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SUMMARY

1. INTRODUCTION

The purpose of this Safety Guidelines is to establish the principles of risk management and the main technical requirements that are to be complied with by all project disciplines engineering design involved in the project of Offshore Units for Petroleum and Gas Production Facilities. These principles and requirements are to provide protection to the Life, Environment, Assets and to preserve the image of the Company.

An Inherently Safer Design shall be implemented based on API 14C and a risk management program for the whole Unit life cycle. Additionally, the ISO 13702 (Control and mitigation of fires and explosions requirements and guidelines) and ISO 15544 (Requirements and guidelines for emergency response) shall be followed in order to define, along with this Safety Guidelines, the required practices for implementing both technologies and emergency preparedness, so that an adequate level of safety for personnel, environment and material assets of the units be established and maintained.

1.1 LIST OF ABBREVIATIONS

The following acronyms are used throughout this document:

ALARP As Low As Reasonably Practicable

ALS Accidental Limit States

CCR Central Control Room

CFD Computational Fluid Dynamics

DAL Dimensional Accidental Load

DLB Ductility Level Analysis

EERS Evacuation, Escape and Rescue Strategy

EERA Evacuation, Escape and Rescue Analysis

ESD Emergency Shut Down

FES Fire and Explosion Strategy

FGS Fire Gas System

FWP Fire Water Pump

HAZID Hazard Identification

HFE Human Factors Engineering

HMI Human Machine Interface

HSE Health, Safety and Environment

HVAC Heating, Ventilation and Air Conditioning

LEL Lower Explosive Level

LQ Living Quarters

MCC Motor Control Center

MOC Management of Change

OIM Offshore Installation Manager

PFP Passive Fire Protection

PHA Preliminary Hazards Analysis

POB People on Board

SCC-CO_2 CO_2 Stress Corrosion Cracking

SIL Safety Integrity Level

SLB Strength Level Analysis

UEL Upper Explosive Level

UPS Uninterrupted Power Supply

3D Three Dimensional

1.2 APPLICABLE RULES AND STANDARDS

The Rules and Standards listed herein are to be observed during the execution of all phases of the Offshore Production Units design. In case of conflict with requirements, rules, regulations and specifications contained in this guideline, Petrobras shall be consulted to define requirements to be followed.

STATUTORY RULES / LEGISLATIONS

IMO - International Maritime Organization:

- SOLAS (Convention for the Safety of Life at Sea) and amendments in force;
- IBC Code (International Bulk Chemical Code);
- MODU CODE: Code for the Construction and Equipment of Mobile Offshore Drilling Units;
- MARPOL: International Convention for the Prevention of Maritime Oil Pollution from Ships;
- COLREG: International Conference on Revision of the International Regulation for Preventing Collisions at Sea;
- LSA Code: Life-Saving Appliances;
- FSS Code: International Code for Fire Safety Systems.

REGULATIONS:

- Rules of the Maritime Administration of the Unit's Flag;
- Rules of the Classification Society of the Unit.

BRAZILIAN LEGISLATION:

- Applicable Rules of the Brazilian Maritime Administration (DPC) – NORMAM;
- Applicable Labor Ministry Regulations (MTE) -Regulating Standards – NRs;
- Applicable CONAMA Resolutions and Technical Notes of the Environment Ministry (MMA);
- Operational Safety Management System (SGSO) – Resolution ANP no. 43/2007- National Agency of Petroleum (ANP).

OTHER REGULATIONS AND STANDARDS:

- ABNT Standards whenever applicable or required by Brazilian Legislation;
- International Standard ISO:
    - ISO 13702: Petroleum and Natural Gas Industries – Control and Mitigation of Fires and Explosions on Offshore Production Installations;

- ISO 10418: Petroleum and Natural Gas Industries – Offshore Production Installations – Basic Surface Process Safety;
- ISO 17776: Petroleum and natural gas industries – Offshore production installations – Major accident hazard management during the design of new installations;
- ISO 17349: Offshore platforms handling streams with high content of CO_2 at high pressures;
- ISO 15544: Offshore production installations – Requirements and guidelines for emergency response;
- ISO 15138: Offshore production installations – Heating, ventilation and air-conditioning;
- ISO 19900: Petroleum and Natural Gas Industries - General Requirements for Offshore Structures;
- ISO 19904: Petroleum and Natural Gas Industries - Floating Offshore Structures.

- API - American Petroleum Institute:
  - API RP 14C: Recommended Practice for Analysis, Design, Installation and Testing of Basic Surface Safety Systems for Offshore Production Platforms;
  - API RP 505: Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1 and Zone 2;
  - API STD 521: Pressure Relieving and Depressuring Systems.
  - API RP 2FB: Recommended Practice for the Design of Offshore Facilities against Fire and Blast Loading.
- IEC - International Electrical Commission:
  - IEC 60092–502: Electrical Installations in Ships, complementarily to API RP 505;
  - IEC 61892–7: Mobile and Fixed Offshore Units – Electrical Installations, complementarily to API RP 505;

- IEC 61511: Functional safety – Functional safety - Safety instrumented systems for the process industry sector (applicable only for the specified critical equipment).

- NFPA - National Fire Protection Association:
  - NFPA 11: Foam Extinguishing Systems, Low Expansion and Combined Agent;
  - NFPA 12: Carbon Dioxide Extinguishing Systems;
  - NFPA 14: Standard for the Installation of Standpipe and Hose Systems;
  - NFPA 15: Water Spray Fixed Systems;
  - NFPA 16: Deluge Foam – Water Systems;
  - NFPA 17A: Standard for Wet Chemical Extinguishing System
  - NFPA 20: Centrifugal Fire Pumps;
  - NFPA 25: Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems;
  - NFPA 30: Flammable Liquids Code;
  - NFPA 72: National Fire Alarm Code;
  - NFPA 96: Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations;
  - NFPA 750: Standard on Water Mist Fire Protection Systems;
  - NFPA 780: Standard for the Installation of Lightning Protection Systems.
- UK Civil Aviation Authority:
  - CAP-437: Standards for Offshore Helicopter Landing Areas;
  - CAP-748: Aircraft Fuelling and Fuel Installation Management).
- Fire Testing Standards suggested:
  - ASTM E 119: Standard Test Methods for Fire Test of Building Construction and Materials;
  - UL 1709: Rapid Rise Fire Tests of Protection Materials for Structural Steel.

- OGP - International Association of Oil & Gas Producers - Report 454 - Human factors engineering in projects.

2. LIFESAVING APPLIANCES

Adequate lifesaving appliances shall be provided for the crew that comes on board and should be available in a safe place and comply with applicable Statutory Rules / Legislations. In addition, the provision of lifesaving appliances should be consistent with to the Evacuation, Escape and Rescue Strategy – EERS.

2.1 LIFEBOATS, LIFERAFTS, RESCUE BOATS

The number and capacity of the Lifeboats, liferafts and Rescue Boats shall be dimensioned as below:

- Totally Enclosed Lifeboats - capacity for 100% of maximum POB and installed on each side of the Unit and the corresponding Davits (100% in each side).
- Inflatable Liferafts - capacity for 100% of maximum POB and installed on each side of the Unit and the corresponding Davits (100% in each side).
- Rescue Boat – One for at least five (05) seated persons plus one (01) person on a stretcher and the corresponding Davit.

The lifesaving equipment shall be test in accordance with LSA code requirements. Each launching appliance shall be so arranged that the fully equipped survival craft or rescue boat it serves can be safely launched against unfavorable conditions of trim of up 10° and list of up to 20° when boarded by its full complement of persons.

The design and specifications of the Lifeboats, liferafts and Rescue Boats shall consider:

- Totally Enclosed Fireproof Lifeboats and Davits:

  The lifeboats and davits for floating installations shall be available in design weather conditions and with dimensional accidental heel angels, plus the significant dynamic heel in the same weather and accidental condition. Each lifeboat shall be provided with a proper Davit.

The installation of freefall type of Totally Enclosed Fireproof Lifeboats will not be accepted.

- Inflatable Liferafts:

  Liferafts shall be lowered with davits. The Inflatable Liferafts and davits for floating installations shall be available in design weather conditions and with dimensional accidental heel angels, plus the significant dynamic heel in the same weather and accidental condition.

- Rescue Boat:

  The Unit shall be equipped with a rescue boat located close to sea level to facilitate launching and hoisting operations.

The embarkation station and the access to lifeboats, liferafts and rescue boats shall be free of obstacles and free of hydrocarbons piping, areas shall provide sufficient space for mustering, donning of lifejackets. Embarkation station that are located in areas that maybe exposed to heat radiation or blast loads should have adequate heat and blast protection.

2.2 LIFEBUOYS AND LIFEJACKETS

The Units shall be equipped with lifebuoys and lifejackets as required by NORMAM. The lifejackets located at the Embarkation Stations and near the rescue boat shall be stored in fiberglass boxes with lids for weather protection.

3. FIRE AND EXPLOSION PROTECTION SYSTEMS

Adequate Fire and explosion protection systems shall be provided for the Unit according to the applicable Statutory Rules / Legislations and applicable other Regulations and Standards. In addition, the design of passive and active fire protection system shall be consistent with to the Fire and Explosion Strategy – FES and shall consider the safety studies results.

Fireman’s Equipment Rooms shall be provided in a safe area close or inside the accommodations module to the firefight brigade. Within such rooms it shall be provided all personal protection, equipment and materials in order to enable a quick response from the brigade upon an emergency situation. The dimensions of each room shall be defined at the basic design phase accordingly with the number of members of the brigade per room, considering a minimum area of 2.0 m² per member, but each room shall not be less than 16.0 m² of area.

3.1 FIXED FIRE PROTECTION SYSTEMS

The objective of the fixed fire protection systems is to supply the Unit with fixed resources to limit the possibility of fire propagation, to extinguish and/or to control the fire in order to mitigate the consequences of possible fire scenarios. The fixed fire protection systems to be provided shall consider the type of fire scenario and type of area to be protected such as foam deluge system for pool fires, water spray systems for hydrocarbons equipment under fire radiation, CO_2 flooding system for electrical panel rooms, etc.

Areas such Living Quarters and repair shops shall be protected by hand-operated firefighting resources.

In addition to the set herein, the active and passive resources for fire protection shall comply with the recommendations of the safety studies and shall be consistent with the FES.

High expansion foam firefighting system will not be acceptable in any area of the unit.

3.1.1 FIXED WATER AND FOAM SYSTEMS

The following items are to be considered for fixed water and foam protections systems design.

3.1.1.1 FIXED WATER SPRAY SYSTEM (DELUGE SYSTEM)

The sprayed water shall be applied to cool off equipment surfaces, avoiding overheating that could lead to their collapse. Equipment that contains combustible or flammable fluids, including, metering stations, risers connections and SDVs in the production lines, gas injection and oil and gas exportation lines, shall be protected with water spray.

