZOP is to identify hazards, not to engineer solutions. Recommendations calling for further review should be avoided if such reviews can be readily accomplished by the HAZOP team and are within its charter.

d. Recommendations shall not be modified without the concurrence and authority of the HAZOP team.

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The leader can use various techniques for ensuring that the team has reached consensus.

10.11. Human factors and facility siting

10.11.1. Human factors

a. The team should pay particular attention to human factors in identification of causes of undesired consequences.

b. Human factors should be addressed in a number of ways, including:

1. As potential for causing the hazard, such as:
   a) Improper operation of valves.
   b) Incorrect or inadequate actions through the control system.
   c) Incorrect response to an alarm.
   d) Operability issues such as instrument visibility, access, or confusing information.
2. Limitations of operator response should be considered.
   a) HAZOP normally gives little credit for operator intervention particularly if the hazard is significant and occurs rapidly.
   b) Alarms may be discounted on the understanding that they only provide an opportunity for the operator to take corrective action before the subsequent executive action shutdown or relief valve operation, etc.

   Alarm management system aids the operations staff in discriminating between the importances of various alarms.
3. Operability issues should be considered
   a) Use of guidewords such as operability or maintenance problems prompt consideration of issues of access, instrument visibility, etc. With the instrumentation guideword, the team can consider human factor issues such as confusing information, alarm overload, and inadequate instrumentation.

   A separate guideword, human factors, may also be used.
   b) Separate reviews of alarm management, control room ergonomics, manual handling/lifting, etc. issues may be justified but outside the scope of a HAZOP study.
   c) The team should consider the potential for:
      i. Human error if manual control is necessary to correct deviations,
      ii. The provision of critical information and alarms to operators if deviations occur, and
      iii. The ability of operators to intervene if deviations occur.
   d) Consideration should be given to the potential for operability problems to become hazards if unsafe practices are necessary to overcome the problems.
4. Human factors can be taken into consideration in the assessment of safeguards and in developing HAZOP recommendations, whether administrative controls are sufficient or if an engineered solution is warranted.

c. A separate analysis of human factors may be warranted if the HAZOP shows that there are significant risks associated with human factors that cannot be properly addressed in the HAZOP

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10.11.2. Facility siting

a. The team should consider facility siting with respect to potential hazards impacting personnel.

The team should consider the relative location and proximity of personnel (including control rooms, offices, and living quarters) to hazardous inventories, flammable materials to ignition sources, and hazards to other hazards. Additional aspects to be considered are suggested in Annex A, Table A.4.

Siting is a critical factor for managing risks and has a predominant influence on the outcome of major accident risk assessments required by GP 48-50.

An option to considering facility siting as part of the HAZOP of each unit is to conduct a study of the entire plant focused on facility siting using a HAZOP format. This could:

- *Examine how potential incidents could impact the plant and surrounding community.*
- *Discuss how plant operating and emergency response personnel will react to the initial leak or spill.*
- *Examine plant policies on shelter-in-place versus evacuation of plant personnel from specific locations.*
- *Discuss plant resources for dealing with the emergency, e.g., fire water system, foam or deluge systems, bunding (diking), and other containment measures.*
- *Evaluate the interaction between plant and community emergency responders, e.g. mutual aid programs, fire fighters, police, etc.*
- *Determine the acceptability of locating occupied buildings in or near process facilities.*
- *Application of local regulations for addressing occupied buildings in or near process facilities.*

A siting guideword list is included in the appendix.

b. A more detailed facility siting study should be conducted to ensure that occupied buildings are not located near potential hazards unless they are adequately protected (blast resistant, fire rated, toxic shelter, etc.)

Facility citing studies are conducted using GP 44-30, GP 44-31, and GP 44-32.

11. HAZOP of batch/sequential operations

a. Batch/sequential operations should be identified before HAZOP studies commence as the application of guidewords/deviations to batch operation systems is more complex than their application to continuous systems/operations.

b. Standard or non-standard operations

1. Examples include any standard or nonstandard operation, such as startup procedures, nonstandard routing of flows, and the launching and receiving of pipeline pigs.
2. Such operations have historically been one of the main causes of major incidents.
3. Thorough review of such operations is one of the key areas in the understanding and management of human factors in relation to major hazards.

c. HAZOP of a batch process normally requires the simultaneous application of guidewords to both the procedural step involved and the associated process and equipment used for the step. The HAZOP is in fact normally driven by a review of the procedural steps with the P&ID review resulting as a natural consequence of this process.

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d. The HAZOP Leader should:

1. Plan and develop a batch/sequential operations HAZOP process.
2. Structure appropriately for operation/system to be reviewed.
3. Coach the team on the process to be used.

e. Some components of batch HAZOP techniques are as follows:

1. Review of the physical location of the operation and relevant engineering equipment/instruments.
2. Consideration of the nature and proximity of neighbouring facility/operations and occupied areas (people at risk).
3. Selection of a set of guidewords based on the list for sequential operations supplemented by the main process deviations of "flow", "temperature", "pressure", etc. appropriate to the nature of the operation (refer to Table 2).

   Typical process deviations are listed in Annex A, Table A.2 and batch process deviations are listed in Table 2.
4. Documenting the procedure/operation and P&IDs being reviewed and the overall intention of the procedure/operation (or subsection of procedure).
5. Review of operating procedures to specifically identify key steps in the batch operation, systems used, and their required state, valve positions, and process/utilities interfaces. These should be marked up on the P&ID as appropriate.

   Suggest that a separate P&ID be used to mark up each sequential step so that it is clear to the team the current status of equipment for that step.
6. Definition of the design intention for each step, including intended condition of the relevant equipment on P&IDs and/or layout drawings.

   For example, coloured discs can be placed on valves to show positions (green for open, orange for "in position", and red for closed). If items are being moved during the batch process, "models" should be used on the layout drawings, (e.g., railcars should be shown with counters or coloured blocks).

   The leader should pay close attention to design intent and how that design intent changes for specific parts of the process through the sequence of batch steps, and take that into consideration in the determination of nodes. It is conceivable that a specific node can have multiple design intents across the batch sequence and at times may be inactive. For each of those states, the node should be reviewed using the batch guidewords, and take into consideration the effects of time, equipment state, and the range of potential failures.
7. Having defined the design intention, application of the selected set of guidewords to identify deviations and potential hazards. This should include the inherent hazards of the step as described/intended.
8. Consideration of existing safeguards referring, as necessary, to cause and effect diagrams and making further recommendations as appropriate.
9. Completing the HAZOP of the P&ID for sections not covered by the review of the procedures.

f. Table 2 presents an example of a deviation matrix applicable to batch/sequential operations.

g. Guideword and deviations in Table 2 may be used to HAZOP sequential operations (procedures) supplemented by a selection of guidewords appropriate to the nature of the operations and scope of the HAZOP.

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h. Guidewords in g. shall include use of the main process parameter guidewords (relating to flow, pressure, temperature, level, and composition) on associated facility sections (HAZOP nodes) at appropriate steps in the procedure.

