INDEX OF REVISIONS

REV	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL
A	REVISED TO COMPLY WITH REQUIREMENTS OF ITEM 8.3 OF SAFETY ENGINEERING GUIDELINE DR-ENGP-M-I-1.3
B	REVISED ITEMS 7 AND 8.10 ABOUT RISKS CLASSIFICATION
C	REVISED ITEM 5 ADDED “COMMENTS ADDED”
D	REVISED WHERE INDICATED
E	REVISED WHERE INDICATED

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	06/23/2020	12/14/2021	03/22/2022	03/13/2023	05/15/2023	JUL/16/2024			
PROJECT	EPS	ESUP	EPS	EPS	ESUP	ESUP			
EXECUTION	U4D4	U4A7	B79G	CWFS	DXVM	F0J9			
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SUMMARY

1. INTRODUCTION

The Hazard and Operability Study (HAZOP) is an inductive and structured technique used to identify hazards in process deviations and their operability characteristics by systematically associating a set of guide words to process variables.

In the execution of HAZOP, the requirements of the National Agency of Petroleum, Natural Gas and Biofuels - ANP, NR-37 of Ministry of Labor and Employment, API 14C Recommended Practice for Analysis, Design, installation and Testing of Basic Surface Safety Systems for Offshore Production Platforms, and Safety Engineering Guidelines - I-DR- ENGP-M-I-1.3 shall be followed.

This Technical Specification (TS) complements the hazard identification requirements of Safety Engineering Guidelines – I-DR-ENGP-M-I-1.3, in force on the date of signature of the contract. It also aims at guiding the development of the implementation of HAZOP and the execution of its respective report.

The risks assessment related to the hazards identified in the HAZOP shall be used to make decisions regarding the adoption of prevention and control measures, for the deviations identified in the analysis, which are necessary to maintain the risks in accordance with the tolerability criteria established in the Safety Engineering Guidelines DR-ENGP-M-I-1.3. For each identified deviation, the measures that make the project inherently safer shall be prioritized.

2. PURPOSE

This specification has the following objectives:

2.1. Define the scope and criteria for conducting HAZOP for project phases of Basic Design, Detailing Design and Pre-Operation of the Floating Production Unit (FPU) and fixed units, hereinafter referred to as the Unit. This TS may optionally be used as a guide in the Operation phase of the Unit.

2.2. Guide the dynamics for the planning, development and monitoring of the study by the parties involved and their final approval.

2.3. Define the standardization, content and minimum requirements for presentation of the HAZOP report.

3. HAZOP SCOPE

3.1. HAZOP shall cover hazardous events which have their causes originated from deviations in the process variables of the analyzed Unit, considering component or system failures, as well as operational or maintenance errors (human errors).

3.2. HAZOP shall cover all unit's process systems, utilities, and hull systems.

3.3. For projects where there are several systems with multiple interfaces, HAZOP shall be done obligatorily with an integrated view of these systems, considering topside (including interface between modules), hull systems and subsea systems, giving special attention to the interfaces between them.

3.4. General Aspects

3.4.1. The final HAZOP report shall be issued in English and then in Portuguese, including all appendices and spreadsheets which shall be presented in both languages.

3.4.2. The analyzes shall be based on the data contained in the design documentation of the Unit used as reference and in the condition released by Petrobras, according to this TS.

In case of pending or incomplete information is identified in the project documents, prior to the HAZOP or during its development, the HAZOP Consulting shall request them from the Designer in accordance with the Communication Management Plan. These requests shall be informed to Petrobras.

3.4.3. The Consulting is responsible for searching and obtain all information necessary to carry out the HAZOP, in responsible organization, whether public or not, including engineering documentation, updated technical data, technical standards and applicable legislation. In case of the project is executed internally at Petrobras, the department responsible for the project will have the same responsibility as the Designer.

3.4.4. The final report of HAZOP shall contain the complete list of reference documents, indicating the revision used in the study, being responsibility

of the HAZOP's Consulting the verification of completeness of the list of documents.

3.4.5. Canceled.

3.4.6. The final HAZOP report shall be submitted to formal approval by Petrobras.

4. DEFINITIONS

- Safety Barriers - all physical and non-physical means designed to prevent, control, or mitigate accidental events. Barriers include project safeguards, and safety and operational procedures.
- Causes - these are the events that initiate the deviation, the reasons why deviations can occur. They may include equipment failures, human errors, unforeseen changes in operational conditions and others.
- Deviations - deviations from design intentions or normal operating conditions. The relation of the applicable deviations is obtained from the combination of the process parameters (variables) with the guidewords.
- Effects - consequences resulting from the deviation event, which may affect people, environment, asset, and image of the Company.
- HAZOP Consulting - company responsible for the execution of HAZOP, which may be a contracted company, either by DESIGNER or Petrobras, or an internal Petrobras department / workforce.
- Detection modes - devices, systems or other means already existing in Unit or provided in the design, used to identify the occurrence of the deviation. Examples: Level control loops, pressure control loops, alarms, fire and gas detectors, etc.
- Node - process segment defined from process and instrumentation diagram in which process deviations are analyzed.
- Assisted Operation - support activity to the operation and maintenance teams to ensure that the operation start up is the safe continuation of the pre-operation and operation, or activity performed with the presence of operators.