A risk-based approach can be used to decide on the protection of equipment and piping that contains an inventory of flammable or combustible liquid after emergency depressurizing, but in this case, the risk-based analysis shall be documented and approved by the Class Society. This analysis shall be based on the Fire Propagation Analysis data.

The design and testing of the water spray system shall consider the requirements of NFPA 15. The water spray rates shall be according to ISO 13702.

Precautions shall be taken in the design to prevent the nozzles from becoming clogged by impurities in the water or corrosion of piping, nozzles, valves and pump.

3.1.1.2 FIXED FOAM PROTECTION SYSTEM

FPSO Units shall be provided with a foam system to protect cargo tanks that store oil to avoid fire in tank, as required in SOLAS Chapter ll-2, part C rule 10, FSS Code Chapter 6 and the Classification Society Rules.

The fixed foam system design shall consider foam application on the main deck areas for purpose of extinguishing at pool fires.

For the main deck cargo area, foam spray system shall be provided from a proper arrangement of piping system, placed underneath the process modules. Main deck cargo areas shall be fully protected by foam spray system. The foam spray system shall be designed according to NFPA-16.

The activation of this system shall be automatic, manual remotely through the CCR and manual on site. The design shall ensure that foam application occurs only on the affected area.

Other areas at main deck, different from cargo areas, where it is possible to have pool fires, shall be protected by fixed foam spray system or fixed foam monitors. In case of using fixed foam monitors, the design shall consider, among others, the following items:

- Foam monitors coverage area drawings shall be presented, including a shadows analysis, properly documented proving that all areas protected by monitors are fully covered by at least one monitor. The foam monitors coverage design shall consider the monitors operational limits specifications;
- Shadow Analysis shall check for obstructions on the main deck, in the area over cargo tanks, caused by process plant deck support elements or any other equipment installed on it. This study shall be carried out for the design of the foam system of the main deck.

- Foam monitors shall preferably be installed outside the projection line of the process plant deck and aft of the area protected by them, in order to facilitate access by the fire brigade without the need to pass through the area under fire.

In order to optimize the use of foam in the main deck area over cargo tanks, in case of liquid hydrocarbon leakage, fixed containment barriers with longitudinal and transvers coamings should be installed to limit the area to be protected. These barriers are also used to contain the movement of oil on the deck in order to avoid spreading to other areas, mainly in case of fire to avoid the "running fire" effect. The height of containment shall be at least 150 mm.

Main escape routes shall be located outside coaming areas on main deck.

The containment is to be provided at unloading and/or offloading stations, pump areas, and overflow/vent line locations, and arranged to direct a possible leak or spill to the open drain system. For these containment places foam application shall be provided by fire water/foam monitors installed in two opposite sides of the containment place.

Topside areas of the Unit subject to pool fire shall be protected by fixed or portable foam application systems.

The Unit shall be provided at least with two foam concentrate pump sets (2 x 100%), proportioning eductors and a main header considering the maximum foam demand for the Unit. The foam concentrate shall be Alcohol Resistant Aqueous Film-Forming Foam 3% (AR-AFFF 3%) for Polar Solvents and Hydrocarbons complying with SOLAS, Chapter II-2, Part A, Reg. 1 item 6.2.1 and IBC Code chapter 11. The system shall be dually fed by the main power generation and by the emergency power generation.

Note: The cargo area is defined as the main deck region between the engine room forward bulkhead, the longitudinal oil barriers at port and starboard, and the forward collision bulkhead.

3.1.1.3 HELIDECK FIRE PROTECTION SYSTEM

In addition to requirements set by this item, the helideck firefighting equipment shall be in accordance with NORMAM 27 and CAP-437.

The minimum operating pressure upstream the helideck eductors shall be 687 kPa, considering the simultaneous fire water/foam monitors operation as per CAP-437 standard.

Electrically driven foam generation pumps shall be fed by two distinct electrical sources, independent and isolated from each other.

The helideck shall be provided with an effective drainage system, which is capable of ensuring the rapid disposal of any liquid fuel to a safe location according to NORMAM 27.

The helicopter refueling stations shall be protected by a foam firefighting system.

The Units shall be provided with helideck equipment locker installed next to landing deck access as NORMAM 27.

3.1.1.4 FIRE WATER PUMPS – FWP

The FWP shall be designed in order to supply the fixed water and foam systems. The Unit shall be outfitted with dedicated fire water pumps with total capacity to cover 100% of the maximum design water flow rate. Shared systems shall not be accepted for the firefighting water supply. The piping and pumping arrangement shall be exclusive for firefighting duty.

The FWP shall be weather protected and located away from risky areas, such as process plants and cargo tank areas. Also, they shall be away from each other, installed preferably on opposite sides of the deck or on different decks.

The FWP discharge head characteristics for each pump unit shall be sufficient to meet firewater system pressure demands plus pressure losses within the firewater main distribution system, according to hydraulic analysis.

If the pumps are powered by electrical motors, they shall have two different powers feed sources, independent and isolated from each other, except for those that are of the diesel electrical type. Electric Power Source, for the Fire Pump drivers, shall be defined as the set that includes driver, distribution panel, control systems and cables that reach the essential power panel, totally independent from the other existing systems so that in case a fire or any other accident affects one system, it shall not prevent the operation of others.

Independently of the number of fire water pumps, there shall always be at least one reserve pump capable of replacing any of the remaining fire pumps. The pumps configuration 2 x 100% is not acceptable.

All FWP shall comply with the requirements of NFPA 20 and NFPA 25 and each one shall be autonomous for at least 18 (eighteen) hours of operation.

Whenever fire water pump system is built using lift pumps inside caissons, the lift pump must be permanently submerged. The use of submersible lift pumps inside caissons is not mandatory. It is acceptable to build the system with centrifugal fire water pumps without lift pumps, but in this configuration, the pumps must be installed so low down the hull that the pumps suction will always be below the lower possible sea level, considering minimum draft and the FPSO motions (roll, pitch and heave).

The fire pump room arrangement shall comply with SOLAS, Chapter II-2, Regulation 10.

Chlorine shall be injected at the inlet of the system, to avoid fouling or marine growth.

Provision shall also be made for manual startup of the pumps in loco and also from remote stations, at least in CCR.

The shutdown of any FWP shall be only caused by over speed, short circuit or local actuation.

The FWP including diesel driven fire pumps shall start-up in at most 45 seconds. The pump motors shall have a startup system with automatic actuation, manual remote and manual on site. The shutdown shall always be through the actuation of the manual control on site.

The maximum water demand of the firefighting system shall be the one required by the largest fire scenario, according to the Fire Propagation Analysis (Safety Studies) plus the water supply to at least two hose lines.

The specification of FWP system shall consider the water supply for the helideck consumers. The minimum set pressure and water flow shall be according to Helideck Fire Protection System item.

3.1.1.5 FIRE WATER MAIN

The Fire Water Main shall be designed in order to supply the fixed water and foam systems. The fire water main shall consist of a pump discharge line header connected to the two main distribution line branches (2x100%), routed separately along the Unit's main deck region with transversal interconnection lines to deliver water to the consumers systems. The fire water main design shall comply with SOLAS, Chapter II2, Reg. 10, item 2.1.

The fire water main must be fitted with an arrangement of isolating valves and appropriate backflow prevention devices strategic installed to block any part in fault or under maintenance in order to guarantee the water flow to the consumers.

All block valves of the fire ring main shall be duly identified and installed in a way for easy visibility, access and operation.

The pressure level of the fire water main shall be set so that the opening of any point of consumption shall causes a pressure drop in the fire water main which shall automatically start the FWP.

All materials used in the fire water main and its components shall be proper to operate with salt water and must be dimensioned to the lifetime period of contract.

Fiberglass reinforced plastic fire water ring will not be accepted for FPSO Units.

3.1.2 FIXED GASEOUS PROTECTION SYSTEMS

The following items are to be considered for fixed gaseous protections systems design.

3.1.2.1 CARBON DIOXIDE (CO_2)

The CO_2 flooding system is applicable to protect enclosed spaces with installed capacity equal to or greater than 1000 kVA, where fire risks consist of electrical equipment; rooms that contain internal combustion machines with installed power above 375 kW; machinery spaces; cargo pump rooms and other spaces with similar fire risk. Additionally, spaces where fire risks consist of oil mist fire (*e.g*. diesel purifier room) shall be protected by CO_2 flooding system.

The system shall be designed and tested according to FSS Code and NFPA 12 requirements.

The spaces protected by CO_2 flooding system shall be properly signaled in accordance with the requirements of NFPA 12 standard.

Local batteries of CO_2 cylinders shall be provided to protect the atmospheric vent discharge, vent post discharge and ducts of the galley hood. The local batteries shall have a stand-by battery of CO_2 cylinders ready for use. For Vent Post snuffing system, CO_2 discharge shall be automatic by temperature sensors installed close to vent post discharge.

Installation of CO_2 flooding system will not be accepted in compartments located on SS-type Unit columns and pontoons or in compartments with permanent presence of people.

3.1.2.2 CLEAN AGENTS

Only the use of clean gas agents without HFC, CFC and HCFC is acceptable and shall comply with FSS Code and respective NFPA Standards.

3.1.3 WATER MIST SYSTEM

The high pressure water mist system can be used as fire protection alternative to the use of the CO_2 flooding system.

High pressure water mist system can be used for protection of spaces with internal combustion machines, diesel purifier rooms, machinery spaces, cargo pump rooms and other spaces with similar fire risk and cannot be used to protect spaces with electrical panels and electrical equipment.

Whenever the high pressure water mist system is used, it shall be designed and tested in accordance with NFPA 750 standard and FSS Code.

When designed to protect machinery spaces and cargo pump rooms, it shall also be in accordance with IMO MSC/Circ. 1165 “Revised Guidelines For The Approval of Equivalent Water-Based Fire Extinguishing Systems for Machinery Spaces and Cargo Pump Rooms".

3.1.4 WET CHEMICAL

The wet chemical fire extinguishing system can be used as an alternative to the use of CO_2 fixed fire protection of galley hood ducts and deep-fat cooking equipment.

The system shall be provided with automatic and manual means of actuation.

The design of the system shall be in accordance with NFPA 17A, NFPA 96 and Classification Society Requirements. Certifications and approval tests shall be provided accordingly.

3.2 MANUAL FIRE PROTECTION SYSTEMS

Manual fire protection systems and equipment shall be provided in way that are strategically dimensioned and positioned to provide a reliable and effective means for firefighting by manual application. Manual fire protection systems shall comply with Statutory Rules / Legislations and applicable other Regulations and Standards.

3.2.1 HYDRANTS AND FIRE HOSES

Fire hydrants shall be installed along the boards of all decks. The location of these hydrants shall be such that a fire in the area protected by them shall not prevent their manual operation.

Fire hoses are to be resistant to oil, chemical, deterioration and to exposure to offshore environment and specified according to NFPA 14.