For sequential operations, it is appropriate to document the overall design intention of the procedure or subsection of a large procedure and, in addition, to consider the design intent and inherent hazards of each step of the operation before considering deviations from the intention.

Table 2 - Example deviation matrix used in batch/sequencial operations

Parameter	Guideword	Examples of potential problems
Design intention of the step (what it is meant to do?)		
Inherent hazards of the step		Inherent hazards and operability problems with the step even if there is no deviation from the intention.
Sequence step	Omitted	Step not done, handover problems, split responsibilities, unclear roles/responsibilities.
		Memory lapse, distractions, excessive workload.
	Incomplete	Step or intention only partially completed or delayed.
		Lack of clear information/indication that step intention achieved.
		Checks not made or incomplete.
	Valve errors	Valve open or closed in error prior to/during step.
		Lack of clear labelling.
		Valve closure/opening incomplete or valve passing/blocked.
		Incomplete or incorrect valve status list in procedure.
	Too short/long	Operation completed too slowly or too quickly.
	Too late/early	Insufficient or excessive delay before moving on to the next step or following completion of previous step.
		Communication delay/error between other parties responsible for preceding steps.
	Wrong order	Step done out of sequence.
		Communication delay/error between other parties responsible for preceding steps.
	Wrong action	Incorrect action substituted for the correct action. (e.g., starting the wrong pump or closing the wrong valve, etc.
		Procedure ambiguity, plant labelling defective.
		Poor access, lighting, time pressure, fatigue.
	Extra action	Another action completed, as well as the action intended.
	SIMOPs	Any other simultaneous activity that may have an impact on the overall safety of the operations.

12. HAZOP of control and computer systems

a. Control systems, such as programmable electronic systems, due to their inherent flexibility and complexity, have the potential to create common mode failures that result in multiple simultaneous process deviations. CHAZOP study reviews how control and computer systems can fail and consequences of deviation from design intent.

The traditional HAZOP does not address issues associated with the control system.

b. The HAZOP leader of a computer or control HAZOP should have an additional competency to those listed for traditional HAZOP team leaders which is experience in control or systems HAZOPs.

c. The response of the control system to a deviation or the potential cause of a deviation by a control system should be factored into the HAZOP.

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d. Based on the types and complexity of the control systems within the scope of the HAZOP, a decision shall be made as to whether the traditional HAZOP adequately addresses control system issues or whether a control system HAZOP (a.k.a. CHAZOP) or other types of studies are necessary.

For traditional HAZOPs, substantial knowledge of the control system is needed in order to identify potential control system induced secondary deviations in response to the original, primary deviation. Often, a traditional HAZOP can be augmented by adding a review of the I/O cards of a computer based control system. Assuming the common mode failure of any single card failing, the points on that card can be reviewed to determine if any resulting multiple simultaneous process deviations would create a safety or environmental hazard.

e. The list of typical guidewords and deviations available in Annex A, Table A.3 may be used to address interlock and control systems.

13. Linkage to LOPA

a. If the current HAZOP conforms to this GP, HAZOP shall form a basis for LOPA.

LOPA is applied to the hazard, not to the cause. In LOPA, it is necessary to consider a hazard first and then consider all causes related to the hazard from related nodes. LOPA is typically conducted immediately following a HAZOP, but in some cases is conducted in conjunction with HAZOP.

GP 48-03 provides requirements on LOPA. The key information needed for LOPA from HAZOP is as follows:

- *Process deviation and initiating cause.*
- *Consequence and severity category.*
- *Safeguards.*

LOPA relies on the result of HAZOP for hazards and associated initiating causes. It is important that all hazards and initiating causes are captured during HAZOP.

b. The team shall identify the scenarios that are consequence categories D through F on the risk matrix in GDP 31-00-01, Appendices 1, 2, and 3 for evaluation in a LOPA.

c. The key participants in HAZOP should also participate in LOPA per team member description defined in GP 48-03.

d. The HAZOP leader should be familiar with the information required to conduct a LOPA and should ensure that the information is discussed and captured on the log sheets.

If a different team is used in LOPA, the LOPA team should spend some time to get familiar with the process and discuss the same hazards already addressed in the HAZOP study.

14. HAZOP revalidation

The intent of HAZOP revalidation is to confirm that the HAZOP conducted previously is consistent with and accurately reflects the hazards of the current process.

a. HAZOP revalidation shall be done by updating and revalidating the previous HAZOP or by conducting a new HAZOP (redo) or a combination of the two approaches, which are defined as follows:

1. Update and revalidate

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a) Modify and/or supplement the previous HAZOP as appropriate to address changes and incidents that have occurred since the previous HAZOP and confirm that the previous HAZOP accurately reflects the hazards of the process and that adequate controls are in place to manage these hazards.

b) This effort may also include upgrading the previous HAZOP for specific deficiencies or weaknesses that should have been addressed as part of the previous HAZOP.

In this case preferably the electronic version of the recordings of the previous HAZOP are still available and usuable. Recommendations from previous HAZOP can be deleted or modified.

2. Redo. Perform a completely new HAZOP as if it were the initial HAZOP.

Some situations could occur in which the HAZOP should be redone, because of factors such as significant changes in a number of nodes, poor information available previously, inadequate documentation, etc.

b. If significant changes have taken place since the previous HAZOP, a new HAZOP of the process or facility (redo) should be completed. If there have not been significant changes or there is confidence that changes have been subject to an effective MOC process, it may be sufficient to review the old study, the changes documented in MOC, changes to the PSI to update and revalidate the HAZOP.

c. The responsible person nominated at an operating facility shall consider the following questions to determine if a full new HAZOP should be conducted:

1. Did the previous HAZOP use methodology consistent with this GP?

2. Did the previous HAZOP report record the study in full such that the hazards can be identified, even if no recommendations were made?

3. Relevant to management of change: have potential hazards been assessed, updates made to the last HAZOP as appropriate, and changes to P&IDs and other PSI made as appropriate?

4. Have potential lessons learned from previous incidents and near misses since the last HAZOP been considered?

d. If the answer is "No" to any of the questions in c., the HAZOP shall be redone rather than revalidated.

e. For a large facility, the view may be that large parts of the facility do not require a new HAZOP, but there may be some units/systems which should have a new HAZOP (e.g., because of the number of changes, inherent hazards, etc.).

f. If the decision is taken to revalidate, refer to Annex C, Table C.1 for suggested discussion topics for the revalidation. A review of the previous HAZOP log sheets should consider

1. Refreshing knowledge and understanding of hazards and safeguards and verifying that they are still valid.

2. Checking for additional hazards not identified in the previous HAZOP.

3. Any change in knowledge or circumstances that might affect the conclusions previously reached regarding the adequacy of the existing safeguards.