- Guidewords - words or expressions applied to process parameters to qualify the deviations.
- Hazard - a condition or property inherent to a substance, an activity, a system, or a process, with potential to cause harm to the physical integrity of people, environment, asset, or image of the Company.
- Designer - company responsible for the elaboration of the engineering project, which may be conceptual design, basic design, detailing project design or pre-operational technical assistance, being Petrobras itself or contracted company.
- Recommendations - proposed measures to prevent the occurrence of the accidental scenario or to mitigate its consequences, whenever the existing safeguards are considered insufficient. In HAZOP, preventive measures shall be prioritized.
- Risk - combination of the expected frequency of occurrence of an accidental scenario with the severity of its consequence.
- Safeguards - any device, system, or action, already planned in the project or existing in the Unit, that are properly sized, that allow effective prevention or mitigation of the analyzed scenario.
    - Preventive Safeguard - any device, system, or action capable of interrupting a chain of events that occurs from an initiating event (cause of the deviation), reducing the probability of the undesirable scenario occurrence (loss of containment). Preventive safeguards do not affect the probability of the initiating cause occurrence, but rather the probability of the undesirable scenario occurrence, given that an initiating cause has occurred.
    - Mitigative Safeguard - any device, system, or action capable of reducing the severity of the consequences of the undesirable scenario, that is, reducing the impacts of the top event (e.g. confirmation of methane gas in a zone, generating an alarm and initiating interlocking actions).

- Safety Critical Procedures (SCPs) - series of tasks which complies with the criteria for safety critical procedures established in corporative standard (PE-2E&P-00261). For this Technical Specification' scope, SCPs are those listed in HAZOP analysis for accidental scenarios classified as "Non-Tolerable" or "Moderate" risk level, with severity category "IV" or "V" for people or environment, or "V" for asset.
- Human Factors (HF) - individual, technological, and organizational factors which influence the human behavior during the execution of activities and may affect the Unit's operational safety.
- ALARP (As Low As Reasonably Practicable) - a concept which seeks to ensure that the magnitude of the risk is reduced, through the application of appropriate prevention and control measures, to a level as low as reasonably practicable, and that additional measures to reduce it would be disproportionately costly compared to the potential benefits of these measures.
- Frequency - physical quantity indicating the number of occurrences of an event in each time interval.
- Severity - represents the magnitude of the consequences of each of the accidental scenarios.

5. REFERENCE DOCUMENTATION

As inputs for the elaboration of HAZOP, the following documents shall be considered, in its most up-to-date revision and with status of COMMENTS ADDED or RELEASED by Petrobras at SIGEM or another electronic document management system defined in a contract. For detailing design, it shall be considered P&IDs, at least, in revision A. The review of each document to be used shall be clearly indicated in the study report.

a) Process Flow Diagrams (PFDs),

b) Process and Instrumentation Diagrams (P&IDs),

c) Cause and Effect Matrix,

d) General arrangement of the Unit and the specific arrangements of the environments of hull systems, utility room / engine room, pump room, bow compartments, the accommodations, process plant and utilities,

Note: In the layout drawings, the location of the equipment with its respective identification (TAGs) shall be indicated, including also: the location of the pipe racks, the arrival location of the risers, diving areas, cranes and laydown areas, helideck, helicopters refueling stations, chemical storage, offloading stations among others. The arrangements shall have the wind rose with the indication of prevailing winds, north of design and true north.

e) Risk Analysis Reports already performed for the Unit, including risk analyzes carried out for hull systems and subsea systems,

f) Systems Descriptive Memorandum,

g) Process/utilities equipment data sheets,

h) Areas Classification Plan,

i) Operational or maintenance procedures from reference Units.

Depending on the project phase for which HAZOP is being prepared, some of the documents mentioned above may not be available; in this case, Petrobras shall be consulted about its relevance to the preparation of the study.

HAZOP shall not be performed with the process flow diagram only (PFD's), being obligatory the use of P&IDs.

6. REQUIREMENTS FOR THE PARTICIPATING TEAM DEFINITION

The following are the main requirements for professionals involved in HAZOP:

- The HAZOP shall be elaborated by a multidisciplinary team involving professionals from the Designer and Petrobras. The team shall be formed by professionals who are experienced in the area they represent, with professionals of the following disciplines, as applicable: process, safety, operation, marine system, mechanics, instrumentation/automation and control, arrangement, maintenance, architecture, and subsea system*.

  **Applicable when the analyzed system interfaces with subsea systems.*

- The HAZOP leader shall have proven training in the HAZOP tool and HAZOP leadership activity.
- The defined HAZOP team shall have composition, function and attributions performed as follows:

Table 1 - Basic composition of the HAZOP participating team.

Function	Activities
Coordinator	Professional of the Designer responsible for the event and who shall: • organize the team; • gather up-to-date information, such as: P&IDs, project technical specifications, etc.; • distribute material to the team; • schedule meetings and provide the resources for its realization. It is not required minimum experience time for this function.
HAZOP Leader	Professional of the HAZOP Consulting who knows the methodology, responsible for: • explaining the methodology to be used to the other participants and making them aware of the need to consider human factors in the analysis; • advising the meetings and defining the pace of their progress; • asking participants for pending information from the previous meetings, if in case; • prior evaluation of the documentation to be used in the analysis, defining the sections to be evaluated; • preparing the final analysis report.
Participants	Professionals of the Designers/Suppliers and Petrobras, representatives of the design project and operation disciplines, who have knowledge about the design project of the Unit or system to be analyzed or experience acquired in similar systems/Units. At least one representative from each discipline shall have the minimum of 2 years of experience in the area they represent. Each discipline shall have a professional with this experience, not necessarily the same professional, for full-time participation during HAZOP, as applicable.
Specialists	Professionals from the Designer, Suppliers or even Petrobras who have advanced knowledge about specific equipment, technologies or systems that can participate on demand, according to the need. It is not required minimum experience time for this function.
Generalist participants	Representants (from the Seller or Petrobras) from Pack engineering, trainee, engineering with experience lower than 2 years, or commercial area, who knows about the analyzed system or who is participating to gain knowledge or experience about the analyzed system. It is not required minimum experience time for this function.

