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SRGE	TITLE: CO_2 HIGH CONTENT GAS LEAKAGE - EMBRITTLEMENT STUDY	INTERNAL ESUP

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INDEX OF REVISIONS

REV	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL
A	REVIEWED WHERE INDICATED
B	REVISED WHERE INDICATED
C	REVISED WHERE INDICATED
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	JUL/24/2020	JAN/24/2022	JUN/22/06/2022	JAN/25/2023	APR/19/2023	APR/12/2024			
DESIGN	EPS	EPS	EPS	EPS	EPS	EPS			
EXECUTION	EU4I	CWEQ	U436	U436	U436	U436			
CHECK	B79G	USX6	B79G	B79G	B79G	B79G			
APPROVAL	UP6E	EK9U	EK9U	EK9U	EK9U	EK9U			

Summary

1. INTRODUCTION

The CO_2 HIGH CONTENT GAS LEAK - EMBRITTLEMENT STUDY aims to assess the need to protect structural elements, equipment and their supports against the CO_2 jet scenarios identified in the Preliminary Hazard Analysis - PHA, initially classified as Not Tolerable in any of the dimensions (people, environment, asset and image of the Company) or Moderated with severity category IV or V in the dimensions of people and assets, on the Main Safety Functions (MSF) of a Floating Production Unit - FPU. The study also aims to assess the frequency of impairment of the escape routes due to gas leaks with high CO_2 content.

Based on this study, accidental loads resulting from low-temperature CO_2 leaks are estimated to assess the need for protective measures for MSF, as well as to evaluate the annual frequency of impairment due to thermal effects.

The MSF are defined in the Petrobras Safety Engineering Guideline DR-ENGP-M-I-1.3.

Experiments carried out by groups in Europe and the USA measured temperature and CO_2 concentration in atmospheric discharges showing that CO_2 is capable of leading to low temperatures, typically found inside the Mach Domes of the leak for so far distances. Experiments carried out in Brazil confirm these effects and have identified that the formation of solid CO_2 particles is responsible for this effect.

The use of computational fluid dynamics (CFD) techniques has not shown representativeness in the approaching of this type of problem, since currently they do not have a validated model that calculates the amount of solid formed, the sublimation of the particles and their transport. Only one work with validated modeling was found, which depends on access to experimental data. PHAST commercial software is a commercial tool calibrated with such experiments.

PHAST has the limitation of not considering the geometry of the platform, which prevents its use for other studies of consequences. Particularly, the cold CO_2 jet will have a localized effect on the geometrical elements with impingement or very close jet, in this case, the geometry effect is not significant since the elements outside the direct action of the jet do not matter to the study.

The frequencies of impairment of the Main Security Functions (MSF) obtained in the present study shall be compared with the corporate tolerability criteria, allowing the assessment of the possible protections to be installed.

Upon the execution of the study, the requirements for analysis and management of operational risks of the National Petroleum, Natural Gas and Biofuels Agency (ANP), Ministry of Labor and Social Security, Petrobras standard N-2782 - Applicable Techniques to Industrial Risk Analysis and Petrobras' Safety Engineering Guidelines shall be followed.

This Technical Specification (TS) is intended to supplement the requirements of the Safety Engineering Guideline, in force on the date of signature of the contract. It also aims at guiding the development of the study, and the preparation of its respective report.

2. OBJECTIVES

The study should evaluate the scenarios of medium and large leaks of flow streams of CO_2 contents (50% of CO_2 and pressures greater than 50 bar) with risk of embrittlement of structural elements, equipment, equipment supports and piping, identified in the PHA and the possible consequences to the unit from using PHAST. From these simulations and technical analyzes performed, the following results shall be presented:

- Isocurves indicating the regions of air temperatures below -40ºC (measured in the environment) [1], based on CO_2 leak simulations;
- Frequency obtained for each of these scenarios (note that there is no probability of ignition associated);
- Structural elements that are simultaneously affected by temperatures below -40 ° C, for the same cold CO_2 jet;
- Frequency of each scenario that contributes to the impairment of an MSF (defined in item 8.4 of the Petrobras' Safety Engineering Guidelines) with a temperature below -40 ° C (or other temperature according to the material test data, if exists). For the MSF main escape route, in addition to the temperature parameter, the impairment for visibility shall also be considered. When it is not possible to establish the visibility impairment criteria, the impairment frequency shall be considered equal to the total frequency of gas leak with high CO_2 content. The global collapse analysis for primary structures, which shall be performed considering the failure of the elements that are within the region of temperatures below -40 ° C [1]. The frequencies of the failure scenarios shall be added-accumulating and the result compared to the tolerability criteria defined in item 8.12 of the Petrobras' Safety Engineering Guideline;
- For the evaluation of equipment that contain combustible / flammable and / or toxic fluids and their supports, the impairment criteria for which the frequencies of the failure scenarios that shall be added, are those in which the supports are within the regions below -40°C, regardless of collapse analysis;
- For the evaluation of the pipe that contain combustible / flammable and / or toxic fluids supports: the supports that are within the regions of temperature below -40 °C, regardless of collapse analysis, shall be considered impaired and shall be protected, regardless of the accumulated frequency;
- For the evaluation of pipes that contain combustible / flammable and / or toxic fluids: the ones that are within the regions of temperature below -29 °C, regardless of collapse analysis, shall be considered impaired and shall be protected, regardless of the accumulated frequency;
- If the frequency of impairment exceeds the tolerability criteria, indicate passive cryogenic protection. For the MSF main escape route, if the impairment frequency exceeds the tolerability criteria, another main escape route shall be indicated for escape.

3. ABBREVIATIONS E DEFINITIONS

For this specification, the following abbreviations and definitions shall be considered:

ABBREVIATIONS

CFD – Computational Fluid Dynamics

FPU – Floating Production Unit

HCRD – Hydrocarbon Release Database

HSE – Health and Safety Executive - Great Britain's independent regulator for work-related health, safety and illness

MSF – Main Safety Function

P&ID - Piping and Instrumentation Diagram

PFD - Process Flow Diagram

PHA - Preliminary Hazards Analysis

SDV – Shutdown Valve

SIGEM - *Sistema Integrado de Gerenciamento de Empreendimentos* - Integrated System of Project Management

TS – Technical Specification

UEP – Stationary Production Unit

DEFINITIONS

Collapse - Any type of deformation or failure in structural elements that could lead to a fire spreading or propagation, contributing to the occurrence or aggravation of an accidental scenario.

Depressurizing System - Valve, piping and vessel protection system, with manual or automatic actuation, to provide a rapid reduction of the pressure in the equipment, by releasing the inventory of the process plant to atmosphere in a safe place.

Designer - company responsible for the engineering design: basic design or detailing project, which may be Petrobras itself or contracted company to carry out the project; Equipment Support Structure - Mechanical structure dimensioned to support the loads of the equipment in operation conditions, as well as the accidental loads.

Main Safety Function (MSF) - Function that a safety item shall fulfill to enable and/or guarantee the effectiveness of the emergency response strategy, escape and abandonment of the Unit during an accidental event. Included in this definition are other elements that shall be kept intact and functional in an accidental condition. These main functions are defined in item 8.4 of Safety Engineering Guidelines and shall remain available for one (1) hour after the beginning of the incident.

Parties involved - Are the Designer, Study Consulting and Petrobras involved in the preparation or monitoring of the study.

Primary Structure - Structural part in which a failure will have significant consequences for the Unit, like the collapse of the structure of a module, loss of MSF, for example.

Secondary Structure - Structural part in which a failure will not have significant consequences for the Unit, without loss of MSF. Scenario - Event considered at the point of interest having the combination of hazard, causes, effects, and associated risk classification, considering Frequency and Severity.

Section - Parts of the same segment that pass-through regions of interest of the analysis.

Segment - Parts of a system comprising piping and equipment between safety block valves (SDV's) or other blocks considered in the analysis.

Secondary Structure - Structural part in which a failure will not have significant consequences for the Unit, without loss of MSF.

Study Consulting - Is responsible for the execution of the study. Study Consulting may be an outsourced company hired by either the Designer or Petrobras, or it can be the Designer itself or an internal Petrobras workforce.

4. REFERENCE DOCUMENTATION

As inputs for the elaboration of the Embrittlement Study, the following documents shall be considered, at least at their revision “A” and with status of RELEASED WITH COMMENTS by Petrobras at SIGEM or another electronic document management system defined in a contract. The review of each document to be used shall be clearly indicated in the analysis report.

a) Process Flow Diagrams (PFDs);
b) Piping and Instrument Diagrams (P&IDs);
c) 3D model of the updated Unit;
d) Reports of the PHA already carried out for the Unit;

Note: For the execution of the study in Basic Design, PETROBRAS will inform the pertinence and availability of each document listed above.