4. Combining any major modification HAZOPs or change management HAZOPs into the main HAZOP of the unit or facility.

g. The revalidation exercise shall be conducted by a team with the same level of expertise as is required for a complete new HAZOP. The difference is that the study length may be significantly shortened and revalidation has limited ability to identify new hazards.

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h. Before commencing the study, the following data shall be available:

1. Previous HAZOP (including drawings used) and action item close documents.
2. Record of MOCs (and associated HAZOP reviews) completed since the previous HAZOP.
3. Copy of current as built P&IDs.
4. Record of process related incidents and near misses since the previous HAZOP and actions taken following the incident investigation. Incident data that occurred in similar operations should also be available.
5. Resolution of previous HAZOP recommendations.

i. Before commencing the study, documentation and information in 9.2 should be available.

j. The team should document the revalidation in report form and forward the report to persons responsible for site document control at the site for storage of this report.

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Annex A
(Informative)
Guidewords and deviations for HAZOP

Table A.1 - Guidewords for continuous process HAZOP

Guidewords	Description	Remark
More of	Quantitative increase of any relevant physical property.	These refer to quantities + relevant physical properties, such as flow rates and temperatures, as well as activities, such as "Heat" and "Reaction".
Less of	Quantitative decrease of any relevant physical property.	
No, not, or none	Complete negotiation of the design intention.	No part of intentions is achieved and nothing else happens.
As well as	Qualitative increase of any relevant physical property.	Design and operating intentions are achieved together with some additional activity.
Part of	Qualitative decrease of any relevant physical property.	Only some of the intentions are achieved and some are not.
Reverse	Logical opposite of intention.	Mostly applicable to activities. For example, reverse flow or chemical reaction. Can also be applied to substances (e.g., "Position" instead of "Antidote" or "D" instead of "L" optical isomers.
Other than	Complete substitution.	No part of original intention is achieved. Something quite different happens.

Table A.2 - Deviations for process HAZOP

Deviation	Causes		
More flow	Bypass valve open	Worn or deleted restriction orifice plates	Large leak
	Increased pumping capacity	Cross connection of systems	Wrong valve open
	Operation of pumps in parallel	Control faults	Wrong lineup or misdirected flow
	Reduced delivery head	Control valve trim changed	Slug flow
	Change in fluid density	Control valve fails open	Water hammer
	Exchanger tube leaks	Burst pipe	Increased flow from upstream process
Less flow	Line restriction	Fouling of vessels, lines, valves, or orifice plates	Inadvertently throttled valve
	Filter fouled	Density or viscosity changes	Incorrect valve sizing
	Defective pumps	Competing pump heads and flows	Wrong lineup
			Surging
No flow	Block valve closed	Equipment failure (control valve, isolation valve, pump, vessel, instrumentation, etc.)	Isolation in error
	Wrong lineup	Control valve fails closed	Power failure
	Slip blind installed	Incorrect pressure differential	Plugged line
	Incorrectly installed check valve		
Reverse flow	Malfunctioning, omitted, wrong type of check valves (note that check valves are not usually bubble tight or positive shutoff devices)	Siphon effect	Wrong lineup or misdirected flow
		Incorrect differential pressure	In line spare equipment
		Two way flow	Connections to utilities (water, N_2, flush systems, etc.)
		Emergency venting	
Misdirected flow	Valve open in error or passing allowing material to be routed to an unintended location		

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Deviation	Causes		
Wrong percentage	Human error	Line restriction	Defective pumps
	Malfunction of control valves	Filter fouled	Fouling of vessels, lines, valves, or orifice plates
Contamination/ composition	Leaking valves	Improper mixing	Wrong additives or catalysts
	Leaking exchanger tubes	Ingress of air, water, or rust	Catalyst poisons
	Changes to feedstock	Identify nitrogen interfaces to process	Preparation for shutdown and startup operations
	Stream composition	Inadvertent mixing	Solvent flushing
	Stream contaminants	Explosive mixtures	Phase inversion
	Inadequate quality control	Interconnected systems (especially services, blanket systems)	Sphere rollover
	Process control upset reaction intermediates		Tower tray damage
	Byproducts		
Wrong material	Human error	Leaking exchanger tubes	Stream composition
	Leaking valves	Changes to feedstock	Stream contaminants
High pressure	Design pressures	Inadequate or defective isolation procedures for relief valves	Failure of ejector/eductor system
	Specification of pipes, vessels, fittings, and instruments	Thermal overpressure	More reaction
	Pressure range for abnormal operations	Positive displacement pumps	Plugged pressure tap
	Surge problems	Control valves failed (closed or open)	Obstructed relief
	Leakage from interconnected high pressure system (HP to LP interface)	Increased centrifugal pump suction pressure - startup of spare pump	Pressure testing
	Gas breakthrough (inadequate venting)		Excessive heating
			Exchanger tube leak
Low pressure/ vacuum	Cooling	Compressor suction line	Blockage of blanket gas
	Condensation	Undetected leakage	Failure of vacuum relief
	Gas dissolving in liquid	Vessel drainage procedure	Inadequate NPSH
	Restricted pump		
High temperature	Fire situation	Heater control failure	Decoking
	Ambient conditions	Internal fires	Heats of reaction
	Fouled or failed exchanger tubes	Reaction control failures	Mixing, reactor hot spots, decomposition, or runaway reaction, absorption, or solution.
	Cooling water failure	Heating medium leak into process	
	Air cooler malfunction	Heat tracing	Burn protection
	Defective control	Regeneration	Abnormal operations
Low temperature	Cold weather operations	Fouled or failed exchanger tubes	Joule/Thompson effect
	Ambient conditions	Loss of heating	Endothermic reaction
	Reducing pressure	Depressuring liquefied gas	Control failure
High level	Outlet isolated or blocked	Filling operations	Interface level control
	Inflow greater than outflow	Liquid in vapour lines	Phase inversion
	Control failure	Vessel overflow	Slug flow
	Faulty level measurement	Deactivated level alarm	Condensation
	Incorrect calibration	Inadequate time to respond	
Low level/ no level	Inlet flow stops	Control valve malfunction	Plugged instrument taps
	Leak	Faulty level measurement	Inadequate residence time
	Drain valve left open	Incorrect calibration	Inadequate mixing, excessive heating
	Outflow greater than inflow	Two phase flow	Gas in liquid lines
High reaction (runaway reaction)	Wrong reactant mix	Incompatible chemical	Side reactions
	High temperature		