7. PLANNING

Prior to the HAZOP, a planning stage shall occur, when shall be defined the objectives and scope of the analysis, the schedule of the meetings, the identification of the necessary documentation, the location of the meetings and the participating team in accordance with item 6.

In addition, invitations shall be sent and all the documentation to be used and this technical specification shall be previously available to the participants.

The language for conducting and recording HAZOP meetings shall be defined.

During planning, all interfaces between systems shall be identified, which shall be included in the scope of the analysis, to guarantee their integrated analysis.

HAZOP shall be performed after Preliminary Hazard Analysis (PHA) with the purpose of, in scenarios with the possibility of loss of containment (LOPC), it is possible to consider the classification of the severity for all dimensions (people, environment, asset and image) based on the severities determined in PHA, according to item 8.10.

8. METHODOLOGY

HAZOP is an inductive and structured technique to identify process hazards and potential operation problems associating, systematically, a group of guidewords to the process variables. For each deviation identified are related its causes, consequences, detection modes and existing safeguards, recommending additional measures when necessary.

The HAZOP methodology shall follow the aspects presented below, illustrated on Figure 1.

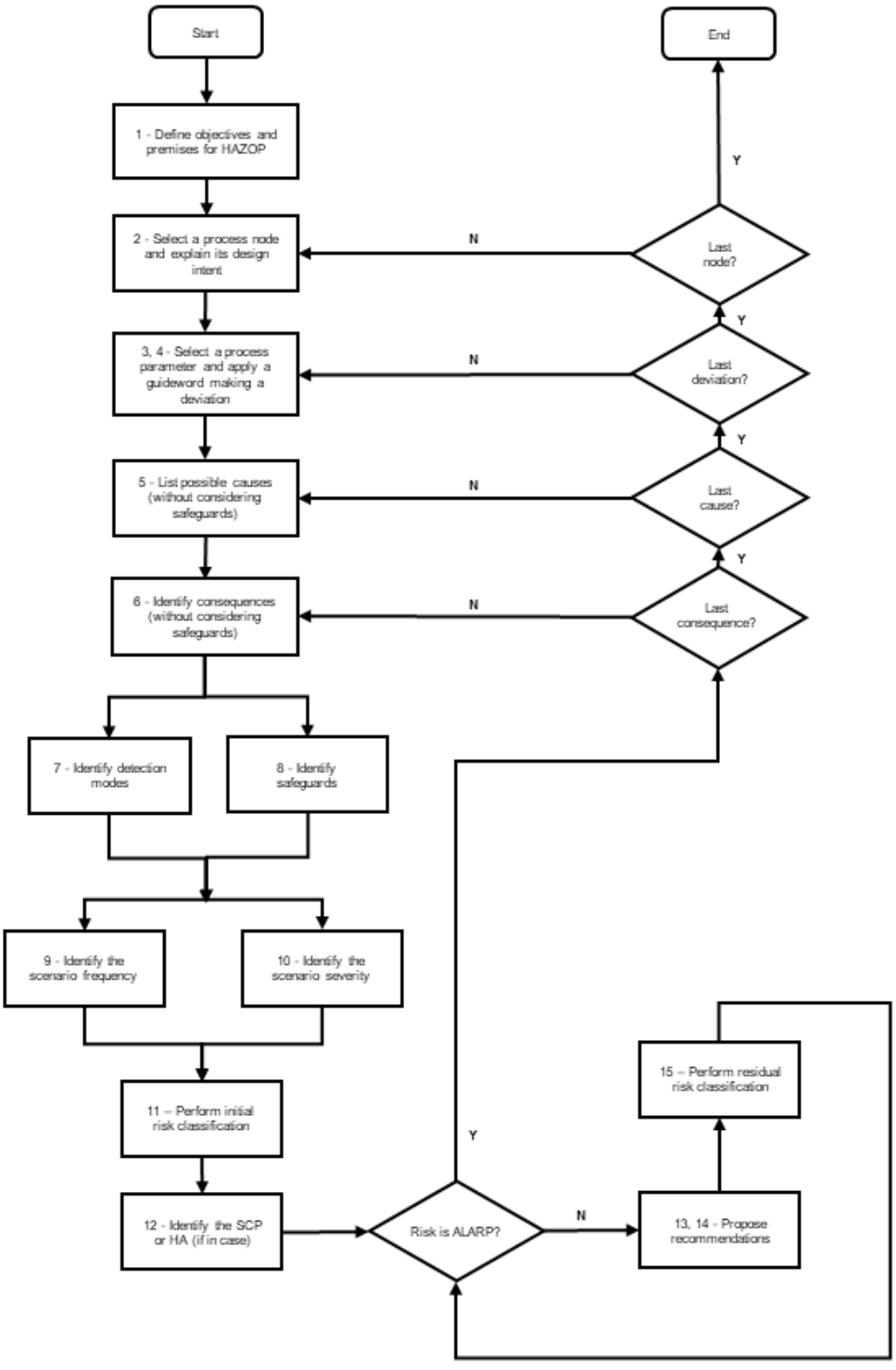

Figure 1 - Flowchart of the HAZOP methodology

8.1. Step 1 - Regarding the assumptions adopted

This step consists of clearly defining the objective with the HAZOP application and the premises which will be considered along the analysis. The HAZOP shall consider:

a) All deviations, observations and recommendations raised during the HAZOP of the basic design project shall be re-evaluated in the HAZOP of the detailing design project, considering the treatment given to the recommendations of the previous phases of the project. For the recommendations, which implementation is ongoing or incomplete, they shall be retained in the HAZOP review. In this case, the description of the recommendation shall reference the original recommendation number and the phase of the study to maintain traceability.

b) The documentation of systems considered as a "package" shall be added to the study documentation, or a specific HAZOP shall be performed for such a system and its interfaces, which later be attached to the main HAZOP report of the unit.

c) The unit shall always be divided into nodes, and the interfaces between the Unit's systems and the discipline of subsea systems shall be considered.

d) All deviation analyzes applicable to equipment / well A shall also apply to equipment / wells B, C and so on, if all are identical.

e) The analysis shall indicate possible interfaces between the systems analyzed in the HAZOP with other systems, outside the scope of the study. Where these are not verified, a note shall be included in the report informing and justifying why the interfaces were not verified.

f) All modes of operation of the process plant shall be considered.

g) Each scenario shall be analyzed separately as a cause-consequence pair to ensure proper analysis of the frequency, for two different reasons: (i) initiating causes may have different frequencies and (ii) each consequence may warrant for

different safeguards. Multiple causes may be grouped if they share the same consequence, frequency and severity.

h) All instruments, valves and equipment mentioned in the HAZOP shall have their tags explained in the worksheet;

During detailing design, once Vendor tags have been replaced by Petrobras tags, the final HAZOP worksheet and report shall be updated accordingly.

i) In carrying out HAZOP, the technique shall be used only for the investigation of the hazards related to PROCESSES and OPERATION, not intended to be used to implement operational improvements or project comments.

j) The final HAZOP worksheet and report shall foresee the update of the safeguards column with safeguards already implemented in the project which resulted from previous recommendations and provide additional risk reduction. Afterwards, the scenario risk classification and ALARP principle shall be reassessed by the team, implementing new recommendations as needed.

8.2. Step 2 - Regarding the identification of the system nodes

It consists of the determination by means of demarcation of the process representative points, where the deviations will be analyzed. The nodes are sections of the equipment or system, with defined boundaries.

The nodes' description shall depict the fluid flow in the P&ID and include tags of all main equipment included in the node analysis. Each segment analyzed shall preferably be segregated by SDVs, and other remote automatic shut-off valves may be accepted. Other types of valves, such as control valves, manual shut-off valves, or check valves, shall not be considered as boundary between sections.

Upon revision of the HAZOP, the node description and P&ID mark-up with the most recent documentation shall be updated.

8.3. Step 3 - Regarding the identification of process parameters

It consists of determining the process variables that affect the system in case of deviations: flow, level, temperature, and pressure.

8.4. Step 4 - Regarding the identification of deviations

Table 2 below shows examples of parameters and guidewords for the formation of deviations. Such deviations shall be recorded in the HAZOP worksheet.

If any deviation is not applicable or has consequences considered to be irrelevant, the expressions "not applicable" or "not relevant" shall be recorded, to ensure that all deviations have been analyzed.

Table 2 - Examples of parameters and guidewords for the formation of deviations.

Parameter	Guideword	Deviation
Flow	None	No Flow
	Lower	Lower flow
	Higher	Higher flow
	Also	Contamination
	Reverse	Reverse flow
Level	Lower	Lower level
	Higher	Higher level
Temperature	Lower	Lower temperature
	Higher	Higher temperature
Pressure	Lower	Lower pressure
	Higher	Higher pressure

The application of the guideword to the process parameter forms a deviation. The guidewords are applied to the process parameters that remain within the standards established by the design project intent or operating conditions.

8.5. Step 5 - Regarding the identification of possible causes

For each deviation identified in the previous step, the possible causes shall be raised. These causes shall comprise inherent failures of equipment (ruptures, instrumentation control loop failures, etc.), spurious actuation of protection devices, as well as human errors. Table 3 shows examples of causes linked to the deviations identified.

Table 3 - Examples of causes related to identified deviations.

Deviation	Possible Causes
No Flow	Improper alignment Improper blocking Equipment failure (pump)
High level	Output blocked

Deviation	Possible Causes
	Failure in control loop (NOTE) Failure in level measurement
Low pressure	Condensation Failure in control loop Improper opening of drain valve

Note: When control loop failure is considered as cause, it may be related to the failure of the actuator, the sensor element, or the control logic.

Human errors shall be considered as possible causes of process deviations when related to assisted operations or those ones that require manual actuation or associated to a possible incorrect or improper valve actuation, or other human intervention.