5. RELEVANT STUDY ASPECTS

The CO_2 High Content Gas Leak - Embrittlement Study shall consider at least the following aspects that influence the magnitude and characterization of the scenarios:

- Leak or discharge conditions into the environment (leak rates, gas temperature, leak direction, fluid phase, etc.);
- The number of equipment, components (flanges, valves, instruments...) and sections of pipelines that can be define as sources of leak;
- The size of the CO_2 jet and the region of temperatures below -40 °C;
- The size of the CO_2 jet and the region of temperatures below -29 °C.

6. SOFTWARE REQUIREMENTS

The study shall be carried out, in the follow order of preference:

- Using software with modeling methodology based on experimental data, validated by Petrobras, E.g.: PHAST;
- Using experimental data as a base;
- Methodologies that use CFD and models for predicting the rate of formation of solid CO_2 and sublimation model, since they are proven against experimental data and validated by Petrobras.

7. METEOROLOGICAL CONDITIONS

Meteorological conditions have poor influence on the region of interest for direct action of the CO_2 jet. Thus, the frequency of the scenario shall be equal to the total frequency of leaks considering only the variation of the jet direction. The frequency will not be weighted by different directions or wind speeds.

8. STUDY METHODOLOGY

The methodology for the shall follow the steps described in this technical specification. Any deviation from the methodology shall be presented to Petrobras for analysis and prior validation. The following steps shall be taken in the development of the study:

8.1. Scenarios Selection

The scenarios selection to be evaluated in the study shall be carried out on risk-based; in this way, the scenarios shall originate from the following sources of information:

8.1.1. Originated from PHA

The study shall simulate and evaluate all the accidental scenarios identified in the PHA that involve thermal effects by CO_2 HIGH CONTENT GAS LEAK, whose initial categorization of risks for the dimensions "People" or "Asset" are classified such as Moderate in severity categories IV or V, and Non-Tolerable (all categories of severity and all dimensions), according to the Risk Tolerability Matrix presented in DR-ENGP-M-I-1.3.

In addition, systems that has flow streams whose composition contains more than 50% CO_2 and pressures greater than 50 bar, fit as scenarios to be considered in the analyzes.

The study shall indicate all the scenarios that shall be simulated, representative of the selected PHA scenarios. According to the experience and analysis of the Study Consulting, some scenarios may be grouped or even excluded from the analysis, however, these shall be technically justified and included in the report with the respective justifications. These cases shall be presented for analysis and prior validation by Petrobras.

The Study Consulting shall include in the report a table with the correlations between the selected PHA scenarios and the various segments and sections of the analyzed systems.

8.1.2. Additional Scenarios

Accidental scenarios that have not been previously assessed in the PHA, identified during the study development, shall also be considered in the CO_2 HIGH CONTENT GAS LEAK - EMBRITTLEMENT STUDY, such as scenarios resulting from design changes and operational changes.

8.2. Process Data

For the determination of the gases or vapors' properties and other data related to the process variables to be used in the study, only updated design data shall be used. All documents used as reference for obtaining the data shall be indicated in the item of reference documents of the report with the respective revisions.

All simulated cases shall have the respective physicochemical properties of the fluids presented in the report, and shall at least be indicated: flow composition, pressure, temperature, density, flow code, reference document (E.g.: PFDs, PI&Ds, data sheets, mass and energy balance, line isometric), operation mode and other properties to track the origin and relevance of the information used. These data shall be provided by the Designer and presented for analysis and validation by Petrobras before being used in the simulations. Validation of process data shall be performed by experienced professionals involved in the project.

It is the responsibility of the Designer to provide the reliable input data to be used in the simulations, so any detected errors that impact the results and that require new simulations is Designer 's responsibility. In case of changes in the project formally requested by Petrobras, as change in the composition of produced fluids or increase/reduction of capacity of the plant that impact the study, will be the responsibility of Petrobras.

8.3. Segmentation

The representative segments of the PHA scenarios and the additional scenarios referred to in item 8.1 of this TS shall be considered in the study, and the Study Consulting shall include as an annex to the report all those segments highlighted in the respective process documents (E.g.: PI&Ds, etc.), so that they can be clearly identified.