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Deviation	Causes		
Low reaction/ no reaction (incomplete reaction)	Wrong reactant mix Low temperature	Insufficient catalyst	Channelling
Reverse reaction	Wrong reactant mix Low temperature	Insufficient catalyst	Channelling
Side reaction	Wrong reactant mix Low temperature	Insufficient catalyst	Channelling
Wrong reaction	Wrong reactant mix Low temperature	Insufficient catalyst	Channelling
Excessive mixing	Agitator set at wrong speed		
Poor/no Mixing	Agitator set at wrong speed Drive stops	Agitator blade drops off Coupling failure	Poor mixing No baffles
Relief	Design basis for relief: How is overpressure protection provided?		
	Relief for process (normal/abnormal - fire, startup/shutdown conditions) What is the controlling scenario? Changes affecting relieving requirements (insulation removal, CV change, new connections, etc.) Backpressure on relief valve vs. design	Effect of debottleneck on relief capability Instrumentation/SIS to reduce relief load Type of relief device and reliability Atmospheric relief valves (discharge location, plume path, dispersion modelling, risk associated with discharge)	Relief composition (e.g., two phase flow) Maximum liquid rate vs. design capacity Tower liquid overfill Relief for reactive chemicals Materials of construction Heat tracing/temperature of rupture disks RV set pressure vs. MAWP
	Path for relief protection and can it be impaired?		
	Blocked path/relief valves Restricted inlet/outlet lines	Plugging/buildup in relief system (hydrates, ice, weep holes plugged, liquid buildup, loss of heat tracing, etc.)	Failure of administrative controls
	Preventive maintenance: inspection/testing results		
	Isolation philosophy	Is a spare relief valve needed to achieve the testing interval?	Location of relief device
	Other		
	Environmental implications Frequency of relief valve use Relief device exposed to abnormal operating temperature or pressure	Near miss incidents Stress on RV inlet/outlet piping Vibration of piping/headers	Rupture disks under RVs - Is pressure between RV and rupture disk checked to identify rupture disk leakage?
Rupture/leak	Hazards		
	Toxic gas Fire/explosion potential High pressure Temperature Local vs. offsite impact	Potential RMP worst case or alternate release scenario - impact on personnel/community/environment/surroundings (major accident risk potential) - impact on occupied buildings/nearby trailers	
	Detection		
	Methods Time required Fire and gas detectors/alarms	Visibility Odour thresholds	Video monitors Routine checks
	Mitigation		

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Deviation	Causes		
	Methods available Isolation points Duration of leak	Containment methods Emergency operations in spill area Procedures/training	Inventory reduction Emergency shutdown arrangements
	Protective systems		
	Turret coverage Fire crew availability/response time Deluge system	Firefighting strategy Required response Alarms Evacuation procedures	Emergency showers/eyewash stations Location of SCBA Emergency training
	Prevention: See equipment integrity for root cause elimination		
Instrumentation	Critical Instrumentation Need for SIS SIL Control strategy Location of Instruments Lack of instrumentation Information/alarm overload Instrument response time Time available for operator intervention Set points of alarms and trips	Alarm and trip testing SIS component testing frequencies Confusing alarms Fire protection Panel arrangement and location Auto/manual facility and human error Sample devices Failure mode of transmitter	Failure mode of control valve or final control element Out of range failure mode vs. range of possible conditions Lack of documentation Computer control Mechanical and PLC interlocks PLC failure mode and its effects Bypassed interlocks Defeated alarms
Chemical hazards	Undefined chemical stability/reactivity Unique hazards of chemicals and methods of control, reactive chemicals Instability/decomposition, such as ethylene decomposition Runaway reactions Initiating mechanism	Chemical interaction matrix Inadvertent mixing Phase change Phase separation Flammability Toxicity Health effects MSDS information Detection of leaks	Chemical storage excess inventory Different fire protection needed for chemical Effect of heat tracing Disposal Phase inversion Azeotropic boundary Compatibility with chemicals in drainage/sewer systems
	Physical Properties		
	Vapour pressure Saturation points of chemicals Solubility Crystallisation	Particle size Settling of solids Sublimation	Freezing temperature Fouling or plating Viscosity
Equipment integrity	Results of equipment inspection and testing Fitness for service	Temporary fixes (clamps, plugs, etc.) Identify dead legs	Injection/mix points Soil/air interfaces Buried piping
	Corrosion/failure mechanisms		
	Internal/external corrosion Corrosion under insulation Embrittlement Stress corrosion cracking Subtle composition change Possible contaminants (chlorides, H_2S, water, ammonia, etc. Erosion	Fluid velocities Vibration Stress Fatigue Small bore pipe Equipment operating outside acceptable limits Water hammer/surging	Stagnant/low points Failure of tank or basin liners Integrity of flanged joints Structural damage Abandoned or out of service equipment Mothballing techniques Condition of grating and handrails
	Prevention		

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Deviation	Causes		
	Appropriateness of specifications/materials of construction	Do inspection and test plans address the potential damage mechanisms?	Underground piping protection
	Compatibility with process conditions and process fluids	Are inspection/testing techniques specified likely to find expected damage?	Cleaning/testing/monitoring of equipment, such as piping, vessels, heat exchangers, flexible hoses
	Adequacy of inspection/testing frequency and procedures	RBI	Safety critical equipment
	Has all equipment been evaluated to determine if it needs an inspection and test plan?	PMI Construction QA/QC	Is equipment designed for inspection?
		Cathodic protection arrangement	Testing of emergency equipment
		Corrosion inhibitors	
Ignition	Static eletricity		
	Earthing (grounding arrangements	Splash filling of vessels	Temporary earthing (grounding) for loading/unloading
	Insulated vessels/equipment	Insulated strainers and valve components	PM for earthing (grounding) systems
	Low conductance fluids	Dust generation and handling	
		Hoses	
	Open flames		
	Flares	Pilot lights	Fired heaters
	Other sources		
	Location of vehicles	Loss of purge to panels	Hot work permits
	Vehicle traffic	Lightning	People in area
	Vehicle entry	Hot surfaces	Nonintrinsically safe equipment
	Electrical classifications	Hot work/welding	
	Flammability		
	Auto ignition	Flash point	Fire triangle
	Upper and lower flammability limits	Metal fires	
Service failure	Failure of		
	Instrument air	Hydraulic power	Contamination of instrument air, nitrogen
	Steam	Water or other	Telecommunications
	Nitrogen	Power loss/blips/failure modes	Heating and ventilating systems
	Cooling water	Trip delay for power failure	
	DCS system		
	Failure	Viruses	Backup
	Loss of view	Reliability	
	Protection systems		
	Deluge systems	Firewater	Emergency dump
	Hydrocarbon detectors	Foam	Previous failures