The following items shall not be considered as causes of deviations:

- Failure on demand of protection devices (e.g. PSV, SDV, BDV);
- Improper operation of manual valves with locking devices (locked open - LO, locked closed – LC, car sealed);
- Rupture of lines for the environment, except in cases where its occurrence is relevant, and the team considers evaluating its possibility of occurrence and the impacts to the process;
- Failure of check valves shall not be considered as a cause of reverse flow;
- Simultaneous faults (except when the consequences are critical and there are previous records of that scenario occurring).

Additionally, HAZOP shall not consider causes that depend on the occurrence of two or more simultaneous and independent faults. However, these causes may be considered if there are previous reports or if they lead to consequences of critical or catastrophic severity, as defined in the Risk Matrix of the Safety Engineering Guidelines.

8.6. Step 6 - Regarding the identification of possible effects

For each deviation identified, the possible effects shall be recorded, disregarding the existence of safeguards. Examples:

a) Loss of containment in systems and equipment;
b) Damage to the functionality or integrity of equipment and systems;
c) Loss of specification of process streams;
d) Production losses etc.;
e) Environmental Contamination (water resources / air contamination);
f) Operational disturbance;
g) Personnel injury.

The HAZOP team shall include as a premise of the study that the assessment of the consequences from the loss of containment (e.g., fire, explosion etc.) and the mitigative safeguards applicable to these scenarios are scope of the PHA (Preliminary Hazard Analysis) assessment.
Consequences such as mechanical explosions of equipment and/or piping (e.g., flame return, formation of an explosive atmosphere inside equipment, rupture of the exchanger shell etc.), which are not within the scope of the PHA evaluation and are intrinsic to the evaluation of the HAZOP shall be considered, if applicable.

8.7. Step 7 - Regarding detection modes

These are devices, systems or other means already existing in the installation or planned in the project, used to identify the occurrence of the deviation. Examples: alarms, gas detectors etc.
Visual and hearing detection, and local instrumentation may be considered as effective detection methods in cases of assisted operation. This action, however, shall not be listed if the execution poses any danger to the operator.
Detection modes do not affect the severity or frequency of the scenario.

8.8. Step 8 - Regarding the identification of safeguards

HAZOP safeguards shall be related mainly to "process deviation" and PHA safeguards related mainly to "loss of containment". When the safeguard aims to reduce the frequency of occurrence of the accidental scenario, it will be considered as Preventive Safeguard and when it reduces the severity of the consequence, it will be considered as Mitigative Safeguard.

Each safeguard shall be identified, that is, describe the means available to eliminate the cause of the deviation, reduce its occurrence frequency or minimize its consequences, and recorded in the safeguard column.

Mitigative Safeguards shall not be listed in the safeguards column unless the consequences of the scenario have not been analyzed in the PHA. In this case, the requirements stated in I-ET-3000.00-5400-98V-P4X-001 - PRELIMINARY HAZARD ANALYSIS (PHA) shall be complied with.

The safeguards listed shall be completely independent from the control system, therefore, control loops shall not be considered as safeguards.

The safeguards listed in the analysis shall possess the following characteristics:

- Independence from the initiating cause and other safeguards;
- Effectiveness, that is, being capable of interrupting the chain of events or avoiding the initiating cause occurrence or mitigating the consequences;
- Auditability.

When the HAZOP analysis identifies the need for a safeguard and it is not present in the project documentation under analysis, even if provided for in a project standard or guideline, this shall be included as a recommendation. Typical examples of safeguards (protection barriers):

a) Safety interlocks (e.g. PSHH with closing action of the vessel inlet valve);

NOTE: Safety interlocks shall be described in the safeguards column including tags for the actuator, the sensor element, and the control logic.

b) Relief and safety valves (e.g. PSV sized for blocked discharge);

c) Operator response to alarms foreseen in an existing operational procedure.

An alarm, listed by itself, shall not be considered as a safeguard. The operational procedure contemplating the operator response associated with a process variable alarm may be considered as a safeguard in an accidental scenario, if it meets all following requirements:

- The alarm shall be generated in a location where the operator is continuously present (control point permanently assisted) and can recognize it;
- Field alarm and response devices shall have initiators independent of the interlocking loop;

- The response time to the alarm shall be enough for the operator to take the actions planned to interrupt the scenario. The response time includes the necessary time interval for the operator to identify and recognize the alarm, make a diagnosis of the situation, perform the necessary action and for this action to have its desired effect, thus interrupting the scenario before the consequence occurs;
- The action performed is described in an existing procedure;
- The action taken is effective to minimize risk without exposing the responding operator.

In this way, the alarm, the element to be actuated and the operating procedure are integral parts of the "operator response to alarm" safeguard. Operational procedures and alarm, without regard to the above, cannot be considered as safeguards. Nonetheless, the related operational procedures shall be registered in the safeguard column.

Human actions and procedures, such as appropriate use of personal protective equipment (PPE), following existing operating procedures, specific training, and inspection/maintenance plans shall not be considered as safeguards to reduce the risks. However, whenever applicable, actions, tasks and procedures which has human intervention shall be recorded in the safeguard column.

To clearly identify elements regarding their function in the scenario in the HAZOP worksheet, they shall be followed by indication letters, or separated and written in specific columns (for instance, a “detection mode” column and a “safeguards” column). The indication letters are the following:

- (D), to indicate a Detection mode,
- (PS), to indicate a Preventive Safeguard,
- (MS), to indicate a Mitigative Safeguard,
- (SCP), to indicate a Safety Critical Procedure,
- (HA), to indicate a non-safety critical procedure.