Location and quantity of hydrants shall be defined considering that at least two water jets come from different hydrants reaching any point of the Unit. One jet come from a 15 m fire hose line connected to a hydrant and another come from a maximum of two 15 m fire hose lines connected to a different hydrant.

Firefighting equipment lockers shall be installed next to each external hydrant, but in way that not may interfere with the proper operation.

The LQ shall be protected by hydrants with one outlet and 15 m long fire hoses installed along the corridors. The external area of the LQ shall be protected by hydrants with two outlets located close to the accesses at each deck level.

All materials used in Hydrants, valves and fire hose connections shall be proper to operate with saltwater and must be dimensioned to the lifetime of the Unit.

3.2.2 FOAM FIRE PROTECTION SYSTEM FOR TOPSIDE AREAS

In Topside areas with equipment operating with flammable or combustible liquids, fixed or portable foam firefighting systems shall be installed, as specified in NFPA-11, with autonomy for at least 30 minutes.

In case of fixed foam systems, they shall be independent (nozzles, automatic deluge valves, distribution piping, system activation) of water spray system, dedicated to foam application at pool fires. Foam concentrate demand for topside systems shall be added to foam concentrate demand for main deck foam system to design foam concentrate tank.

Fireman's outfit lockers shall be installed next to the accesses of process areas.

3.2.3 FIRE EXTINGUISHERS

Fire extinguishers shall be distributed everywhere on the Unit for manual fire fighting against incipient fire. Fire extinguishers must be proper to the class of fire that existing in each protected area and shall comply with Statutory Rules / Legislations and applicable other Regulations and Standards (NR-37 standard, ANNEX IV-F of NORMAM 01).

The maximum distance to reach a fire extinguisher shall be 15 m.

Fire extinguishers shall be identified and installed in such a way for easy visibility, access and operation. Extinguishers located in open areas shall be provided with weatherproof shelters.

3.3 PASSIVE FIRE PROTECTION - PFP

Passive Fire Protection (PFP) shall be provided in accordance with the requirements of the FES.

PFP should be applied in order to segregate and isolate areas with different risk levels, to protect manned areas, to protect safety functions that need to operate in an emergency condition under fire attack (e.g. flare system, BDV and SDV valves and their actuators) and to protect critical structures of the Unit, as primary structures of the modules, support of equipment, living quarters bulkheads, etc. In addition, PFP should also be applied to protect equipment and piping that handle hydrocarbons according to

FES. Hydrocarbon risers (upper riser balcony/porch area) and their ESDV's shall be provided with passive fire protection adequate for one hour protection against jet fires.

PFP specification shall consider the duration of protection required, type of fire and the temperature limits for the structure/equipment to be protected.

Materials used for fireproofing protection shall comply respectively with the applicable test standards and shall be certified by the Classification Society.

3.3.1 PASSIVE FIRE PROTECTION FOR ENCLOSED SPACES

Classified bulkheads and decks shall enclose and/or segregate high risk areas isolating them from normally serviced areas or safe areas, as well as from low risk areas, as defined in the SOLAS Regulation, ISO 13702 and Class Society Rules.

PENETRATION, DOORS, AND WINDOWS

Wherever it is necessary to penetrate a classified bulkhead or deck with piping, ducts, trays or cables, proper measures shall be taken to ensure their integrity, according to classification at the penetration point. For that purpose, duly homologated fireproof sealing shall be used to seal the penetration, and thus avoid fire and smoke propagation.

Doors and windows shall follow the classification of the bulkhead in which they are located. Fireproof doors shall be of the self-closing type.

3.3.2 STRUCTURAL PASSIVE FIRE PROTECTION - SPFP

Structural elements, supports of equipment, bulkheads and floors and ceilings in open deck areas, which may be exposed to fire, whose failure could totally or partially impair the integrity of the Unit, shall be protected with Structural Passive Fire Protection to resist the fire conditions and comply with the applicable rules and test standards.

The needs for application of Structural Passive Fire Protection on structural support elements shall be defined based on the Fire Propagation Study.

4. FIRE AND GAS DETECTION SYSTEM

The fire and gas detection system shall be installed for monitor continuously the presence of a fire or gases to alert personnel and allow control actions to be initiated manually or automatically to minimize the likelihood of fire escalation, explosion and personnel exposure.

Fire and gas detection in any area according to FES should generate an emergency shutdown, according to items 4.1, 4.2 and 4.3. For more information about proposal actions and emergency shutdowns, see Annex IV.

4.1 FIRE DETECTION SYSTEM

The Unit shall be covered with a fire detection system to monitor any area with risk of fire. The installation, operation and location of each sensor shall be established in accordance with the FES, manufacturer specifications, recommendations of API RP 14C and ISO 13702.

The voting logic shall be 2ooN (N ≥ 3) and the confirmation by two (2) detectors shall initiate shutdown and alarm actions as Annex I.

For information purpose, the fire detection and actions adopted by PETROBRAS in case of fire is presented in Annex I.

4.1.1 FLAME DETECTORS LOCATION

An analysis shall be made, with the aid of the 3D model, considering the equipment and the coverage area of the detectors. Subsequently, the analysis shall be refined by adjusting the position of the detectors, considering existing structures as possible supports for the detectors. Interference with flare flame itself and other elements such as pipes, structural elements and other equipment that may obstruct or provide reflections of flare in the detectors' fields of view shall be analyzed.

Allocation reports for flame detectors for hull and topside modules shall be prepared. The reports shall be issued preliminarily in the design phase but shall be revised and validated in the installation and construction phase. There shall be integration between hull and topside reports.

When designing a fire detection system, there are several factors to consider in determining the use of flame detector:

a) Dimensions of the space to be protected. This will help to determine how many detectors are needed. Using the field of view and distance, the coverage area can be determined for each detector.

b) Existence of obstructions in the line of view. More detectors may be required to overcome obstructions.

c) Existence of potential sources of false alarms for radiation. What are the conditions that can prevent the fire detection by detector? In addition to obstructions, are there other factors that can block the detector from "seeing" the fire? An example could be the presence of smoke before the fire.

d) The response time for a detector. The distance the detectors shall be assembled away from potential sources of fire can be affected and more detectors would be needed.

e) Expected flame size. The larger the flame, the farther the detector may be.

f) Existence of undue alarm sources that shall be suppressed. For this case, 2 detectors can help to reduce the risk of false alarms, regarding the voting criteria.

g) Adjustment of assembly height. Detectors shall be directed downwards as prescribed by Manufacturer (or, in the absence of that requirement, at an angle backed up by the field of view projections in 3D model), to prevent dirt on the lenses, thereby reducing maintenance.

4.2 GAS DETECTION SYSTEM

The Unit shall be covered with a gas detection system to monitor any area with risk of accidental gas release or formation. The installation, operation and location of gas detectors shall comply with the FES, manufacturer specifications, standards requirements and Gas Dispersion Study.

The voting logic shall be 2ooN ($N \geq 3$) and the confirmation by two (2) detectors shall initiate shutdown and alarm actions as Annex II.

For information purpose, the gas detection and actions adopted by PETROBRAS in case of gas releases is presented in Annex II.

The effects of people exposure to atmospheres containing CO_2, considering the aspect of concentration and exposure time, are reported in Annex V.

All air intakes shall be monitored by gas detectors (CH_4) independently of the results of the Gas Dispersion Study. The provision of monitoring occupied compartment air intakes with CO_2 and H_2S gas detectors interlocked with closing of dampers in ventilation ducts shall be confirmed by Gas Dispersion Study.

For confined areas such as generator hood, CH_4 detection shall comply with actions indicated in item related to HVAC System.

The Table 1 presents levels for gas detection with proposed action. The actions proposed in the notes shall be observed according to ESD actions presented in Annex IV.

Table 1 –Values for Emergency Actions for Gas Detections

Component / Concentration	**Concentration to ESD** (Note 2)	**Concentration to alarm**
CH_4 (open areas)	60% of LEL	20% of LEL
CH_4 (machinery hoods)	15% of LEL	10% of LEL
H_2S	20 ppmv	8 ppmv
H_2S (enclosed spaces where gas stream may have H_2S)	(Note 5)	5 ppmv
CO_2 (Note 3)	30,000 ppmv	3,900 ppmv
H_2	15 % LEL (Note 1)	10 % LEL

Note 1: Other Action: Inhibition of deep battery charge.
Note 2: ESD actions are presented in Annex IV.
Note 3: See Annex V.
Note 4: More stringent levels can be proposed by contractor.
Note 5: Concentration to confirmed gas: 10 ppmv. However, it shall not generate an ESD signal.

4.2.1 FOR PUMP ROOM

Gas detected inside the Pump Room up to 10%LEL (1ooN) shall generate the following actions:

1) Immediately escape of all personnel from the Pump Room to a safe location;
2) The Pump Room exhaust fans shall remain in operation, with the respective dampers open;

3) Initiate an audible and visual alarm in the following points:

- Pump Room;

- Engine Room and HMI of the control station of the Engine Room

- HMI of the CCR

Gas confirmed inside the Pump Room up to 50% of LEL (2ooN) shall generate the following actions:

1) Automatic activation of the Emergency Shutdown (ESD-3P - see Annex IV);
2) Escape from the process areas to the muster station, avoiding passing through the escape routes immediately adjacent to the exits of the Pump Room;
3) The Pump Room exhaust fans shall remain in operation, with the respective dampers open;
4) Emergency lighting of the Pump Room shall be kept on;
5) Manual remote closure of all hydrocarbon block valves to isolate the inventory of Pump Room. A procedure shall be prepared to assure the proper Pump Room inventory isolation, indicating which valves shall be closed;
6) Keep the gas detection system of the Pump Room in operation, to monitor the internal gas concentration;
7) Stop cargo pumps to interrupt the offloading operation. A procedure shall be prepared to assure these actions;
8) Stop stripping pumps. In case of steam driven pumps the stop shall be implemented by the interruption of the steam supply;
9) Stop accommodation ventilation and automatically close its dampers;
10) Close steam system feed valves to the pumps of the Pump Room and subsequent escape of the Engine Room;
11) Monitoring of the bilge level of the Pump Room and activation of the emergency drain system in case of high level. The bilge level alarm is only a detection mode for oil leaks inside the Pump Room. The response actions shall be taken in the control room;

12) The exposure of any people, including members of the firefighting brigade, to explosive atmospheres is prohibited. The atmosphere inside the Pump Room shall be periodically monitored (%LEL) to assess the risks of entry and stay inside the Pump Room.

If there are equipment on the other floors of the Pump Room that handle flammable hydrocarbons from cargo tanks, slop tanks or settling tanks (when applicable), with poor ventilation conditions, dedicated gas detectors shall be installed for these equipment. Considering the type of floor (grid or plate) and the voting logic for emergency actions of 2ooN, with $N \geq 3$, these dedicated detectors must perform the same actions as the detectors located on the bottom floor of the Pump Room.

In case of confirmed gas outside the Pump Room, the decision to stop the exhaustion and close the dampers shall be made by the OIM and this closing shall be manual remote.