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Deviation	Causes		
Abnormal operation	What are the potential abnormal operations and is system designed for it?		
	Extended operations	Fire	Operation of common spares
	Purging	Turnarounds	Loading/unloading of trucks or railcars
	Flushing	Off shift operations	
	Removal of solids	Shift change	Spills/spill containment
	Contaminants	Flaring	Evacuation plans
	Water or air, etc.	Bypassed safety devices	Bypassing procedures
	Startup	Bypassed equipment/controls	Workarounds
	Normal shutdown	Time (sequence)	Using extraordinary effort
	Emergency shutdown	Startup following emergency shutdown	Extended shift schedules
	Operations under emergency conditions	Regeneration	Previous incidents and near misses
	Severe weather conditions	Decoking	Use of contractors
	Spills	Filter changes	Written procedures (accurate, updated, followed)
Sampling	Is sampling required?	Sampling apparatus	Diagnosis of result
	Online vs. manual sampling	Environmental, compliance points	Industrial hygiene (personnel exposure/monitoring)
	Is the sampling device and location appropriate?	Spill and leakage monitoring	PPE required
	Is sample return point appropriate for abnormal operation?	Sampling procedure	Sample disposal
		Time for analysis result	Operator intervention
	Risk of sampling (hot/cold, high/low pressure, toxics)	Calibration of automatic samplers	Process changes because of sample result
	Hazards of gaging tanks/silos	Reliability, accuracy, or representative sample	Is there an inspection and test plan to ensure the integrity of sample cylinders?
	Purpose of sample		
Maintenance	Preparation		
	Verify equipment can be properly isolated and prepared for maintenance, including:		
	Isolation philosophy	Drying	Hot bolting
	Drainage	Opening lines	Equipment LOTO procedures, including isolation lists
	Purging	Blinding	
	Cleaning		Risk of metal or packing fires
	General issues		
	Work required on operating ("live", "hot", "active") equipment	Procedures (verbal, written)	Breaker identification
		Preventive maintenance	Vent discharges near work areas
		Predictive maintenance	
	Confined space (entry into vessels with hazardous atmosphere)	Accessibility	Contractors
		Training	Nitrogen asphyxiation risks
	Rescue plans	Control of work permits	Golden Rules enforcement
	Equipment Installation/demolition		
	Hot and cold taps	Pneumatic pressure testing	Pile driving
	Pressure testing	Overhead lifting	
	Sparing philosophy		
	Installed/noninstalled spare equipment	Modified specification	Catalogue of spares
		Storage of spares	Test running of spare equipment
	Availability of spares		

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Deviation	Causes		
Equipment siting	Access to local field instrumentation	Fire protection systems	Location of occupied buildings vs. process hazards
	Accessibility to equipment and valves (maintenance hindered from accessing equipment (i.e., access to valves needed to prepare equipment for maintenance)	Location of breathing air apparatus	Entry into flare exclusion zone
		Location of LELs and/or toxic gas detectors and adequacy of coverage	Location/accessibility of emergency isolation valves
			Need for lifting heavy equipment over process lines
		Location of nearest emergency shower and eye bath	Tripping hazards
	Equipment spacing standards/codes applied	Location of vents and emission sources vs. people	Placement of trailers
	Escape routes		
Previous incidents	Incidences at similar processes		
	HIPOs/MIAs		
	Review of any previous incident with having potential for catastrophic consequences, including near misses		
	Undocumented incidents		
	Were hazards addressed by the incident investigation?		
	Were recommendations from the incident investigation resolved/implemented?		
	Were root cause(s) of the incident resolved?		
Human factors	Interfaces with process		
	Ability to read or confusion with local instrumentation	Auto restart	Confusion over information on computer systems (e.g., too many alarms?, incorrect displays?)
	Consistency (layout, labelling, operation action, instrument spans, etc)	Gaging operations	
		Clarity of signs/labelling	
		Communications	Methods for detecting process problems, failures, status
	Actions during an emergency	Confusion on operation of valves	
	Automatic vs. manual control		Feedback on changes made
	Human capabilities		
	Potentially hazardous tasks	Complex tasks	Adequate tools for job
	Fitness for task	Ergonomics	Confined work space
	Infrequent tasks	Experience levels	Inadequate lighting
	Opportunity for operator errors	Competency	Night work
	Physical work environment	Unclear responsibilities	
	Administrative controls		
	Changes affecting procedures or safe work practices	Procedures extending across shift	Administrative vs. engineered safeguards
	Confusion over procedures	Variances from written procedures	Training
Environmental	Potential sources and impact of environmental incident or excursion (range of operations, weather, etc.)		
	Solids		
	Filter elements	Catalysts	
	Spent chemicals	Residues	
	Liquids		
	Soil contamination	Pickling fluids	Collection/disposition of drained fluids and final destination
	Underground piping leaks	Discharge and drain points	
	Failed tank or basin liners		
	Air emissions: (gases and particulates)		
	Flaring	Point source	Odours
	Fugitive	Vents	Atmospheric relief
	Mitigation		

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Deviation	Causes		
	Proper disposition/treating	Reclamation	Scrubbing/adsorption
	Storage of chemicals and spill containment/abatement requirements	Recycle/recovery options Methods to reduce flaring	Options for reducing greenhouse gas emission Equipment specifications
	Waste treatment		
	Compatibility with WWT or alternate treatment methods Excessive water usage	Discharges to waste treatment (different chemicals, creation of or changes to solid waste streams, process wastes, increases in loading or increases in concentrations, pH, etc.)	
		Surface water	
	Other		
	Contingency plans for handling leaks or spills from equipment Firewater disposal	Impact of Spill Prevention, Control, and Countermeasure (SPCC), Oil Pollution Act of 1990 (OPA90), Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act [Superfund] (CERCLA)	
		Noise to community	
	Design change		
	What is the potential effect on permits for air or water (i.e., NO_x/SO_x/VOC /HRVOC generation and applicable permit limits)?	Capacity creep vs. permit limit	Does equipment need to be included in VOC monitoring?
Safety	Unique situation or unrecognised hazard		
	Status of written operating and maintenance procedures (available, accurate, updated, followed)		
	Accuracy of PSI		
	Hazards created by others and contingency plans - (adjacent storage areas/process plants)		
	Compliance with local/national regulations and codes		
	Location of safety showers/eye wash (10 s access)		
	Housekeeping in dust environments		
	Industrial hygiene		
	PPE	MSDS	Antidotes/decontamination
	Noise levels	Health map	Lifting (back injury)
	TLVs of process materials and methods of detection	First aid/medical resources/ supplies	
	Security		
	Monitoring	Entrance control	
	Vulnerability	DCS security, etc.	

Table A.3 - Deviation for interlock and control system

Deviation	Description
No interlock	Causes What hazard does the interlock address? Does the interlock address all causes of hazard?
	Consequences Determine consequences if interlock failed to activate or if there were no interlock.
	Safeguards Identify all other safeguards, layers of protection that either prevent of mitigate hazard
	Recommendations Formulate a recommendation if the safety integrity level required by the process has not been determined. Rank the recommendation based on severity of the consequences and its Likelihood without benefit of the interlock.