8.9. Step 9 - Regarding the severity classification

Accidental scenarios shall be classified into the severity categories available in the Annex I of the Safety Engineering Guidelines for People, Asset, Environment and Image. The classification shall reflect the physical effects consequences’ magnitude (over pressure,

toxic/asphyxiant concentration, fire, thermal radiation, explosion etc.) and provide a qualitative indication of the severity level regarding its consequences.

For the determination of initial risk in HAZOP, the categorization of the severity of the residual risk generated in the PHA (severity considering the PHA recommendations) shall be used as initial estimate, but it shall be evaluated if there are no specific consequences in the HAZOP scenario that result in a greater severity than determined in the PHA (for example: different severity due to rupture of equipment and with possibility of projecting parts etc).

The classification of the PHA scenario which contains the same consequences as the HAZOP's may be used as the initial estimate for analyzing the severity. If so, the PHA scenario number shall be referenced in the consequence of the HAZOP scenario.

8.10. Step 10 - Regarding the frequency classification

This step consists in qualitatively selecting the frequency category, shown in Table 4, which best describes the cause-consequence pair frequency. The scenario frequency shall be estimated considering the combined frequency of the initiating cause frequency and the probability of failure of all safeguards listed. Additionally, the following items shall be observed:

a) The initiating cause frequency and the impact of the safeguard in the scenario frequency reduction shall be evaluated case-by-case;
b) Frequency conditional modifiers, such as ignition probability and probability of personnel in the affected area, shall not be considered in the frequency of the scenario;
c) Scenarios shall not be classified as extremely remote (frequency "A"), except if it is unheard of in the industry.

Table 4 - Frequency categories of accidental scenarios

A EXTREMELY REMOTE	B REMOTE	C NOT LIKELY	D PROBABLE	E FREQUENT
Conceptually possible, but with no references in the industry (never occurred worldwide).	Not expected to occur, although there are references in similar facilities in the industry (already occurred at least once worldwide).	Not likely of occurring during the lifetime of a group of similar units (already occurred at least once at Petrobras).	Possible of occurring once during the Unit lifetime.	Possible of occurring many times during the Unit lifetime.

8.11. Steps 11 and 15 - Regarding the risks classification

Upon ranking the frequency and the severity of the scenario, HAZOP shall have the risks classified according to the risk matrix of the Safety Engineering Guideline.

The scenarios that generate recommendations shall be classified without the recommendations (initial risk) and with the implementation of the recommendations (residual risk).

In HAZOP, the recommendations generated shall be considered for the classification of residual risk.

The scenarios with a “Non-Tolerable” initial risk level, and "Moderate" initial risk level with severity categories “IV” or “V” for people or environment or “V” for asset, which are associated to safety critical procedures (SCP) or human actions (HA), are considered as accidental scenarios associated with human factors and shall be evaluated by human reliability analysis for human errors identification and reduction.

All scenarios analyzed shall be classified according to Annex A of Safety Engineering Guidelines, even if the multidisciplinary team has described the scenario as having no impact on safety, installations or the environment.

8.12. Step 12 - Regarding the identification of Safety Critical Procedures (SCPs) and Human Actions (HAs)

The Safety Critical Procedures (SCPs) are the procedures listed in accidental scenarios classified as “Non-Tolerable” initial risk level, or “Moderate” initial risk level with severity category “IV” or “V” for people or environment, or “V” for asset (“accidental scenarios associated with human factors”).

Considering the project's procedures are elaborated and issued at the end of detailing phase, the procedures identified and listed in accidental scenarios, throughout the analysis, shall not be considered as preventive or mitigative safeguards.

When a SCP is identified as related to an "accidental scenario associated with human factors", the operations representative shall indicate an existing procedure to be considered as reference for the project's human reliability analysis. The reference procedure shall be registered in the safeguard column and indicated as "(SCP)", as per described on item 8.8 of this TS, and a recommendation shall be registered to project elaborate its own procedure at the end of detailing phase and classify it as safety critical procedure.

When a procedure is indicated in an "accidental scenario associated with human factors" and there is no existing procedure to be considered as reference for the project's human reliability analysis, it shall be registered in the safeguard column and indicated as "(SCP)", as per described on item 8.8 of this TS, and two recommendations shall be registered to the project: (i) elaborate at basic design a proposal of procedure, including tasks sequencing and responsibilities, for the human action to be evaluated on the project's human reliability analysis; and (ii) elaborate its own procedure at the end of detailing phase and classify it as safety critical procedure.

As output of HAZOP, it shall be issued a List of Safety Critical Procedures (SCPs) which will be used as input to the project's human reliability analysis.

When a procedure is indicated in an "accidental scenario non-associated with human factors", it should be registered at safeguard column and indicated as "(HA)", as per described on item 8.8 of this TS, since it is a non-safety critical procedure. In this case, no recommendation is required to be registered to the project and this procedure shall not be part of the List of Safety Critical Procedures (SCPs) which will be used as input to the project's human reliability analysis.

NOTE: The SCP or HA registered in the safeguards column shall clearly describe the action which would be effective for the prevention/mitigation of the possible effects and specify the internal Petrobras operating standard (PE - *Padrão de Execução*), if applicable, for future human reliability analysis.