On hull conversion design, pre-existing sensors on the ship will not be accepted, which shall be replaced by models of the same technology of the open areas, suitable to operate in Zone 1.

4.3 SAFETY PRECAUTIONS FOR H_2S EXPOSITION

H_2S gas detection, alarms and safety precautions shall be provided for normal or accidental operation conditions. Risk analysis should determine the potential frequency and consequences of specific H_2S related events in the Unit, including non-routine operations, concurrent operations and confined space entry and indicate risk reduction measures. H_2S area drawings shall be provided based on the likelihood of H_2S presence and the maximum concentration of H_2S that may be occur in each area. H_2S detection system shall be considered according to gas dispersion study and risk analysis. These studies shall consider the H_2S concentration increase, e.g. due to gas recirculation or during regeneration of molecular sieves. Operational procedures with safety precautions shall be provided prior commissioning or operation of systems where H_2S may be present.

Enclosed spaces where gas stream may have H_2S shall be monitored by fixed H_2S gas detectors. The H_2S gas detectors shall be installed inside the rooms, next to the access' doors (at 1.5 meters high) and in the lower areas where H_2S may be accumulated. H_2S

gas detectors shall generate visual and audible alarms inside the rooms, outside of the access doors and in the CCR. In case of confirmed gas, fuel gas supply shall be shut off and ventilation system shall remain in operation.

Results of H_2S dispersion modelling shall be considered for the emergency response scenarios to be addressed in Evacuation, Escape and Rescue Analysis (EERA).

5. RISK MANAGEMENT AND ASSESSMENT STUDIES

5.1 RISK MANAGEMENT PROGRAM

A Risk Management Program shall be developed and implemented at early stage of design phase, to continuously monitor and control the risks identified in the risk assessment studies during the operational lifetime. This Risk Management Program shall be submitted to PETROBRAS.

As minimum, the Risk Management Program should consider:

- Risk management Goals;
- Risk definition, levels and management of HSE Risks;
- Qualitative and Quantitative tolerability criteria;
- Use of Qualitative and Quantitative Risk Assessment;
- Approach to achieve ALARP;
- ALARP demonstration requirement;
- HSE Critical Element Criteria and Performance Standards;
- Technical Authority Approval Process;
- Approval of deviation, and;
- Management of Change Process.

5.2 RISK MANAGEMENT REQUIREMENTS

Risk Assessment Studies shall focus on Safety for Personnel, Asset, Environment and Reputational Damage, showing recommendations to reduce the frequency of accident scenarios and/or reduce associated damages.

Unit Design shall be based on an inherently safer conception, and during the hazard identification assessment, risk prevention measures should take precedence for Major Accidents. The Major Accidental Hazards shall be further assessed with consequence analyses to support decisions related to design, and to emergency response procedures.

In terms of alignment with the Petrobras Risk Matrix, presented in Annex III, Major Accidents Hazards shall be considered similar to Not Tolerable scenarios and Moderate scenarios with Severity IV and V to people and asset.

A Management of Change (MOC) program shall ensure that all changes temporary or permanent that occur during a design, construction, commissioning and at operational phase to a process plant, equipment, arrangement, procedure, operation and personnel are properly reviewed and the hazards introduced by the change shall be identified, analyzed, and controlled prior to start, resuming or continuing operation. The MOC report shall be registered in a structured form.

All design documents, risk analysis, safety studies, operational procedures and others aspects affected by the changes shall be reviewed to ensure that they are updated.

A Design Safety Report for the FPSO shall be presented with follow minimum requirements:

- Unit description;
- Identification and risk assessment of all Hazards of the Unit;
- Identify the Major Hazards (high risk and/or consequence);
- Summary with the scope and results of Consequence Analyses;
- Recommendations of Major Hazard Consequence Analyses;
- Design actions for treating the recommendations of Major Hazard consequence analyses considering ALARP principle;
- ALARP demonstration after Design actions, with assessment of risk reduction alternative proposals;
- Identify Safety Critical Equipment, Systems and Procedures as per ANP Operational Safety Management System Requirement.

An Operational Safety Report shall be developed, before of the beginning of operation, and demonstrate that during the operation of the facility, all major hazards are managed to ALARP Risk. Design Safety Report should be used to develop the Operational Safety Report.

Design Safety Report and Operational Safety Report shall be submitted to PETROBRAS for comments/information. The Operational Safety Report shall be updated up to two years after start operation. Revisions shall be made at least every 5 years. In case of operational or design changes the operational safety report shall be reviewed.

5.3 RISK TOLERABILITY CRITERIA

The risk tolerability criteria can be qualitative or quantitative according to the kind of study applicable. The ALARP concept is applicable to both types of risk tolerability criteria.

- Qualitative Criteria - Risk Tolerability Matrix comparable to the Matrix presented in Annex III.
- Quantitative Criteria – The risk assessment the shall consider the following items:

  a) The possible loss or impairment of the Main Safety Functions and Relevant Safety Items by applicable accidental loads shall be evaluated, in order to comply with items “c” and “d”;

  b) The minimum accidental loads to be considered are: fire, explosion, ship collision and dropped objects.

  c) For each Main Safety Function and Relevant Safety Item, the overall tolerable frequency of loss or impairment is $1x10^{-3}$ occurrence per year. Anyone of the accidental loads cannot contribute with more than $2.5x10^{-4}$ occurrence per year.

  d) Each Main Safety Function and Relevant Safety Item shall maintain its integrity, withstand for at least 60 minutes.

5.4 RISK ASSESSMENT STUDIES

5.4.1 GENERAL

Risk assessment techniques shall be applied during different design phases of the Unit as defined in ISO 17776 e ISO 31000.

An auditable action tracking system able to control of approved/rejected recommendations from risk assessment studies shall be established and maintained. Rejected action shall have appropriate technical justification as per ANP requirement.

The risk assessment studies of the platform shall be reviewed before the start of the operation, in order to consider the changes implemented and the characteristics of the as built unit. This review shall have the participation of unit design and operation teams (crew and office staff) and inspection of the concessionaire. This review should be evidenced.

The latest revision of Unit reference documents shall always be used for the review.

For each accidental load, the studies shall evaluate integrity of the following items:

- **Main Safety Functions -** Accommodations, Embarkation Station, Temporary Refuges, Muster Station, CCR, Escape Routes;
- **Relevant Safety Items:**
    - Primary structures of process, utilities and flammable/combustible chemical products modules;
    - Primary structures that support safety equipment and lifesaving equipment;
    - Primary structures that support risers;
    - Fireproof bulkheads;
    - Support structure of hydrocarbons equipment;
    - Central pipe-rack;
    - Impairment of the safety equipment (eg: fire pump, emergency power, communications, fire ring main, ADV, FGS remote panel);
    - Ballasting System;
    - Mooring System;

- Flare structure and piping, including equipment and depressurization header;
- Main deck cargo area;
- FPSO and FSO hull;
- Semi-submersibles structural columns and pontoons.

Note: The Relevant Safety Items is not limited to the list presented above and should be complemented according to the features of the Unit design.

5.4.2 QUALITATIVE RISK ASSESSMENTS

HSE activities during the design process shall focus on the identification of HSE risks and the hazards and effects that generate them. Risk management shall be by control (threat barriers) and recovery (mitigation and emergency response) measures, to ALARP risk levels. A detailed HAZID (or PHA) shall be carried on during design development.

Performance Standards shall be identified and set for design of threat controls and recovery measures (HSE Critical Systems) to ensure that they address availability, functionality, and survivability.

A critical analysis of the design barriers (threat control and recovery measures) shall be carried out, e.g. bow tie review, considering the Major Accident scenarios in the industry, e.g. TR impairment, Riser Events, pump/machinery room explosion.

All safeguards (Critical Elements of Operational Safety) foreseen in the risk analysis and safety studies shall be implemented before the start of the operation. The implementation of all safeguards must be verified during the Critical Elements of Operational Safety audit.

Comprehensive HAZID (or PHA) and HAZOPs (Including close-out reports) shall be carried out to identify the hazards present in the design scope, and used to assist qualitative assessment of HSE risks and identification and definition of Major Hazards. These HAZOPs shall include vendor´s packages and their interface, small diameter process lines and drainage lines. Other interfaces shall also be covered in the HAZOPs, as well as stimulation, offloading and hose flushing operations.

HAZOP and HAZID (or PHA) shall estimate the risks before and after the implementation of recommendations and display it on the HAZOP worksheet.

The categorization of HAZOP scenario risks shall be in accordance to the Risk Tolerability Matrix used in PHA/HAZID study.

5.4.3 CONSEQUENCE ANALYSES

All Consequence Analyses shall be in accordance with the following requirements:

- All leak scenarios classified as high, medium risk or with catastrophic consequences to personal safety and assets/operational continuity, in qualitative risk assessments shall be evaluated. The assessment shall indicate scenarios which shall be simulated and those that can be grouped or even eliminated. In both cases scenarios shall be documented and justified.
- For inventory calculation of flammable and toxic materials shall be considered the content between SDVs for the respective scenario and a maximum time of 45 seconds for surface SDV closing, included the time to detection. The specific closing time for subsea isolation valves in gas pipelines and satellite wells ducts with gas shall be that considered in the project.
- Damage calculation to the Installation including evaluation of the impairment of Main Safety Functions and Relevant Safety Items;
- Consider existing fire passive and active protection;
- Proposal recommendations to reduce the risks when applicable. The results of such recommendations shall be justified and quantified, if necessary.
- The scenarios of cold jets resulting from a loss of containment of a high CO_2 stream shall be evaluated and their consequences shall be assessed.
- A specific study shall be performed considering the scenario of accidental leak of flanged connections of systems with supercritical CO_2 or CO_2 in the liquid phase. This condition is expected to happen at pressure higher than 50 bar and CO_2 content equal to or higher than 60% molar. Low temperature embrittlement of materials shall be addressed. Based on technical studies evaluation, the following alternatives shall be assessed and implemented:

  a) The selection of materials that are appropriate for low temperature conditions. This includes the materials selected for the flanges, gaskets, bolts and nuts.

b) The selection of a flange technology that is less prone to leakage.

Other alternatives may be proposed and shall be approved by Petrobras. Solutions other than material selection approach shall be based on a technical study.

Structures that support these lines shall be evaluated for leak scenarios that lead to the reduction of temperature below the design temperature due to cold CO_2 jets. In addition, impairment of main safety functions due to cold CO_2 jets shall also be evaluated.