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Deviation	Description	
Interlock input	Review input to interlock	
	Purpose of input	Other inputs needed
	Does input adequately detect hazard/concern?	Inputs from other interlocks or instruments
	Can input cause trips without a hazard?	Bypassed/malfunctioning inputs
Interlock output	Review output of interlock	
	Purpose of output	Are unnecessary actions taken?
	Does output adequately deenergise hazard/concern?	Are required actions missing?
		Required output to other interlocks
Interlock activation	Review impact on process	
	Does activation create a hazard (upstream or downstream with pressure, temperature, level, flow, reaction)?	Equipment still operating
		Does the interlock cause the process to fail to a safe state?
	Does activation damage equipment, foul process, or cause extensive problems?	What are the effects of interlock activation and are they acceptable?
	Venting	
Reset of interlock	Automatic reset	Startup bypasses
	Component reset	Fails to reset
Purpose not achieved	Bypassed	Card failures
	Inadequate testing/maintenance	Insufficient redundancy
	Operator fails to reactivate	Switching of interlock inputs/outputs
	Mechanical, electrical, or signal transmission failures (see detailed list in Annex A)	
Lack of information for operator	Required operator intervention	Operator does not have clear and immediate access to pertinent process variable data
	Adequate warning of impending activation?	Algorithms may be too complicated for operator to understand the relationship between variables
	Operator does not know if interlock has activated or control loop failed	Alarm status to interlock status not clear
	Operator cannot tell why interlock has activated	
Erroneous activation	The team should discuss what happens if an interlock operates when it is not supposed to do so (e.g., if it is supposed to be activated by high temperature, what if it activates at a lower temperature? If it is activated by the ratio between two flows going too high, what if it activates at a lower ratio than intended?)	
	Consider equipment failures	
	Wiring malfunctions	
Adverse effect/ other loop	Can any other interlock or loop malfunction in such a way as to cause the loop under consideration to malfunction?	
Inadvertent alarm	Can the operator easily identify this circumstance (e.g., normal level showing on analogue process variable but separate discrete alarm activates)?	
Operator fails to act	Define actions required by operators	
	Why the operator might not respond to incorrect operation of interlock or control loop	
	Too many alarms go off at the same time	
	Alarms are acknowledged without operator looking at the display screens associated with the part of the process that has alarmed	
	Operator might not understand procedures or may have forgotten system knowledge	
	Procedures may not cover all circumstances that can cause the alarm to be activated	
	Multiple inputs to single DCS alarm or alarm located remotely or at a separate panel	
Wrong operator action	The team discusses why the operators may fail to respond correctly	
	Operator misjudges system state	Incorrectly times task actions
	Misuse procedure	Misuse controls
	Incorrectly recalls response strategies	Resets controller mode incorrectly
	Misreads displayed data	

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Deviation	Description		
Incorrect sequence	If the interlock requires multiple steps, are they in the right sequence (e.g., if the interlock shuts down the facility, can it be dangerous if some actions happen in the wrong order?)?		
	Can the sequence be monitored step by step for verification?		
	Can stop-hold points be implemented for troubleshooting if needed?		
Time delay too long	Programmed delays? - Response to interlock (automatic or operator) not quick enough to achieve desired effect		
Time delay too short	Not enough time for operator to evaluate alternatives		
Service failure	Does interlock fail safe?	Instrument air	Is there redundancy?
	Impact of service failures	Power	Is an uninterruptible power supply needed?
	Signal	Can operator shut down blind?	
Recovery	What steps and sequence are necessary to recover from the interlock trip? Resets? Recovery time?		
	Consequential damage?		
Abnormal operations	Interlock operation during startup, shutdown		
	Special procedures		
	Fire (or other emergency)		
	Restoration of program		
	Downloading		
	How do you test the interlock (is online testing required?)?		
	Evacuation of control room		
	What are out of range values for interlock, and does it cover potential range of abnormal operations?		

Table A.4 - Deviation for facility siting

Deviation	Description
Occupied buildings or high manned areas	Is the construction design adequate given the hazards of the operation? Is the building within a blast/fire/smoke/toxic zone?
	What is the size of potential events/effects of ventilation/wind conditions?
	If this information is not known, a more quantitative analysis is required.
Response to event	Can personnel respond appropriately in an emergency? Does the facility have the following?
	Means of communication during emergency
	Alarms
	Assigned responsibilities
	Evacuation procedures
	Identified safe havens and muster points
	Escape routes
	Visible wind sock
	Multiple exits
	Trained personnel
	Signs and directions
	Emergency power
	Procedure for total abandonment
	Access to medical facilities
	Emergency responders
	Have drills for emergency response been conducted? How often? Are the learnings from the drills communicated to personnel?

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Deviation	Description
Protective equipment	Is the following equipment available if required? Fresh breathing air Escape air packs Scott air packs Is there a shutdown system? Is it automatically activated? Is there a fire suppression system, sprinklers, extinguishers, etc.?
Fresh air intake	Are fresh air intakes located to minimise contaminants and toxic gases? Is there an automatic shutdown of the HVAC system in the event of a release?
Housekeeping	Is housekeeping at the site good? Is equipment stored in appropriate places? Are exits and walkways cleared of debris?
Containment	In the event of a liquid release, can the release be contained? Does containment consider the following? Depth of liquid pool Wave effect Secondary containment Drainage and sewers in containment area Location of ignition sources Method of isolation and cleanup
Drainage/sewers	Have the drains and sewers considered the following? Spill volume versus drainage capacity (including deluge and fire fighting water) Drainage direction Slope Spills into ditches Drainage destination Method of cleanup
Ignition	Are there policies and procedures in place to control hot work and ignition sources? Does it include static electricity, vehicles, hot work permits, cameras, etc.? Are known fixed ignition sources (heaters, etc.) beyond the range of credible releases?
Fire protection	Has a fire and explosion assessment been completed? Is passive protection in good condition? Is there a fire fighting strategy? Are personnel trained? Are drills conducted? Is the equipment maintained and inspected?
Effect on surroundings	Has a review been conducted that considers the potential onsite footprints from different hazards, including explosions, fires, and toxic releases? Does the review consider knockon effects to other equipment? Are there appropriate detection systems with alarms? Is this information communicated to employees and used during drills?
Effect on other areas	Has a review been conducted that considers potential offsite impacts from the site? Have the community and mutual aid responders been made aware of potential hazards and what to do in the event of an emergency?

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Annex B
(Informative)
Sample HAZOP log sheet

Node B-1	Debutanizer Overhead Trim Condenser								
Drawing No.	101, 102								
Parameter	Pressure		Intention	To operate at 5.5 barg in debutanizer overhead.					
GW	Deviation	Cause	Consequence	S	L	Risk	Safeguard	Recommendation	Remark
More	High Pressure	Block valve mismanaged closed on cooling water.	Potential overpressure in Debutanizer. Potential release of hydrocarbon. Potential fire and/or explosion.	H&S: C Env: D	4 4	9 8	PAH-410 on Debutanizer. PSV-123A/B/C set at 7.4 barg.	Provide high temperature alarm on Debutanizer overhead after trim cooler (TI-123). To: Engineering By: June 30	

Node B-2	Heavy Naphtha Rundown System								
Drawing No.	201, 202								
Parameter	Flow		Intention	To rundown heavy naphtha from naphtha splitter at a rate of 150 tons/hr.					
GW	Deviation	Cause	Consequence	S	L	Risk	Safeguard	Recommendation	Remark
Reverse	Reverse Flow	Upset in other unit.	Potential reverse flow from flare. Potential off spec product.	H&S:H Env:H	7 7	7 7	None identified.	Provide a check valve on Flash Drum vent line to prevent reverse flow from flare. To: Operations By: June 30	