8.13. Step 13 - Regarding the elaboration of additional recommendations, observations, and additional comments

Recommendations are proposed measures to prevent the occurrence of the accidental event or mitigate its consequences whenever the existing safeguards are considered insufficient.

Recommendations shall be clear, concise, well-defined, and preceded by action verb. Terms such as plan, design, elaborate, identify, specify, install, etc. shall be complemented by conclusive actions. Interfaces identified during the execution of the analysis that depend on the analysis in another system shall be recorded in recommendations for future verification

Non-tolerable scenarios shall have recommendations that effectively reduce the risk to moderate levels. Procedural-based recommendations should be avoided as the sole protection.

Moderate scenarios shall be subjected to the ALARP principle as described in section 8.14

The designer shall manage the implementation of the recommendations generated in HAZOP, including the impact on the revision of reference documents used in HAZOP. For each recommendation, the company or organization responsible for its implementation shall be identified according to I-ET-3000.00-5400-947-P4X-002 - Management of Safety Studies Recommendations.

Observations shall be regarded as complementary information that may be recorded to clarify the scenario analyzed, without, however, requiring any action.

Further comments are general or specific information that may contribute to the clarification of aspects considered in the study, but which do not fit into recommendations or observations.

The recommendations generated in the HAZOP will be identified as Rxxx, the observations will be identified as Oxxx, and the Additional Comments will be identified as Cxxx, where xxx corresponds to the sequential numbering.

8.14. Step 14 - Application of the ALARP Concept in HAZOP

a) It is recommended, as good practice, the application of ALARP concept in qualitative and quantitative risk analyses with the purpose of risk reduction to a level as low as reasonably practicable through the adoption of proper prevention and control measures, when additional measures for risk reduction are disproportionally expensive if compared to their benefits.

b) This concept shall be applicable only to the scenarios classified as “Moderate” initial risk level, because all scenarios with “Non-Tolerable” initial risk level shall be reduced to lower risk levels.

c) The ALARP concept includes the following four concepts:

1. Good Practice - adoption of good practices can serve as an appropriate indicator to demonstrate that the ALARP region has been achieved. However, it should be emphasized that "good practice" evolves over time, requiring updates by risk study and project teams due to the need for continuous improvement.

2. Precautionary Principle - it can be described as exercising special caution in cases involving hazards linked to technical scientific uncertainties in innovative processes, technologies, or operations with little known and assessed impacts on HSE (Health, Safety, and Environment). This principle should be observed when the associated risk cannot be confidently assessed for decision making due to the level of uncertainty regarding the possibility of undesirable events and detrimental effects on people or the environment.

3. Disproportionate Effort - if a measure is feasible and the implementation effort is not considered disproportionate to the benefit of risk reduction, then the measure will be considered "reasonably practicable", and its implementation is recommended.

4. Inherently Safer Process - it applies to a design or process in which risks associated with it are reduced or eliminated by incorporating one or more of the following principles: substitution, minimization, simplification, and moderation. Examples include:

- Substitution: using aqueous solvents instead of organic ones and employing safer chemical routes.
- Minimization: reducing the use, storage, and transport of hazardous substances.
- Simplification: using fewer complex systems with lower failure rates and greater error tolerance.
- Moderation: reducing process severity or criticality, diluting reagents, and using cooling to lower the pressure of stored products.

d) The questions which are potentially applicable along the qualitative analysis are:

- Was the "Good Practice" principle applied?
- Was the "Precautionary Principle" applied when relevant?
- Was the "Disproportionate Effort" principle applied?
- Was the "Inherently Safer Process" principle applied?

e) For scenarios with “Moderate” initial risk level, that the analysis team has not suggested any additional risk reduction measures, the following sentence shall be included as scenario’s observation: “During the evaluation of the present scenario, the concepts of Good Practice, Precautionary Principle, Disproportionate Effort, and Inherently Safer Design were considered”. The observation shall only mention concepts that are relevant and applicable to the scenario and shall be mentioned only concepts that were assessed by the team during the analysis.

9. REQUIREMENTS FOR HAZOP MEETINGS

Meetings shall follow the following guidelines:

9.1 Planning Meeting

This meeting is designed to summarize the project in question, define the objectives and scope of the contracted study, as well as evaluate and make the necessary adjustments in the work schedule proposed by the HAZOP Consulting, where the minimum agenda shall be:

- Sizing of Petrobras teams, designer and HAZOP Consulting (preparation of list of participants to issue invitations);
- Clarifications on objectives and scope of the study;
- Prior analysis of all necessary documentation for the execution of the HAZOP and elaboration of pending list, if any, for supply by the Designer;
- Presentation of the proposal for the schedule of meetings by the HAZOP Consulting and evaluation of this schedule to meet the project schedule;
- Definition of locations, resources needed and duration of meetings;

Participants: Representatives of Petrobras, Designer and HAZOP Consulting (mandatory participation of the leader of HAZOP).

9.2 Initial HAZOP Meeting and other study development meetings

At the initial HAZOP meeting, the Leader shall address the following topics:

- Safety briefing;
- Presentation of participants;
- Presentation of the objective and scope of the analysis;
- Presentation of the schedule of meetings;
- Brief presentation of the methodology and premises;
- Short description of the Unit;
- Presentation of a summary of the historical analysis of incidents occurring in the Installation or other similar installations;
- Description of the systems to be analyzed and indication of HAZOP nodes.