- Scenarios related to riser failure due to SCC-CO_2 with large fluid/gas leaks above or below water level shall be included in FPSO risk assessments.
- The software used for leak simulation shall be able to simulate the leak decay rate due to the ESD systems actuation and the automatic blow down influence. The decay shall be considered in fire simulations and, whenever applicable in explosion simulation.
- For the consequence analyzes the impairment criteria for the Main Safety Functions and Relevant Safety Items are presented in the ANNEX VI as a reference.
- The leak frequency of equipment shall be set using as specialized reference database, such as: LEAK (DNV), International Association of Oil & Gas Producers (OGP), AIChE or HSE (UK). Petrobras shall be consulted in case contractor intends to use any other database. Database used shall be able to relate leakage proportion and occurrence frequency according with the equipment where the leakage occurs.
- In definition of Ignition Probability (immediate or delayed) shall be considered the correlations presented in ENERGY INSTITUTE, Ignition Probability Review, Model Development and Look-Up Correlations – UK, Section 2 (Look-up correlations) to offshore units. Each scenario shall be analyzed to determine the more applicable correlation to be used.

Note: The Study recommendations that can interfere in another study analysis, and these interferences shall be considered in the conclusion of the affected study, in order to validate the effectiveness of measures or proposed modifications.

5.4.4 METEOROLOGICAL DATA

Meteorological data such as the relative frequency of occurrence of wind speed and direction, temperature and air humidity shall be used as an input for risk assessment, and shall be according to the Metocean Data applicable to the Unit.

For each wind directions considered, at least the following speeds shall be analyzed in the consequence analysis:

- The most frequent, the speed with higher occurrence probability. This value must be simulated using numerical model of Computational Fluid Dynamics (CFD);
- The intensity of the calm weather condition, corresponding to 0.5 m/s, which should also be simulated with CFD;
- Other wind speeds obtained by interpolation from simulations of the more frequent speeds. In this type of analysis, the purpose is to characterize the consequences for the range size of gas cloud, degree of filling, etc. Thus, the amount of additional simulations can be reduced by measuring the speed modification impact on variables of interest.

5.4.5 LEAK RATES

Initial leak rate shall be calculated and classified into leak categories based upon the pressure, temperature and fluid composition for each scenario. The most probable leak rate of each category shall be applied.

The leak categories applied in safety studies shall be as follows:

- Small leakages: from 0.1 to 4 kg/s;
- Medium leakages: from 4 to 32 kg/s;
- Large leakages: from 32 kg/s to maximum flow rate.

At least two leak points identified for each scenario shall be analyzed, considering four leak directions. There must be at least one scenario with the leak direction against the prevailing wind direction.

In order to define the leak rates to be used in the simulations of the Gas Dispersion Study, a sensitivity analysis shall be performed for each system and subsystem. To do so, for a given point and direction of leakage, using the predominant wind, three or more leak rates shall be simulated, within the range of small leaks. Then, the leak rate values (among those simulated in the sensitivity analysis) that best meet the detection strategy will be obtained.

Scenarios where the leak and wind are aligned and directed outwards the installation don't need to be modeled. This assumption is valid only for leak points at the border of the facility.

To reduce the simulated cases, similar cases in a determined region can be grouped, considering the consequences in the leakage area, where different leak points will produce similar results. However, the project and risk reduction actions shall not be limited to the simulated cases, and other similar and not simulated points shall receive equivalent treatment of the simulated.

Cases grouped to reduce the number of simulations shall be documented.

5.4.6 GEOMETRY MODELING

Detailed 3D geometry shall be used to construct the analysis model. The Installation shall be modeled taking into account bulkheads, decks, pipes and equipment with dimension larger than 1.0 meter.

For pipes or other components with diameter lower than 6 inch, pipes or small pieces which could lead to localized blockage can be simplified with demonstrated justification.

5.4.7 GAS DISPERSION STUDY AND DETECTORS LOCATION

Gas Dispersion Study shall be performed to define the location of flammable, asphyxiant and toxic gas detectors, to be installed in open areas, as well as number of detectors, in order to that all simulated scenarios can be detected.

The study shall consider leak scenarios indicated in risk assessments, the voting logic and the detector type to be used.

The study shall consider, among other things, the following aspects:

- Determination of gas leakage points;
- Leaks occurrence frequency;
- Inventory and conditions of released gas;

- Simulation of gas dispersion process, using CFD model. Semi-empirical software as PHAST, EFFECTS and similar are not acceptable.

Release scenarios of condensate and/or hydrocarbon based refrigerant in Dew Point Control System shall be included in the scope of the Gas Dispersion Study.

METHODOLOGY

The study shall consider, at least, the following steps:

a) Leaks

Accidental scenarios considered in analysis shall be those from small leaks defined in Leak Rates item, however able to generate clouds at relevant concentrations. All gas leakage scenarios identified in qualitative risk assessment shall be included in the Gas Dispersion Study.

In FPSO case, piping accessories associated to vent post system shall be considered as leakage points for the gas detectors location.

Gas Dispersion Study shall consider all riser rupture scenario in the gap between inlet SDV and water and under water level that can lead to gas cloud formation reaching the FPSO.

b) Quantity and Properties of Gas

Review the inventory, thermodynamic and physicochemical characteristics of dangerous gases present in the Unit. Depending on the process conditions, leaks from high CO_2 streams may produce solids. In order to quantify and locate the detectors it shall be considered that all leaked mass is in gaseous phase.

c) Gas Dispersion Model

Dispersion analysis shall be realized through an appropriated CFD tool.

d) Design Criteria

Gas detectors number and location shall be based on tridimensional modeling for gases concentration. Detectors shall be positioned to permit detection of all selected cases.

For FPSOs, Gases Dispersion Study shall verify if there is interference of process vents with final location of gas detectors and, if necessary, propose a solution.

A safe location study for the slop tank vent shall be realized, evaluating flammable gas dispersion through the same CFD model used in detection system design. This Study shall also consider the possibility of non-stabilized oil in slop tanks resulting from accidental releases.

Non-stabilized oil refers to the worst process condition that may occur in the event of equipment failure. This condition must be specified by the process team and submitted to PETROBRAS.

5.4.8 GAS DISPERSION STUDY FOR VENT POST LOCATION

A study for vent post location shall be performed, evaluating flammable gases dispersion through the same CFD model used in detection system design. Vent Post dispersion Studies shall consider the real composition of fluids sent to cargo tanks. If there is any additional scenario that the vent post study should consider, it shall be informed, as well as the properties of its currents. This study shall ensure that exhaust discharged gases do not interfere with Gas Detection System of Unit and do not increase the risks for personnel. In addition, the impact of vented gases on main safety functions such as air intakes of firewater pumps, temporary refuges or areas provided with lifesaving appliances located at the bow of Unit, among other, shall be evaluated.

5.4.9 GAS DISPERSION STUDY FOR EXHAUST GAS

Gas dispersion analysis shall be developed for exhaust discharges from machinery such as: internal combustion engines (such as FWP, auxiliary and emergency generators) and turbines for driving generators and compressors, to check their interference on the air intakes, in order to avoid contamination of indoor environments and also to check other places of the Unit where there are risks to people, such as intoxication, suffocation or burns. The study shall provide alternatives for proper positioning of the chimneys, whenever identified risk situations as mentioned above.

It shall be considered specific discharge rates for the various operating conditions of each equipment.

In order to evaluate the simulation of vented gases and the exhausted gases from internal combustion engine discharge dispersions, gas clouds shall be simulated in the directions of air intakes and manned locals. Additionally, in case of the existence of gas clouds that may interfere with the Unit's gas detection system, a recommendation for new coordinates position (x,y,z) for vent and/or engine discharges shall be made.

5.4.10 EXPLOSION STUDY

Overpressure levels in Main Safety Functions and Relevant Safety Items shall be calculated, providing blast overpressures on surfaces, dynamic pressures and duration of equivalent triangular pulse. Based on these results, it shall be checked the impact of loads on Main Safety Functions and Relevant Safety Items and providing, when necessary, measures to maintain their integrity.

Explosion analysis shall be developed with the use of CFD tools that uses finite volume meshes and porosity to conduct the simulations.

The software approved by Petrobras are: KFX (Kameleon) and FLACS. Other software shall be previously authorized by Petrobras before being used in the simulations.

METHODOLOGY

Scenarios shall be defines according to item 5.4.3.

The main study phases are described below:

a) Geometry Modelling

The geometry shall be in accordance with item 5.4.6 Geometry Modeling.

b) Leaks

Leak flow rates considered shall be according to item 5.4.5 Leak Rates. In case of high leak flow rates, resulting in large areas with concentration above the UEL, a lower leak flow rate shall be used and / or higher wind speeds that may produce an ignition condition.

The contribution of gas detection, ESD and blowdown shall be considered in the explosion study.

c) Ignition assessment

Ignition probability shall be as described in item 5.4.3.

Different ignition points in the same module or area, generating different accidental scenarios, shall be considered.

Ignition probabilities have to be calculated for each leak category, and shall be recorded.

d) Event Tree

Explosion and fire scenarios shall be represented in an event tree, where the values of each event must be indicated in terms of frequency or probability of occurrence and final value of frequency of occurrence of each accidental hypothesis (jet fire, pool fire, explosion, flash fire ...). The event tree shall be complemented with events of direction of leak, direction and wind speed and others considered relevant for analysis.

The event trees shall be elaborated for all the scenarios defined according to item 5.4.3. The event trees shall be included in the study report with the frequency results of all accidental hypotheses, highlighting the values corresponding to the explosion hypotheses, object of the study. The results shall be included in an annex to the report, preferably in a table format.

e) Segmentation and Inventory Calculation

The representative segments of HAZID/PHA and additional scenarios shall be considered in the study.

These segments shall be considered for the counting of leakage elements, leakage frequencies and hydrocarbon inventories calculation, according to the criteria established in this Safety Guidelines.

All those segments shall be cleared identified in the respective process documents (P&IDs, PFDs, isometric, etc) and shall be registered in a report annex. In addition, a table containing all information described above shall be provided.

f) Explosion Modeling

Scenarios shall be selected with variation in cloud sizes, cloud location, and ignition location. Results in terms of pressure and drag on panels and monitoring points in the area should be obtained for each scenario. Monitoring points to be located at the points of highest expected overpressure (congestion areas, close to blockage points…).

Figures showing the distribution of the explosion overpressure contours in different time steps shall be presented. It is important to identify the panel and the monitoring point positions in which the higher overpressures take place, explaining the reasons for the pressure increase.

Note: Panel refers to monitoring planes created in the CFD software where the total load shall be calculated. Monitoring points represent the localized pressures. Panel and monitoring points have different applications for structure design.

g) Explosion Assessment

An approach shall be applied which gives as results, curves showing the yearly frequency as a function of the explosion overpressure (pressure exceedance curves). Input shall consist of results from the CFD analysis in terms of ventilation rates, transient cloud size and explosion overpressure obtained from results from ventilation, dispersion, and explosion simulations. Probability distributions of the dependent variables shall be applied as input to the probabilistic assessment. Wind probability is obtained from the wind rose, and the leak frequency shall be developed from equipment count in combination with statistical leak data.

The explosion study recommendations shall consider the results of fire propagation analysis.