Node B-3	Crude Storage Tank								
Drawing No.	301, 302								
Parameter	Level		Intention	To maintain crude oil level in the storage as required.					
GW	Deviation	Cause	Consequence	S	L	Risk	Safeguard	Recommendation	Remark
Level	High Level	Malfunction of level controller (LIC-153).	Potemtial overfilling of crude oil leading to potential damage to storage tank and release of crude oil to atmosphere. Potential environmental impact. Potential fire.	H&S:E Env: H	6 6	9 6	None identified.	Provide independent high level alarm on storage tank. To: Engineering By: June 30	

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Annex C
(Informative)
Discussion topics for HAZOP revalidation

Table C.1 - Discussion topics for HAZOP revalidation

Topic	Points for Team Discussion		
Process hazards	Hazards of the process and effectiveness of control		
	Flammability	Instability/decomposition, such as ethylene decomposition	Phase separation
	Toxicity		Detection of leaks
	Health effects	Runaway reactions	Chemical storage excess inventory
	MSDS information	Initiating mechanism	
	Undefined chemical stability/reactivity	Inadvertent mixing	Different fire protection needed for chemical
	Reactive chemicals	Phase change	Effect of heat tracing
	Disposal		
	Phase inversion		
	Azeotropic boundary		
	Compatibility with chemicals in drainage/sewer systems		
	Physical properties		
	Vapour pressure	Settling of solids	Cross connection of systems (high/low pressure interfaces, N_2 to process interfaces, air to process connections, N_2 to instrument air)
	Saturation points of chemicals	Sublimation	
	Solubility	Fouling or plating	
	Crystallisation	Viscosity	
	Particle size		
Rupture/leak	Hazards		
	Toxicity	Temperature	Potential RMP worst case or alternate release scenario
	Fire/explosion potential	Potential offsite impact	
	High pressure		Impact on surroundings
	Detection		
	Methods	Visibility	Video monitors
	Time required	Odour thresholds	Routine checks
	Detectors		
	Mitigation		
	Methods available	Containment methods	Procedures/training
	Isolation points	Emergency operations in spill area	Inventory reduction
	Duration of leak		
	Protective systems		
	Turret coverage	Firefighting strategy	Evacuation procedures
	Fire crew availability	Required response	Emergency showers/eyewash stations
	Deluge system	Alarms	
			Location of SCBA
	Prevention		
	Root cause elimination	Mechanical stress	Defect identification
	Materials of construction	Overhead lifting procedures	Inspection methods
	Maintenance/mechanical integrity procedures	Overpressure protection	
Environmental	Potential sources for environmental incident or excursion		
	Solids		
	Filter elements	Catalysts	Residues
	Spent chemicals		
	Liquids		

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	Soil contamination	Pickling fluids	Collection/disposition of drained fluids and final destination
	Underground piping leaks	Discharge and drain points	
	Failed tank or basin liners		
	Air emissions (gasses and particulates)		
	Flaring	Point source	Atmospheric relief
	Fugitive	Vents	Changes to greenhouse gas emissions
	Mitigation		
	Proper disposition/treating	Methods to reduce flaring	Options for reducing greenhouse gas emission
	Reclamation	Scrubbing/adsorption	
	Recycle/recovery options		Equipment specifications
	Waste treatment		
	Compatibility with WWT or alternate treatment methods	Discharges to waste treatment (different chemicals, creation of or changes to solid waste streams, process wastes, increases in loading or increases in concentrations, pH, etc.)	
	Excessive water usage		
	Surface water		
	Other		
	Contingency plans for handling leaks or spills from equipment		
	Impact of SPCC, OPA90, RCRA, CERCLA, etc.		
	Design change		
	What is the potential effect on permits (air or water, i.e., NO_x/SO_x/VOC/HRVOC generation and applicable permit limits)?	Does equipment need to be included in VOC monitoring?	
	Capacity creep vs. permit limit	LDAR	
		Odour source	
Previous recommendations	Does a system exist for effective and timely closeout of all PHA/HAZOP recommendations?		
	Does the system include means of verifying that the recommendation was completed or dismissed? If so, how?		
	If a recommendation was rejected, is there sound evidence as to why? Does the hazard still exist?		
	Are there any rejected recommendations that the revalidation team believes should not have been, and wants to reissue?		
	Did the action taken based on the recommendation require any further safety review? Was it done?		
Effect of revisions	Overview of changes made since the last HAZOP from the perspective of the system as a whole, versus the individual changes.		
	Is there a system for MOC? Does the system include identifying the need for a HAZOP?		
	Were there any revisions that required engineered changes? If so, was a HAZOP completed for the revision?		
	Were there any changes to an alarm or safety system? If so, was a HAZOP required and completed if necessary?		
	Did any of the changes require modifying the operating conditions outside the operating range? If so, was a HAZOP or safety review conducted?		
	Did any of the change require a modification to the chemistry of the process? Did the change(s) require modification to the timing or sequencing of the operations? If so, was a HAZOP completed?		
	Did any of the changes require modifications to the maintenance procedures or schedule? Does the change affect safety or the environment?		
	Have process conditions or fluid compositions changed gradually over time without an MOC or safety review being performed?		
	Change in staffing level		
	Operator experience		
	Changes to safeguards		
	Changes to equipment reliability		
	Changes to safe or operating limits		