According to DR-ENGP-M-I-1.3 depressurizing of the module only occurs in case of confirmed fire, and, as so, depressurizing of the systems involved in this study shall not be considered.

For the segmentation process, the following requirements shall be considered:

- PV, XV, TV, LV, manual block valves, shall not be considered as isolated parts. Exceptionally for segmentation these valves shall be considered segment limitation under the following conditions:

- PV, XV, TV, LV and/or manual block valves having located downstream of them pipes with service type of F (Flare), DA (Open Drain) and DF (Closed Drain);
- PV, XV, TV, LV and/or manual block valves having located downstream of them blind flanges;
- PV, XV, TV, LV and/or manual block valves having located downstream of them closed spectacle blind;
- Manual block valves having located downstream of them instruments.

- Double check valves shall be considered as segment limitation.

Redundant equipment shall be considered in the segmentation/parts counts with a suggested utilization factor of at least 0,5.

Pig Lauchers/Receivers shall be considered in the segmentation/parts counts with a suggested utilization factor of at least 0,5.

All P&Ids of all production risers, gas lift/gas injection lines, all production trains and compression trains shall be segmented and presented for Petrobras approval, not being accepted “typical” segmentation P&Id markups for these systems.

These segments shall be considered for the counting of leak elements, the calculation of leak frequencies and the calculation of hydrocarbon inventories, according to the criteria established in this TS. These segments shall appear in the report in the form of tables in a specific item that shall contain at least the following for each segment:

1. Description and identification of the segment;

2. Quantitative and description of the components (E.g.: equipment, flanges, instruments, accessories, etc.) associated to them by category of leak;

3. Frequency of leak by category (medium and large) for each component.

These results shall be presented in a specific meeting for validation by the Designer and Petrobras before being used in the simulations.

8.4. Parts Count

It is fundamental that counting parts considered as sources of leak (contributors) is the closest to the reality of the Unit in the operational condition (as built), to avoid imprecision in the calculation of leak frequency.

For the determination of the contributors in the calculation of the leak frequency, the portion related to the straight sections of piping (holes in the pipeline) containing more than 50% CO_2 and pressure higher than 50 bar. The updated 3D model shall be used for the measurement of the line lengths.

For the other contributing elements such as flanges, valves and other components, the counting shall be carried out in the following order of priority:

1. Data from other existing installations of the same type (E.g.: FPSO / Semi-submersible, etc.) and production capacity, when available. In this case, the experience of professionals of process, arrangement and piping of the Designer and of Petrobras shall be used to validate the adequacy of the criterion of similarity and use of the data;

2. Data taken from updated project documentation (P&IDs), with the participation of Process, Arrangement and Piping professionals of the Designer. In this case, the correction factors listed in the table in ANNEX I shall be applied.

The definition of how elements shall be counted shall be carried out in a meeting with the participation of the parties involved. The accomplishment of the count is the responsibility of the Designer and shall occur with participation of the Study Consulting. The result of the count shall be presented in a table which shall be included in an annex of the report. The result of the count shall be sent for analysis and prior validation by Petrobras.

The definition of how to count and how to use contributory elements that are not described in this item shall be discussed and agreed in a meeting with the parties involved.

Risers identified as “Future” and/or “Reserved” and/or other similar nomenclature, they shall also be considered in the parts counts if they are identified as Production Risers, Gas Injection Risers, Exportation Risers and/or Gas Lift Risers.

In the executive design, the minimum level of completeness of the 3D model that shall be considered to start the study is 60% for topside and 60% for HULL.

At 90% of 3D model completeness, considering HULL and TOPSIDE, in the executive design, the study executioner shall perform a re-count considering 3D model database (E.g.: flanges, valves, straight sections of piping, equipment, instruments, etc.) when the difference between this new parts count and the previous one is equal or higher than 10%, the impairment frequencies shall be recalculated, new simulations performed and new recommendations provided, if applicable.

8.5. Calculation of the Leak Frequency

The leak frequency for each component (E.g.: equipment, flange, piping, valve, instrument...) shall be obtained by means of databases specified in the Safety Engineering Guideline. The use of any other database shall be previously agreed-upon with Petrobras.