The DAL against explosions for the Main Safety Functions and Relevant Safety Items shall be presented as pressures (overpressures and dynamic pressure) exceedance curves and corresponding triangle pulse duration. If necessary, reduction of overpressure shall be preferentially achieved with frequency reduction, geometry changes instead of structure reinforcement. For that reason, it is recommended to identify the factors which are interfering mostly in the results.

Blast load verification shall cover the foundation and also equipment supporting structure such as saddles, skirts, racks for the equipment containing hydrocarbon.

Flare system including the blowdown valves and piping from the hydrocarbon inventory vessels to blowdown valves, shall also be covered in the blast loads verification.

Areas such as riser balcony, riser pipe rack, central pipe rack and main deck shall also be assessed.

STRUCTURAL ANALYSIS

The structural analysis shall be performed considering the values of explosion loads (DAL) obtained in this study. The structural analysis shall demonstrate that, for each Main Safety Functions and Relevant Safety Items, the accidental loads from explosion assessment were considered besides that normally considered in the design of the structures.

The performance standard criteria to be considered in the structural analysis as a result of the explosion loads (DAL) must be in accordance with ISO 13702, complemented by the following functional criteria:

- Structures of accommodations, modules, pipe racks and rooms / areas that contain Main Safety Functions and Relevant Safety Items shall not undergo permanent deformation, with the exception of the case where ductility level analysis (DLB) is used for the structural analysis. In which case, additional analyses shall be provided, as described in the structural blast assessment methodology, in order to comply with the safety performance criteria presented.
- Closing panels, floors, ceilings, and decks of the rooms / areas that contain Main Safety Functions and Relevant Safety Items may suffer permanent deformation, but they cannot fail / break or lose function.
- Supports of equipment and lines containing hydrocarbons shall not undergo permanent deformation or deformation in an elastic regime that may lead to the failure of such lines and equipment, in order to avoid uncontrolled fire propagation.
- Embark stations, lifeboats and other lifesaving embarkations shall remain intact and functional after the effects of explosion. These areas must be protected by bulkheads to prevent damage to embarkations and people.

- Lines and equipment of firefighting systems (water and foam) and deluge valves panels shall remain intact and functional.
- The escape function of all areas must be guaranteed. In this way, the explosion dimensional scenarios cannot cause simultaneous impediment of the existing escape routes.
- The area over cargo tanks on the main deck and risers area must remain intact.
- The unit's isolation system (SDVs) and depressurizing system (BDVs) must remain intact (tubing, brackets, valves, drum and flare tower).

Where blast walls are used in the design, they shall be duly calculated and certified for this purpose so that they can be considered as protection barriers, having their characteristics duly described in the report, and having their locations indicated in Unit Safety Plan.

The structural blast assessment is based in the methodology and criteria from API RP 2FB standard (screening check, strength level analysis and ductility level analysis) and the design requirements for Accidental Limit States (ALS) according to ISO 19900 and ISO 19904, as described below.

According to ISO 19904, the representative value of an accidental action shall correspond to a value with an annual probability of exceedance equal to 10−4. The primary and secondary structure shall be able to comply with the adopted criteria for the 10-4 blast event. API RP 2FB addresses the use of two levels of explosion loading for blast checks: SLB, related to operational continuity and DLB, related to survival of the platform. A conservative screening analysis may be performed to assess the robustness of the structure. If the structure is not able to comply with the criteria from the Screening Analysis, both Strength Level Analysis and Ductility Level Analysis shall be performed and complied with the respective acceptance criteria.

For the structural blast assessment, the following methodology shall be complied:

1) SCREENING CHECK: This criterion will provide an idea of the robustness of the design for explosion. The premises of structural modeling and analysis of SLB (or more conservative) shall be used in the screening analysis. For the screening check, the overpressure associated to DLB shall be used together with an utilization ratio of 1.0 in order to avoid permanent deformation. Dynamic strength increase factor and dynamic

increase factors may be used. Allowable stresses for Accidental Limit State shall be used. The analysis might be dynamic or static including dynamic amplification factors to consider the dynamic effects. The design checks shall address both primary and secondary structure. If primary and secondary structure passes the checks with DLB overpressure, the verification can be stopped and no additional analyses (SLB and DLB) are required.

2) STRENGTH LEVEL ANALYSIS (SLB): This criterion is related to operational continuity and will provide an idea of the robustness of the design for explosion. The structural members are permitted to experience member utilization ratio up to 1.0 in order to avoid permanent deformation, according API RP 2FB. Instead of allowing increase in utilization factors, structural reserve shall be exploited only with the DLB analysis. As stated in API RP 2FB this utilization factor is consistent with overpressure as 1/3 of the DLB overpressure. It should be noted that the 1/3 reduction factor is applicable only in primary structure and it is related to absorption of blast loads by the secondary structure, barriers, cladding and plate (see UKOOA FIRE AND EXPLOSION GUIDANCE) and, if considered, the premise shall be confirmed by the DLB analysis for both primary and secondary structure. Additionally, dynamic strength increase factor and dynamic increase factors may be used. Allowable stresses for Accidental Limit State considering buckling and yielding checks shall be used.

3) DUCTILITY LEVEL ANALYSIS (DLB): This criterion is related to the survival of the facility. The Ductility Level Analysis shall be performed with the overpressures associated with an exceedance probability of 10−4 per year, according to ISO 19904. Permanent deformation may be acceptable for the DLB as long as the following safety performance criteria are demonstrated:

a) there is no sudden or progressive collapse of the overall topsides structure;

b) Safety Critical Equipment (SCE) shall remain intact (deflections and acceleration of the structure shall be taken into account in order to avoid escalation);

c) there is no structural damage that significantly affects subsequent fire endurance;

d) plastic strain shall be limited to 15% for the base material and 5% for welds.

The design checks shall address both primary and secondary structure.

5.4.11 FIRE PROPAGATION STUDY AND SMOKE DISPERSION ANALYSIS

The study shall consider the fire scenarios and their propagation possibilities, as well as their consequences in the structure integrity, impacts in the Main Safety Functions, Relevant Safety Items and location of safety equipment, providing recommendations that privilege an inherently safer design.

The study shall evaluate if there are any scenarios that can simultaneously impact all main escape routes and shall determine the frequency associated to this impact. To avoid these scenarios, a design solution shall be implemented.

Additionally for each fire scenario shall be performed a smoke dispersion analysis using CFD in order to evaluate the impairment of escape function, embarkation stations and muster station. This study shall present cloud concentration as a function of time, checking the radius of visibility and breathable atmosphere.

Impairment criteria shall foresee visibility above 3.0 m and breathable atmosphere. See ANNEX VI as reference for additional impairment criteria.

For the purpose of structural PFP indication, a failure of a structural element means any failure that could lead to fire propagation or escalation, and not only a structural collapse (disruption of beams).

METHODOLOGY

Fire Propagation Study shall comply, at least, with the following phases:

a) Determination of Flames Characteristics

Identification of main thermophysical characteristics of each type of fire, analyzing different characteristics of flames derived from gas and oil fuels, as follows:

- Jet Fire

Flames dimension and geometry shall be calculated through CFD model. Initial leakage flows for each range shall be simulated. Immediate ignition shall be considered and flame properties variation with time shall be included in calculations.

- Pool Fire

Oil leakage flows analyzed shall produce evaporation rate equivalent to leak rates. In case of pool fire, flame dimension can be determined by CFD model or semi-empirical models.

b) Determination of Incident Radiation

For each selected scenario shall be calculated the incident heat flux in structure elements, pipe-racks and others equipment, as a time function.

c)Calculation of Structure Temperature Distribution

For each selected fire scenario shall be calculated resulting temperatures, and shall be presented a temperature distribution in each Unit point over the time. This analysis shall consider material properties variation and heat exchanges as a function of temperature variation. The study shall calculate total heat flux in the following points:

- Structural elements (including pipe-racks and others mains support structural elements);
- Equipment;
- Main Safety Functions;
- Relevant Safety Items.

d) Fire Propagation Analysis

The possibility of fire propagation to others equipment or piping, with consequent escalation, shall be verified. Analysis shall be evaluated with or without water spray system.

e) Fire-Structure Analyses

The objective of this analysis is to evaluate the behavior of the structure considering the mechanical loading of the structure plus the thermal loads of incidental fire and to define which structural elements should be protected, the type and the extent of PFP necessary and sufficient to guarantee the integrity of the elements, based in the collapse criterion established. The type of protection should be in accordance with the scenario that leads to structural collapse: pool fire or jet fire. The protection specification time shall meet the minimum duration of the scenario that leads to collapse.

The structure of the Unit shall be analyzed using a finite element model, based on three-dimensional, non-linear analysis, integrating thermal and mechanical loads. Mechanical loads shall be applied before the start of the fire to represent the normal operating condition of the Unit. The thermal loads must be applied transiently to represent the evolution of the fire over time, for 60 minutes.

Elastoplastic analyzes shall consider scenarios whose temperature in the primary structures reaches values higher than 450 ° C.

In the case of the main structural elements that can be directly impacted by jet fires, with sufficient duration and intensity to promote their collapse, the PFP shall be applied to the entire extent of the collapsed element, without disregarding the impact on the other structures.

In addition to the primary structures, the support structures of modules and pipe racks, responsible for supporting equipment and lines containing hydrocarbon inventories, shall also be subjected to elastoplastic analysis, if the temperature in the primary structural elements, including columns and beams, exceeds the 450°C.

The requirements stated in I-ET-3010.00-1300-140-P4X-003 – FIRE-STRUCTURE ANALYSES FOR PASSIVE FIRE PROTECTION DESIGN can be used as a reference for methodology and calculation. See ANNEX VII for reference.

f) Collapse Analysis

The collapse analysis shall be evaluated according to the temperature increase, globally, to contemplate the redistribution of stress, locally, so as to allow the preservation of the structural items listed below:

- Main structural elements shall not be subjected to permanent structural deformations (flow);
- Secondary beams and columns (which are not part of the main structural elements) can only be subjected to the flow condition if the failure does not cause the collapse of other main structural elements, based on the effect of the redistribution of stress;

- Structural elements supporting piping connected to safety systems (depressurizing, firefighting, emergency generation etc.) and equipment and / or piping containing high inventory of hydrocarbons (production separators, oil dehydrators, etc.) shall be preserved, to prevent failure and ensure the integrity of the safety systems support as well as the integrity of pipes and equipment. The analysis of collapse shall consider stress, deformation, buckling and excessive displacements.

5.4.12 DROPPED OBJECTS

A safety study focusing on the risk caused of dropped objects on the deck and overboard from lifting operations during the operational phase shall be prepared. It shall assess the effects of dropped and swinging loads to topsides process equipment, the deck, piping, subsea risers and gas export pipeline (keel-hauling), and propose mitigating measures, where needed.

This study shall also verify the impact of dropped objects on Main Safety Functions and Relevant Safety Items, aiming to identify if these impacts occur with a frequency below the acceptance criteria.

Additionally, a detailed analysis shall be provided for the riser balcony area, in order to verify the occurrence frequency of dropped objects impact in this specific area of the Unit.