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Previous incidents	Were there any incidents or near misses since the last HAZOP? If so, was there a thorough investigation, and was the pertinent information shared with those involved in operating and maintaining the process?		
	Were there any incidents from outside the facility (other BP facilities or industry) from which learnings could be applied to the process undergoing HAZOP revalidation?		
	Did any changes take place as a result of the incident investigation? If so, was the MOC procedure followed? Was a HAZOP completed if necessary?		
PHA quality	Are there any known causes of process incidents that were not adequately covered in the baseline PHAs? Have all causes been considered?		
	Are there any engineering or administrative controls and their relationships that were not fully discussed in the baseline study? Are there any consequences that were not fully developed in the baseline?		
	Were safeguards valid and fully documented?		
	Gaps in PHA documentation		
	Equipment previously not reviewed		
Facility siting	Plant siting		
	Blast overpressure	Evacuation plans	Site specific natural hazards
	Spacing criteria	Fire suppression equipment	Damage due to vehicle impact
	Design and location of portable and permanent occupied buildings	Reliability of critical building equipment	Emergency vehicle access
	Changes to building occupancy	Toxic releases	Control of motor vehicle access
	External events	HVAC	Unauthorised access
	Egress routes	Equipment setbacks	Buried equipment identification
	Segregated sewer systems	Equipment spacing	Electrical area classification
		Containment	Surface drainage
	Equipment siting		
	Access to local field instrumentation	Location of nearest emergency shower and eye bath	
	Accessibility to equipment and valves (maintenance blocked from accessing equipment, access to valves needed to prepare equipment for maintenance)	Location of vents and emission sources vs. people	
	Equipment spacing standards/codes applied	Location/accessibility of emergency isolation valves	
	Fire protection systems	Need for lifting heavy equipment over process lines	
	Location of breathing air apparatus	Tripping hazards	
	Location of LELs and/or toxic gas detectors and adequacy of coverage		
Human factors	Interfaces with process		
	Ability to read or confusion with local instrumentation	Clarity of signs/labelling	Confusion over information on computer systems (e.g., too many alarms?, incorrect displays?)
	Capability to detect hazardous situations	Communications	
	Actions during an emergency	Confusion on operation of valves	Methods for detecting process problems, failures, status,
	Automatic vs. manual control	Feedback on changes made	
		Alarm priorities established	
	Human capabilities		
	Potentially hazardous tasks	Complex tasks	Adequate tools for job
	Fitness for task	Experience levels	Confined work space
	Infrequent tasks	Competency	Inadequate lighting
	Opportunity for operator errors	Unclear responsibilities	Night work
	Physical work environment		
	Administrative controls		
	Changes affecting procedures or safe work practices	Procedures extending across shift	Administrative vs. engineered safeguards
	Confusion over procedures	Variances from written procedures	Training

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Relief	Design basis for relief: How is relief protection provided?		
	Relief for process (normal/abnormal - fire, startup/shutdown conditions) Validity of controlling scenario Backpressure on relief valve vs. design Changes affecting relief requirements, such as insulation removal, CV change, new connections, increased flow Backpressure on relief valve vs. design Effect of debottleneck on relief capability Type of relief device and reliability	Relief composition (e.g., two phase flow) Relief for reactive chemicals Materials of construction Temperature of rupture disks Current MAWP vs. RV set pressure Maximum liquid rate vs. design capacity Tower liquid overfill Atmospheric discharge (discharge location, plume path, dispersion modelling, risks associated with discharge)	
	Path for relief protection and can it be impaired?		
	Blocked path/relief valves Restricted inlet/outlet lines	Plugging/buildup in relief system Failure of administrative controls	
	Preventive maintenance: inspection/testing results		
	Isolation philosophy Is a spare relief valve needed to achieve the testing interval? Location of relief device		
	Other		
	Environmental implications Frequency of relief valve use Relief device exposed to abnormal operating temperature or pressure	Near miss incidents Stress on RV inlet/outlet piping	Vibration of piping/headers rupture disks under RV's - is the pressure between the RV and rupture disk checked to identify rupture disk leakage?
Operating experience	Are there any incidents of operational problems or difficulties with existing equipment? Have there been any recent significant changes in operating philosophy? Workarounds using extraordinary effort Have there been improvements to the control strategy for the equipment under discussion? Abnormal operating conditions experienced? Unexplained events (not fully understood)		
Safety systems	Effectiveness/reliability of safety systems Bypassed or disabled safety systems Spurious trips Interlocks	Shutdown systems Analysers Firefighting equipment Hydrocarbon detectors Safety system training	Capability to detect/prevent tower overfill Documentation and procedures Critical instrumentation Need for SIS SIL
	Is any control loop, interlock, device, sensor, or alarm that: 1) Is the primary or only means of detecting an excursion of the process outside the limits defined by the PSI (design pressures, temperatures, inventories, etc.) 2) Failure of the instrument/devise contributes to substantial, uncontrolled, or catastrophic release of an HHC. 3) Failure of this instrument/device affects operability of any system (scrubbers, flares, surge, or overflow tanks, etc.) designed to provide for a controlled release of an HHC. 4) Failure of this instrument/device affects operability of any system (fixed fire suppression, sprinklers, deluges, water spray, monitor guns, etc.) designed to mitigate effects of an uncontrolled release of an HHC. 5) Is designated as "critical" using additional criteria as defined by the plant.		
PSI	Is all PSI accurate and up to date for the system? Safe upper and lower limits Consequences of deviation MSDS information	Corrosivity Maximum intended inventory Any reactivity or toxicity concerns with chemicals in area P&ID updates	Electrical classification Ventilation design for area buildings PFD Material and energy balances

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Operating procedures	Written procedures (accurate, updated, followed?), e.g. - Are there procedures for all modes of plant operation? - Do the procedures contain all the information required? If not, where is the information? - Are those documents also certified annually to be current and accurate? Have procedures been assessed for hazards? Training/awareness of emergency procedures		
Equipment integrity	Changes to equipment integrity Results of inspections and tests Is equipment still fit for service?	Are inspections/tests/PMs up to date? Piping corrosion problems Critical temporary fixes (clamps, plugs, etc.)	Identify dead legs Injection/mix points Soil/air interfaces Buried piping Threaded connections
	Corrosion/ failure mechanisms		
	Internal/external corrosion Corrosion under insulation Embrittlement Stress corrosion cracking Erosion Fluid velocities Vibration Stress	Fatigue Small bore pipe Are actual corrosion rates as expected? Any deviations from expected corrosion rates? Any incidences of unexpected damage?	Equipment operating outside acceptable limits Deviations from integrity operating envelopes - Water hammer Stagnant/low points Failure of tank or basin liners Integrity of flanged joints
	Prevention		
	Appropriateness of specifications/materials of construction Compatibility with process conditions and process fluids Potential contaminants (chlorides, H_2S, water, ammonia, etc.) Adequacy of inspection/testing frequency and procedures Has all equipment been evaluated to determine if it needs an inspection and test plan? Do the inspection and test plans address the potential damage mechanisms?	Are the inspection/testing techniques specified likely to find the expected damage? PMI Construction QA/QC Mothballing techniques Cathodic protection arrangement Corrosion inhibitors Underground piping protection Integrity of grounding systems Cleaning/testing/monitoring of equipment, such as piping, vessels, heat exchangers, flexible hoses	Safety critical equipment Is equipment designed for inspection? Testing of emergency equipment, Incidences of integrity failures on similar equipment HIPOs MIAs Incident tables Failure databases Handbooks ETPs GNs
Maintainability	Is equipment safe for maintenance? Hazardous tasks LOTO (isolation and capability to verify zero energy)	Working on live equipment Capability (LOTO) Workarounds Tasks requiring extraordinary effort	Inaccessibility Confined work areas Preventing metal/titanium fires Control of work
General safety	General safety concerns Control and location of ignition sources Equipment electrical classification	Panel purges Changes in reliability of utilities or services	Changes to fire protection systems Change in sampling location or procedures

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[3] GP 44-32, *Protection of Personnel from Explosion, Fire, and Toxic Hazards on Offshore Facilities.*

[4] GP 48-01, *HSSE Review of Projects (PHSSER).*

[5] GP 48-50, *Major Accident Risk (MAR) Process.*

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