The other HAZOP meetings shall address the following topics:

- Presentation of new participants, if any;
- Description of the systems to be analyzed and indication of HAZOP nodes.

Participants: Professionals from Petrobras, HAZOP Consulting and Execution Engineer (including the HAZOP Leader), as defined in item 6 of this TS.

10. HAZOP REVIEW

The HAZOP shall be reviewed in the following cases:

a) at each phase change of the project (mandatory all systems);

b) when changes in the project occur that generate new risk scenarios and/or change the risks previously considered.

c) when Petrobras detects systemic or critical deviations from reports in relation to this specification;

d) in the pre-operation and operation phases in the situations established in the Company's operational safety management standards.

11. REPORT CONTENT

The HAZOP Report shall include at least the following items:

1. Purpose and scope of the analysis;

Description of the searched objectives with the application of the technique, the scope covered by the analysis, and the structure of the report.

2. List of participants

The list of participants shall contain the general data of each participant (full name, company, company position (management), position, contact email, discipline representing, function according to Table 1 and time of experience in it).

A daily attendance list shall also be generated.

3. Executive summary

4. Introduction

The introduction shall contain the description of the Unit, its capacity (POB), description of the analyzed systems, considering modes of operation, and any relevant aspects related to the study.

5. Justification and description of the HAZOP technique

6. List of reference documents

All the documents that were used for the study with their respective revisions shall be listed.

7. Historical Analysis

Consider the historical analysis of incidents occurred in the Unit or other similar Units;

Shall be presented evidence that the occurrence of accidental scenarios in similar units, especially at Petrobras, with the respective Reports of Treatment of Anomalies (RTA), when applicable, whose cause is associated with deviations of process variables, were considered. National and international database events can be used, considering the applicability of the data to the project (unit type and complexity, sea conditions, modes of operation of the unit / equipment, etc.).

The historical analysis shall be presented to all participants on the first meeting day, before the start of HAZOP, and it shall be attached to the final HAZOP Report.

References that can be used to elaborate the historical analysis:

a) Hydrocarbon Release Data Base (HCRD - HSE)

b) WOAD -World Offshore Accident Database - https://www.dnvgl.com/services/world-offshore-accident-database-woad-1747

c) Report Blowout and Well Release Characteristics and Frequencies, 2014 - SINTEF Technology and Society - Safety Research 2014-12-30;

d) Accident Statistics for Floating Offshore Units on the UK Continental Shelf 1980-2005. HSE Research Report RR 567 2007;

e) Process Release Frequencies, IOGP Report 434-01, 2021;

f) Accident Statistics for Fixed Offshore Units on the UK Continental Shelf 1980-2005, HSE Research Report RR 566 2007 - http://www.hse.gov.uk/research/rrhtm/rr566.htm,

g) Reports of Treatment of Anomalies - Petrobras' RTA,

h) ANP Incidents Database - https://www.gov.br/anp/pt-br/assuntos/exploracao-e-producao-de-oleo-e-gas/seguranca-operacional/incidentes.

8. Assumptions Adopted in HAZOP

9. List of recommendations

It shall be presented in a table to enable management of the implementation of the recommendations. It shall be listed in this table, the department responsible for implementing each recommendation, the implementation design phase, as well as the scenario number and corresponding node.

10. List of observations

The corresponding scenario number and node shall be displayed in a table.

11. Table of Safety Critical Procedures (SCPs)

The SCPs identified along the analysis shall be displayed in a table, with the corresponding accidental scenario number and description. In case of SCPs which have a reference procedure related, the table shall also present the number of the reference procedure listed on HAZOP spreadsheet.

12. List of Additional Considerations

These shall be presented in a table along with the identification of those responsible.

13. Conclusions

This item shall contain, at least, the following information set out below:

- Total systems and scenarios evaluated;

- Total of recommendations and observations generated;

- Identification of interfaces between topside systems and their modules, marine systems and submarine systems, indicating the HAZOP scenarios in which such interfaces were analyzed. The studies of Hull and Submarine disciplines that also contain analysis of these interfaces shall be related.

- Total of Safety Critical Procedures (SCPs) and the “accidental scenarios associated with human factors” identified during the HAZOP and which will be evaluated in the project’s human reliability analysis.

14. References

15. Annexes

A. Filled HAZOP Worksheets

All completed worksheets shall be presented in the analysis run. The scenarios shall be numbered to facilitate their identification, and scenarios related to different systems of the Unit cannot have the same numbering. They shall be identified as "N.XXX", where N" is the HAZOP node and "xxx" refers to the sequential numbering.

The worksheet header, for each node analyzed, shall contain the following information:

- operational unit, followed by the identification of the process facility under analysis;
- identification of the system under analysis;
- identification of the subsystem which is under analysis (when applicable);
- description of the study node, including the beginning and the end of the segment, which receives a sequential identification number;
- coded number of all engineering flow charts used in the analysis of the node, including revision;
- date of the analysis of each node in the HAZOP study.

B. Documents Reviewed

An annex shall be included in the report with all analyzed P&IDs, with the highlighted segments (nodes) analyzed and identified by the node number, among other relevant documents.

C. Attendance list

The daily attendance lists shall be attached. The lists shall inform which systems were analyzed at each meeting.

D. List of Barriers.

A list of barriers shall be drawn up and annexed to the final report, which lists their respective safety barriers for each of the accidental scenarios and classifies them as preventive or mitigative barriers.