The databases used shall have information that allows to relate leak rates and the corresponding frequency of occurrence according to the element where the leak occurs (E.g.: flanges, valves, line segments, etc.) and their characteristics (E.g.: diameter, type, etc.), such as the HSE Hydrocarbon Release Database (HCRD) database.

The leak frequency of the segment shall be obtained by the product between the number of elements counted in the counting step and the individual leak frequency of each type of component obtained in the database. The product of the linear leak frequency is also added in straight sections of piping, according to the database, by the length of the respective sections.

It should be noted that piping sections may contain contributory elements in different physical areas and modules of the unit. The frequency portion of these elements shall be used where they are physically located (area where the leak occurs or near area).

For the segments between emerged part of production risers and BSDVs and between production BSDVs and their choke valves, the leak frequencies calculation shall also be performed at the shut-in pressures at the choke valves and for other pressures that is provided in the basic design phase. This evaluation shall be performed respecting the leak categories provided in the DR-ENGP-M-I-1.3 of small, medium, and large leaks.

The results of these calculations shall be presented in the report to be developed by the Study Consulting and shall be validated with the participation of the Design Engineer and Petrobras prior to the start of the simulations.

8.6. Leak Rates

The Study Consulting shall consider the two leak rate ranges (medium and large) specified in the Safety Engineering Guideline. In each of the ranges different leak rate values shall be adopted to represent the consequences spectrum of the scenarios and at least the following leak rates shall be used:

- Medium: 4 kg/s, 12 kg/s and 24 kg/s;
- Large: 32 kg/s and full bore (note1).

Note 1: For the riser balcony area, it shall be included the leak rate of 64 kg/s. The determined rates shall be validated with the participation of the Designer and Petrobras prior to the start of the simulations.

8.7. Leak Directions

The leak directions shall be in accordance with Safety Engineering Guidelines, being possible to carry out simplifications since previously agreed with Petrobras. All the directions considered per scenario shall be presented in the report, as well as the justifications for possible simplifications.

8.8. Selection of Leak Points to be Simulated

For the selection of the leakage points, a meeting with the participation of professionals from Safety discipline, either from Design Engineer and Petrobras, shall be held. The participation of professional from Process team is recommendable.

The objective of this meeting is to define the leak points to be used in the simulations for the representative segments of the scenarios selected for simulation. In order to do this, it is recommended the following characteristics to be considered: fluid composition, leakage rates, inventory, leakage frequencies, leakage directions, and area arrangement.

At that meeting, the Designer shall conduct a design review session using the Unit's updated 3D model to facilitate the selection and identification of leak points.

The selection of leak points shall occur in order to identify for each scenario / segment, in each module or area evaluated, the points that historically present a higher chance of leak, not necessarily only the inlet and outlet of large inventory equipment, but also other susceptible points, such as connections on high vibration lines.

Leak points from riser balcony and riser pipe rack shall also be considered.

The simulations performed for a module / area shall not be used in other modules regardless of the similarities of the process and arrangement conditions. This means that each module shall have its own simulations.

Any simplifications shall be discussed with the Designer and validated with the participation of Petrobras. These shall be included in the report with their respective justifications.

8.9. Considerations to be Adopted on PHAST

Since PHAST models do not properly calculate the mass and heat balance of gas/solid CO_2 mixture jets when in comparison with experimental results, the following shall be considered on the simulations:

- No ESD and/or blowdown;
- It shall be considered pure CO_2 composition (PHAST results are too sensitivity to small changes on the composition).

8.10. Embrittlement Analysis

The integrity of the MSF shall be assessed in relation to the impact of the simulated scenarios, which cannot be embrittled:

- Floors and stairs made of composite material: the Designer shall inform the Study Consultant the places where floors and stairs made of composite material belonging to the escape routes will be installed so that the temperatures for the simulated CO_2 embrittlement scenarios can be evaluated, in order to verify the resistance of the materials to these temperatures as foreseen in the Safety Engineering Directive. The report shall present the temperatures on the floors and the limits of thermal / mechanical resistance of the materials used according to the information and certificates provided by the manufacturers, to be made available by the Designer, in order to confirm the possibility of use or the change by metallic material. The evaluation shall consider the guarantee of resistance for the condition after the event;
- Safety valves and valves that need to operate in an emergency situation: the protection of BDVs shall be certified to ensure that the minimum operating temperature of BDV is not reached. The Border SDVs from the production, gas injection, service risers (gas lift and diesel injection) and export wells, as well as their

actuators, shall be protected with passive protection for cryogenic temperatures, regardless of the impairment frequency, that is, the application is deterministic and compulsory;

- Deluge valves: automatic deluge valves (ADV) should be evaluated for impact by CO_2 embrittlement scenarios due to leak from the areas served by them. The impairment of local manual action should be assessed, according to the criteria defined in item 8.12 of this TS. If the limit is exceeded, the change in the position of the impacted ADV or other mitigating measure shall be reassessed.