5.4.13 SHIP COLLISION

A safety study focusing on the risk caused by a Ship Collision shall be prepared. This study shall analyze the following collision scenarios:

- Collision caused by a supply vessel during normal operation in the supply vessel mooring area (including fairleads);
- Collision caused by a passing vessel (supply or oil tanker) at cruising speed;
- Collision caused by shuttle tanker during the offloading operation, considering the peak offloading frequency.
- Additionally, the study shall consider the following aspects:
- The potential ship activity in the Installation area, considering pull-in, pull-out, and special operations;

- Assess the consequences of ship impacts and determine the potential for damage to the vessel and ancillary items, the risk to personnel and/or the environment;
- Assess the likelihood of collision;
- Identify and record mitigating measures for the reduction of ship collision risk.
- Evaluate the impairment of Main Safety Functions and Relevant Safety Items, when applicable.

5.4.14 EVACUATION, ESCAPE AND RESCUE ANALYSIS

The design shall include evacuation, escape and rescue strategy as required by ISO 15544.

An Evacuation, Escape and Rescue Analysis (EERA), using the results of the Consequence Studies shall be carried out to develop the Evacuation, Escape and Rescue Strategy.

EERA shall examine the proposed provision of escape routes, evacuation facilities and facilities for rescue of personnel from water to ensure that:

- There are no incidents that could lead to entrapment of personnel, no single incident can impair all escape routes from an area;
- The provisions are in compliance with ISO 13702;
- The provisions are adequate to keep the risks to personnel as low as practicable.
- In case of process systems with high CO_2 content and high pressure, EERS shall consider its effects and consequence on people and main safety functions.

EERA shall consider all process deck, accommodation, Pump Room and any other enclosed spaces where the presence of personnel is expected. The location of diving areas shall be considered in the EERA.

EERA shall consider the possible occurrence of a toxic and flammable gas cloud on the escape routes near the exhaust exits of the Pump Room. The project shall present alternatives to reduce the impact on people on these escape routes, considering the transient development of the gas cloud from the exhaustion of the Pump Room.

The time necessary to reach Unit Muster Stations and Embarkation stations shall be evaluated, considering the accidental scenarios evaluated in the safety studies, additional difficulties due to specific operations (e.g. cargo tank cleaning and diving operations) and aligned with EERS.

5.4.15 SAFETY INTEGRITY LEVEL (SIL)

The decision of using Safety Instrumented Systems (SIS) in accordance to IEC 61508/61511 shall be evaluated by contractor taking into account the associated risks, the risk tolerability criteria, proper risk tool analysis and Classification Society requirements.

In case of using SIS a Safety Integrity Level (SIL) determination review shall be carried out during the Unit life-cycle, according to IEC 61511-1.

5.4.16 HUMAN FACTORS ENGINEERING (HFE)

Human factors engineering design principles shall be applied during the design. The OGP Report 454:2011 may be considered as a reference.

5.4.17 CO_2 HIGH CONTENT GAS LEAKAGE - EMBRITTLEMENT STUDY

The study shall evaluate the scenarios of medium and large leakages of flow streams of CO_2 contents (60% molar of CO_2 and pressures greater than 50 bar) with risk of embrittlement of structural elements, equipment and their supports, 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), 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 Main Safety Function with a temperature below -40 ° C (or other temperature according to the material test data, if exists).
- 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. The frequencies of the failure scenarios shall be added-accumulated and the result compared to the tolerability criteria defined in item 5.3.
- For the evaluation of equipment supports that contain combustible / flammable and / or toxic fluids, 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 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.
- If the frequency of impairment exceeds the tolerability criteria, indicate passive cryogenic protection.

SOFTWARE REQUIREMENTS

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

- Using software with modeling methodology based on experimental data, validated by Petrobras, eg 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.

METHODOLOGY

Scenarios shall be defined according to item 5.4.3. The study shall consider the accidental scenarios identified in the PHA that involve thermal effects by CO_2 high content gas leakage.

In addition, systems that has flow streams whose composition contains more than 60% molar of CO_2 and pressures greater than 50 bar, fit as scenarios to be considered in the analyzes.

a)Embrittlement Analysis

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

- Floors and stairs made of composite material belonging to the escape routes shall be assessed, so that the temperatures for the simulated CO_2 embrittlement scenarios can be evaluated to verify the resistance of the materials to these temperatures. 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. 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: the protection of BDVs must 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, must 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) shall be evaluated for impact by CO_2 embrittlement scenarios due to leakage from the areas served by them. The impairment of local manual action shall be assessed. If the limit is exceeded, the change in the position of the impacted ADV or other mitigating measure shall be reassessed.

b)Structural Analysis

The structural analysis should consider the elements of each scenario of leakage 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.

6. SAFETY REQUIREMENTS FOR ELECTRICAL SYSTEMS

6.1 EMERGENCY ELECTRICAL POWER SOURCE

Provision shall be made for a source of electrical power to operate under emergency conditions (Emergency Generator) after a breakdown of the main generation system. It shall be sized so as to meet essential safety requirement services (Emergency Services); the following Safety Consumers shall remain energized:

- Davits for lifeboats and rescue boat;
- Essential lighting;
- Helideck lighting;
- Air obstacle lighting;
- Ventilation/exhaustion of rooms containing safety essential consumers, as electric motors, switchgear, MCC, UPS, battery chargers, telecommunication or emergency / essential panels room, among others to be defined during design;
- Flare ignition panel;
- Battery chargers and UPS that feed emergency consumers;
- Control and auxiliary systems of the essential consumers such as: well controls, fire pumps (water and foam), emergency generators air compressor;
- Fire Pump – water and foam (if electric);
- Water mist pump (if applicable);
- Floodlight for lighting life-saving craft launching area;
- Search light;
- Uninterrupted Power Supply (UPS);
- Stand-by air-conditioning system of CCR, radio and telecommunications rooms;
- Gas turbine enclosure ventilation fans (at least one fan for each hood);
- Valves actuation hydraulic system power pack (HPU);
- At least one ballast pump (only for semi-submersible units) and one bilge pump;

- Nitrogen generator to purge the closed flare, if applicable;
- At least one sea water deck seal pump (for inert gas system);
- The exhaust fans and stand-by fans of the Pump Room;
- The remote control system of the load system valves (to enable inventory isolation action);
- The bilge level monitoring system of the Pump Room;
- The emergency drain system of the Pump Room.
- Other essential consumers for naval systems, when applicable, defined by classification society, or if defined and justified during design phase.

Notes:

1) If the Unit is equipped with instrument air compressors driven only by electric motors the powering of those electric motors by emergency or auxiliary power generators shall be considered. Only one compressor shall be considered for the dimensioning of the emergency power generator.
2) The design of the emergency generator shall consider the simultaneous operation of a number of ballast pumps corresponding to 50% of the required capacity of the ballast system (only for semi-submersible units).
3) Electrical Fire Pump shall have dual powering (main and emergency).

6.2 UNINTERRUPTIBLE POWER SUPPLY (UPS)

Systems requiring independent battery back-up power supplies, to keep permanently energized all essential emergency consumers, that remain energized even in the period between the blackout of main electrical generator and subsequent start of emergency generation, shall include as a minimum:

- Gas/fire detection system — 30 minutes
- Firefighting system — 30 minutes
- Emergency shutdown system — 30 minutes
- Emergency lighting — 30 minutes (See Note)

- Navigation lighting and Foghorns 96 hours
- Telecommunications and inter communicators 30 minutes
- Public Address/General Alarm 30 minutes
- Equipment of the CSS related to safety system and process control 30 minutes

Note: Design shall provide 12 hour autonomy only for emergency lighting of the area considered essential for maintenance of personnel on board during this period, such as: switchboard of the emergency and auxiliary power generators; muster station, embarkation stations, CCR.

6.3 ELECTRICAL CABLE PROTECTION

Electrical cables, data cables, communication system cables, signal cables (network, optical fiber, etc.) that feed essential and emergency services that are installed in Hazardous Areas must be specified as fire resistant. As an alternative to the requirement to be fire resistant, these cables may be routed through two distinct routes where possible. The routing definition should consider that a fire risk scenario does not reach the two routes simultaneously.

6.4 AREA CLASSIFICATION

The classification of areas shall comply with the requirements of IEC 60092-502, IEC-61892-7 Standards and API RP 505. When standards present different solutions, the most restrictive solution shall be adopted, e.g. the solution that results in a larger classified area and classified with higher risk rate (zone).

Note: The IEC 60092-502 shall be applied to ship part of FPSO. The IEC 61892-7 and API RP 505 shall be applied to production plant hazardous area classification and the most stringent requirement must be applied. The volume between main deck over cargo tanks and topside lower deck shall be classified as Zone 1 hazardous area.

Any electrical equipment in open areas that shall remain energized during an emergency shutdown shall be certified for installation in Zone 2 Group IIA, T3.

7. SAFETY REQUIREMENTS FOR PRESSURE RELIEF AND DEPRESSURIZATION SYSTEMS

The Unit depressurization system shall comply with requirements of API STD 521.

For providing the safeguarding of persons and assets from hazards arising from exposure to lightning, the vent and depressurization system shall comply with requirements of NFPA 780.

The activation of the de-pressurizing system shall be possible from the CCR or locally, as well as when the abandon shutdown push button is activated. For more details see Annex IV.

The project of the de-pressurization system of the Unit that operates with oil at temperatures above 100ºC shall take into considerations the steam explosion phenomenon for definition of the control devices.

8. SAFETY REQUIREMENTS FOR HVAC

For compartments where the inside equipment handle hydrocarbons, the minimum HVAC air renovation of closed or semi-open areas shall comply with 12 renovations of air per hour.

In addition to the above, the battery room ventilation shall comply with the requirements of IEC-61892-7 and the specific guidelines of the Classification Society, whenever applicable.

The HVAC for the battery room shall also provide a number of air volume exchanges so as to guarantee the dilution of hydrogen to levels under 4 % LEL according IEC 61892-7 and shall have two (2) exhausts at 100 %. The interlocking shall comply with item 4.2.

For the ventilated type battery system and inert gas generation room beside the above mentioned a minimum of 30 air volumes exchange per hour shall be considered.

The air admission inside the battery room shall be located close to the compartment floor and the exhaust shall be located close to the ceiling so as to avoid the formation of hydrogen gas pockets near the room’s ceiling.

In case of loss of main ventilation of classified areas, the stand-by ventilation shall be automatically started up.

The HVAC for essential service rooms shall be provided even in case of trip or failure of the normal ventilation systems. The essential service rooms are as follow:

a) Radio room;

b) Utilities or Process Control Room;

c) Room where critical equipment such as Programmable Logical Controller (PLCs), Fire and Gas Detection Panel, etc are installed;

d) Battery Room of the Emergency Systems;

e) Battery Charger Room of the panel and transformers of the Emergency Systems;

f) Cargo and Ballast System Control Room;

g) Navigation and Dynamic Positioning (Bridge) Equipment Room;

h) Telecommunication Equipment Room.