As a product of the assessments described above, information shall be provided to identify the locations of the composite material floors with the respective temperatures. For the other items, the results obtained shall be presented in a table containing at least:

- TAG;
- Location;
- Impairment Criteria;
- Analysis Results;
- Critical Analysis (with indication and justification of the proposed measures);
- Demand for cryogenic protection and respective extension of the application area, when applicable.

8.11. Structural Analysis

The structural analysis should consider the elements of each scenario of leak with Q rate with temperatures below -40ºC as embrittled and proceed with the analysis of global collapse. The collapse frequency of that scenario will be equal to the cumulative frequency of leaks with rates greater than or equal to Q.

The structural analysis should consider the guidelines of this TS, complemented with the requirements contained in the reference [2].

NOTE: This item is not applicable to the basic/FEED design phase.

8.12. Impairment of Critical Safety Items

8.12.1. Parameters Considered for Impairment

The parameter for impairment of a MSF due to CO_2 leak is temperature.

For primary escape route impairment, in addition to the temperature parameter, the impairment criteria of 3.0 m for visibility shall also be considered.

In the case of a scenario in which the main escape route is impacted by visibility and temperature, the frequency of this scenario shall only be considered once to compose the total impairment frequency.

A specific MSF will be considered impaired when one or more of the criteria established for the set of associated parameters in the impairment analysis is exceeded.

8.12.2. Impairment Frequencies

The total frequency of impairment for each MSF will be the sum of the frequencies of all scenarios that affect that MSF above the established criterion.

8.12.3. Impairment Analysis

The total impairment frequency for each of the MSFs shall be compared according to the impairment frequency criterion established in the Safety Engineering Guidelines.

NOTE: Exceptionally for structural impairment analysis, after performing the structural analysis according to reference [2], the scenarios that generate collapse for the same structure will be accumulated. When the accumulated value of 1.00E-04 occurrences/year is exceeded, the contributing scenarios shall be ordered by the severity of their impacts, giving priority to the recommendation of applying cryogenic protection until the accumulated frequency is below the criterion of 1.00E-04 occurrences/year.

These results shall be presented in the form of tables for each MSF, and recommendations in a specific item of the report should be proposed for cases where these frequencies are higher than the criteria established in the project's safety guideline. The recommendations should, preferably, act to reduce the frequency of impairment of the MSF. If this is not possible, they should consider mitigating the consequences of the scenario.

9. REQUIREMENTS FOR FOLLOW UP MEETINGS

The study follow-up meetings shall follow the guidelines below.

9.1. General Considerations

The follow up of the development of the study shall be carried out by the team of the Designer with Petrobras participation in the cases mentioned in this specification.

The follow-up meetings shall be held in the office of the Study Consulting, except for the planning and analysis of the project documentation meetings, which shall be carried out at the Designer's offices. The meeting local may be changed by common agreement between the parties involved. Petrobras, at its discretion, may attend meetings by videoconference.

9.2. Planning Meeting

Meeting for the summary presentation of the project, clarification of aspects related to the objectives and scope of the study, delivery of project documentation, evaluation and necessary adjustments in the work schedule and resources required for the study, where the minimum agenda should be:

- Clarifications on objectives, scope of analysis and requirements of the study (Designer and Petrobras);
- Delivery of the project documentation as foreseen in item 5 of this TS (Designer), including the 3D model of the FPU;
- Presentation of the planned schedule for the execution of the study in accordance with the project schedule (Study Consulting and Designer);

Participants in the planning meeting: The single points of the parties involved, the professionals responsible for the study, and the Designers' disciplinary leaders responsible for the follow-up of the study shall be involved.

Note: The schedule shall include a deadline for comments on reports (partial and final) by Petrobras.

9.3. Documentation Review Meeting

Meeting for the analysis and validation of the project documentation required for the development of the study and preparation of the pending list, if any. The objective is to avoid errors and rework in studies due to possible failures or omissions of information in the documentation, which will serve as the input database for the study.

The meeting shall also cover the evaluation and validation of the Unit's 3D model as to its suitability for exporting or developing the CFD model.

From the analysis of the document list of project and documents provided, the Study Consulting may request clarification and clear questions about the information contained in the documents. In case of identification of pending documents or the need to provide other documents, the Designer shall inform the deadline necessary to solve the pending issues and/or to send the documents, in a way that does not affect the schedule for the study.

At the end of the meeting, the Study Consulting shall sign an accepted document containing the pending list, if any.

Note: The Designer, as responsible for project change management, shall inform the other parties involved of any change in the project that affects the study. Documents changed because of the project changes, affecting the study, shall be sent to the Study Consulting.

The Study Consulting shall evaluate the changes and report the impacts of the changes in the analysis and schedule. This information shall be sent formally to the designer and communicated to Petrobras.

Participants in the documentation analysis: professionals involved, and the discipline's design leaders shall be involved in the follow-up of the study. This meeting is optional for Petrobras.

9.4. Meeting of Premises and Methodology

Meeting for the presentation and definition of assumptions to be used in the study, clarification of the methodology and confirmation of basic data of the Installation.

The Study Consulting shall present the proposed premises for the development of the study and its doubts about the methodology proposed in this TS. The Designer with the participation of Petrobras shall clarify the doubts.

Assumptions shall be defined by mutual agreement between the parties involved and shall be included in the study report.

In addition to the assumptions and methodology, the Designer shall confirm the basic information for the start of the study, such as meteorological conditions, confirmation of the positioning coordinates of the Unit, the arrangement of risers (submarine and surface - arrangement at the risers balcony) and the MSF shall be evaluated in the study. The information shall be ratified or rectified by Petrobras.

Participants of the meeting of premises and methodology: professionals involved in the study and the discipline leaders of the Designer and Petrobras responsible for the follow-up of the study shall participate.

9.5. Follow up and Validation Meetings

Meetings to follow-up the study by the Designer with the participation of Petrobras where the items required in the methodology shall be addressed.

The Designer, in agreement with the Study Consulting, and considering the schedule for the study, shall present the agenda of meetings to follow up the development of the study. The meetings shall comprise the study steps foreseen in item 8 (Methodology) of this TS. Follow-up and validation meetings shall be provided in Table 1 below:

Table 1: Follow up and validation meetings

Item	Minimum Agenda	Ref.
R1	**Validation of accidental scenarios and the event tree:** Confirmation of the selected scenarios to be analyzed (PHA and Additional) and proposition of the configuration of the event tree.	8.1 8.2
R2	**Validation of process data:** Confirmation of process data, modes of operation.	8.3 8.4
R3	**Segment Validation**	8.5
R4	**Validation of count, leak frequency, leak direction:** Presentation of parts count and leak frequencies	8.6 8.7 8.8
R6	**Validation of leak conditions:** Definition of the leak conditions and selection of the leak points to be simulated.	8.11 8.12 8.13

Table 1 is based on Petrobras' experience, and the number of meetings may be altered by mutual agreement between the parties involved, provided that all the items that compose the methodology and that require validation are addressed, as well as the analysis of results and recommendations are discussed and evaluated for their applicability to the project.

Participants in monitoring and validation meetings: Study Consulting, disciplines representants of Designer and Petrobras technicians involved in the study follow-up shall attend the meetings.

10. STUDY REPORTS

The final report, including its attachments, shall be issued in Portuguese and English. The report shall comply with the content required in the Safety Engineering Guideline and as specified in this document.

All simplification and premises adopted shall be presented and explained in the corresponding part of the report. In addition, the minutes of the meetings shall be presented in annex, especially those that have validation of stages of the methodology. The charts and figures of the reports shall be presented with the respective scales, captions, the rose of the winds, and predominant direction of the wind. For the elaboration of the tables, graphs and figures, the units of the International System - IS shall be applied.

All charts and figures that support the conclusions and recommendations of the study shall be presented in the final report.

10.1. Partial Report

At least two partial reports shall be presented by the Study Consulting to Petrobras.

The first, informative, shall contain at least: the premises, 3D model, geometry if applicable, mesh if applicable and simulation domain if applicable, ventilation study results if applicable, scenarios to be analyzed, scenarios discarded, segment definition and inventory calculation and scenario frequencies.

The second, for comments, shall present the results of the computational simulations, all the analyzes foreseen in the scope of the study, conclusions, recommendations and actions to comply with the recommendations, P&IDs, in addition to the other items included in the first partial report.

10.2. Final Report

The Final Report corresponds to the issue of the report under revision 0, original issue. For this issue, the comments made to the second partial report shall be met and implemented. Additional revisions shall be provided for any changes in the project that impact the study, as provided for in items 8.3 and 9.3of this TS, or in the event that failures in the final emission are identified.

This report shall also contain attached P&IDs with highlighted piping segments/piping items that needs to be protected.

11. DEADLINES

According to the complexity of the project, the scope of the study and the deadlines established in the contract, it shall be defined by the designer, in agreement with the Study Consultant, the deadlines required for the study and the issuance of the partial and final reports. These deadlines shall be included in the schedule mentioned in item 9.2 of this TS.

12. TECHNICAL SKILLS TO CARRY OUT THE STUDY

Due to the complexity involved in the methodology and the use of the software applicable to the study, and also due to the importance of this study for the safety of the Unit, it shall be carried out by a qualified company.

13. APPLICATION OF THE CHECKLIST (LV)

The Designer shall provide a checklist (LV), which shall be included as an annex to the report, as a follow-up to the activities of the Study Consulting. The LV shall contain the requirements of the Safety Engineering Guidelines and the requirements of this TS. The verification of each requirement shall have the identification and signature of the person in charge of the verification.

14. INFORMATION SECURITY

In addition to the provisions of the Safety Engineering Guidelines, the Project Designer and the Study Consulting shall have a data security system that guarantees the integrity, reliability, traceability, confidentiality and inviolability of the data contained in the study and the data provided by Petrobras. All information shall be preserved against accidental or information security events for at least five years.

15. REFERENCES

[1] Guidance Notes for Risk Base Analysis: Cryogenic Spills, August 2015, Lloyd's Register;

[2] I-ET-3010.00-1300-140-P4X-005 - Guidelines for Structural Analyses for Cryogenic Protection Design.

16. ANNEXES

ANNEX I - CORRECTION OF COUNTING PARTS

Table - CORRECTION FACTORS FOR COUNTING PARTS

ELEMENT TYPE	DIAMETERS	GAS			OIL			WELLS		
FLANGES	Count flanges as per P & ID - also considering FE, figure 8, FO and spool - and multiply the total of each system by the following factors:									
	D≤3"	Qtt GAS	x 2,00	x 0,45	Qtt OIL	x 4,00	x 0,35	Qtt WELLS	x 3,00	x 0,45
	3"<D<12"			x 0,35			x 0,45			x 0,50
	D≥12"			x 0,20			x 0,20			x 0,05
	Subtitle: Qtd GAS = total quantity accounted for GAS system in P&IDs (for all diameter ranges) Qtd OIL = total quantity accounted for OIL system in P&IDs (for all diameter ranges) Qtd WELLS = total quantity accounted for WELLS system in P&IDs (for all diameter ranges)									
BLOCK VALVE	Count the block valves in P&ID and multiply the quantitative by the corrections factors below:									
	D≤3"	x 1,50								
	3"<D<12"	x 1,20								
	D≥12"	Use directly the quantitative found.								
BLOWDOWN VALVE (BDV)	D≤3"	Count the blowdown valves in P&ID and use directly the quantitative found.								
	3"<D<12"									
	D≥12"									
CONTROL VALVE	D≤3"	Count control valves in P&ID and use directly the quantitative found.								
	3"<D<12"									
	D≥12"									
CHECK VALVE	D≤3"	Count check valves in P&ID and use directly the quantitative found.								
	3"<D<12"									
	D≥12"									
SHUTDOWN VALVE (SDV)	D≤3"	Count SDVs in P&ID and use directly the quantitative found.								
	3"<D<12"									
	D≥12"									
INSTRUMENTS	D≤3"	Count instruments in P&ID and use directly the quantitative found.								
	3"<D<12"									
	D≥12"									
PRESSURE SAFETY VALVE (PSV)	D≤3"	Count PSVs in P&ID and use directly the quantitative found.								
	3"<D<12"									
	D≥12"									