The HVAC systems shall not connect the following compartments:

- Battery room and laboratories exhaust with risk of contamination with other compartments;
- Rooms with different hazardous area classification of electric equipment installation;
- CO_2 battery rooms and areas protected by CO_2 firefighting systems with other compartments not protected by this system.

Requirements for Material, Painting and Support of ventilation ducts (intake or exhaust) shall comply with the Classification Society and SOLAS Chapter II-2-16 criteria.

Closed areas with openings less than 3 meters away from the limits of classified areas for electrical installations shall be provided with monitored positive pressurization.

The operational conditions of the mechanical ventilation system and the air conditioning system shall be continuously monitored and any failure shall activate a remote signal in the CCR.

Closed areas that contain sources of combustible gases or vapors shall be provided with a pressure level lower than adjacent areas.

For confined areas as generator hood, CH_4 detection shall start stand by fan of ventilation system at 10% of LEL without shutdown the operations of the fans that are working, to increase exhaust air exchange rate. At 15% of LEL (at exhaust ventilation outlet or inside the confined area) shall:

- Initiate an audible and visual alarm in the CCR;
- Shutdown affected equipment and fuel supply when applicable;
- Depressurized the fuel gas supply piping located inside the affected confined area.

For Pump Room, the following requirements shall be considered:

- The number of air changes shall be at least 20 per hour, according to SOLAS;
- The exhaust fans shall have redundancy;
- Ventilation with under-pressure in relation to adjacent less hazardous locations; shutdown of ventilation shall initiate an audible and visual alarm in the CCR;
- Fixed gas detection system to ensure monitoring gas concentration @ 10% LEL for alarm and 50% LEL for emergency shutdown actions;
- Detection of gas concentration @ 10%LEL shall initiate an audible and visual alarm in the CCR and start the stand-by fan of the ventilation system without shutting down the operation of fans that are working, to increase the exhaust air rate.;

Gas confirmed @ 50%LEL (2ooN):

- Shall initiate an audible and visual alarm in the CCR, Pump Room and Engine Room;
- Shall initiate Emergency Shutdown (Gas Confirmed), and maintenance of stand-by exhaust fans in operation. The stand-by exhaust fans shall be suitable to remain in operation after the shutdown of main generators.

All external air intakes shall have devices to prevent gas admission into the protected areas. These devices can be fire dampers or shut-off/gas tight dampers. The damper installation shall comply with SOLAS, MODU CODE and the Classification Society requirements.

Air intake of the VAC shall come from a safe area located at least 3.0 meters away from classified areas and 4.5 meters away from the exhaust of the ventilation systems, from combustion gas discharge and from vents.

The areas protected by CO_2 system shall have gas tight dampers, to ensure tightness in the ducts and/or on the ventilation openings of the rooms, so as to prevent CO_2 leakage and maintain the bulkhead integrity level.

Wherever classified fire bulkheads are penetrated by ducts, fire-proof dampers shall be provided in accordance to SOLAS. The fire damper's panel shall be installed on the opposite side from the area of fire risk as determined by SOLAS.

9. SAFETY REQUIREMENTS FOR LAYOUT

The layout shall consider among others aspects, the following:

- Segregation of hazardous areas from non-hazardous areas;
- Maximize equipment installations in open areas with natural ventilation;
- Analysis of FPSO mains deck, providing that the piping layout, equipment layout and deck support structure design do not compromise the efficiency of the ventilation, the firefighting system and the escape routes of the cargo deck;
- Minimize fire or explosion consequences;
- Provide escape means for the evacuation and abandonment;
- The results from the Fire Propagation and Explosion Studies.

SDV valves shall be installed in full access and safe locations, where not impaired by fire originating in other areas. When this is not possible, the risk shall be assessed in the fire propagation study and respective mitigations measures shall be applied.

The riser inlet / outlet SDVs should preferably be installed horizontally across piping and transverse direction to the Unit in order to minimize the fire scenarios directed to the inside of the Unit and those that may lead to impairment of escape routes. In the case of adopting the vertical position for the riser inlet/outlet SDVs, firewall shall be provided, in addition to the other protections. Other solutions instead of adopting firewall, shall be certified by Classification Society and approved by Petrobras.

The bulkheads of the fire-fighting water pumps compartment shall be at least "A0" class. Wherever the adjacent areas contain equipment handling flammable or combustible fluids the bulkhead class shall be upgraded according to the fire propagation study.

No tanks or vessels interconnected to oil, gas or water process shall be located inside enclosed rooms, regardless of the provision of any other international criteria, standards, rules, or regulations.

9.1 ESCAPE ROUTES

The Unit shall be fitted with primary and secondary escape routes and these shall always be obstacle free, painted, indicating escape directions and comply with the following specifications:

- Primary Route: shall be at least 1.2m wide and 2.1m high;
- Secondary Escape Route: shall be at least 1.0m wide and 2.1m high.

Rooms with central batteries of CO_2 cylinders, rooms protected by fixed CO_2 firefight system and rooms with inert gas generators shall have at least two access doors, where, at least, one shall open for the external area and the others, for rooms not protected by CO_2. When one of the doors cannot access the external area, two doors shall give access to rooms/internal areas not protected by CO_2.

Escape routes shall enable stretcher carrying an injured person to pass, held by two attendants.

9.2 TEMPORARY REFUGE

The Primary TR shall be integral to the Accommodations and shall be designed such that personnel are protected from the effects of fire, explosion blast overpressure, and smoke for an endurance period associated with the duration of the hazardous event or time required for complete evacuation. Adjacent structures which could collapse onto and significantly damage the TR or its systems, or could obstruct escape and evacuation routes shall also be evaluated.

The primary muster station(s) shall be inside the Primary TR and be sized to accommodate the maximum POB. The Primary TR shall also have command and support functions including:

- Internal and external communications;
- Activate general alarms;
- Monitor fire/gas system;

- Visually monitor escape and embarkation station (CCTV);
- Emergency lighting;
- Initiate ESD, emergency depressuring and deluge.

HVAC sizing shall consider TR congestion and personnel density during muster. Air locks/lobbies shall be incorporated at Primary TR access/egress doorways to the external environment so as to prevent smoke ingress and maintain the Accommodations interior at a positive pressure in the range of 0.25 mBar - 0.65 mBar with respect to atmosphere at design wind speed and direction. The Primary TR shall be smoke-tight with dampers to provide a smoke-free environment inside.

Normally manned buildings are defined as those buildings that experience at least 175 man hours/week of total occupancy, or buildings where an individual can be expected to spend 25% or more of their working hours.

The Primary TR and other normally manned buildings shall be designed according impairment tolerability criteria and loads predicted by the Fire and Explosion Analysis.

Penetrations, windows and doors to the Primary/TR shall meet the fire and blast ratings of the wall in which they are contained.

In case of the Fire and Explosion Analysis defines a necessity of a Secondary TR shall be provided at the forward part of the FPSO.

All practical measures should be taken to avoid having to establish a secondary TR on the FPSO, as this would place an additional burden on TR facilities and installation management. Such measures include steps to mitigate the effects of incidents and/or the provision of alternative escape and evacuation routes.

If required, Secondary TR shall be able to accommodate all individuals potentially isolated from the primary TR according to the Emergency, Escape & Rescue Assessment, plus a contingency. The contingency shall be individually determined for each case, considering the margin of error in the anticipated numbers.

The Secondary TR shall comply to DAL reported in the Explosion Study and J60 for fire exposure. The Secondary TR shall provide direct safe access to a davit launched life raft. The Secondary TRs essential command support functions shall provide:

- Means of communicating with the Primary TR;

- Means of monitoring conditions on the designated evacuation route, which may be done visually.

The Primary TR shall comply with the following:

- ISO 13702 – Control and mitigation of fires and explosions on offshore production installations – Requirements and Guidelines;
- ISO 15544 – Offshore production installations – Requirements and guidelines for emergency response;
- ISO 15138 – Offshore production installations – Heating, ventilation and air-conditioning.

The Secondary TR shall comply with the ISO 13702 and ISO 15544. In case of Secondary TR impairments from smoke or gas, the ISO 15138 requirements shall be assessed based on Evacuation, Escape and Rescue Strategy.

10. SAFETY REQUIREMENTS FOR INERT GAS SYSTEM FOR CARGO TANKS ON FPSO

The Unit shall be provided with an inert gas system for protection of cargo tanks on FPSOs. Inertization using fuel gases in the cargo tanks shall not be accepted.

The location of the Vent Post of the cargo tank system shall be defined after a Gas Dispersion Analysis considering the effects of combustible, asphyxiant and/or toxic gases in order to avoid interference with the gas detection system and the risks for personnel.

11. SAFETY REQUIREMENTS FOR PUMP ROOM

Design should preferably provide deep well pump systems. If not achievable the design should comply with SOLAS requirement. Fire and gas detection executive actions shall follow Annex I and II and Safety Requirements for HVAC item. Additionally the following risk reduction design measures shall be adopted:

11.1 VIBRATION MONITORING

Fixed vibration monitoring equipment shall be provided on all centrifugal cargo pumps. The equipment should include a remote alarm facility. Consideration should also be given to monitoring other rotating elements within the Pump Room, such as ventilation fans.

11.2 CARGO PUMP LEAKAGE DETECTION

All centrifugal cargo pumps shall be equipped with a double seal arrangement designed to contain any leakage from the shaft seal and to provide remote alarm indication of its occurrence.

Alternative pumps for transfer of hydrocarbons must have their discharge protected by interlocking and alarm systems.

11.3 CARGO SYSTEM DRAINING ARRANGEMENTS

Cargo systems shall be provided with a comprehensive stripping arrangement to enable all lines and pumps to be effectively drained to a cargo tank, slop tank or dedicated reception tank for subsequent discharge ashore.

Any equipment located at upper levels of the Pump Room that handle hydrocarbons must have a basin for oil spill containment and a drain to send the oil to the bilge well located at the bottom of the Pump Room.

Stripping pumps shall not be the only mean of Pump Room drainage. In addition, one of two solutions shall be adopted:

a) Use of a dedicated emergency bilge pump with hydraulic or pneumatic compatible drive for Zone 1, suitable for operation in the case of a confirmed gas Emergency Shutdown (ESD-3P) and are only driven by the CCR. In the event of a hydraulic drive, the HPU must be installed in a safe location outside the Pump Room. The dedicated emergency bilge pump must be operated by the CCR and must not be automatic;

b) Use of an eductor operated by a salt water pump external to the Pump Room, subject to remote operation.

To calculate the proper drain flow rate of the Pump Room, a leakage equivalent to 10% of the rated operating flow of the stripping pump(s) shall be considered.

The downstream line of the dedicated emergency bilge pumps shall be independent of the cargo system and aligned to the slop tanks.

The design shall present the calculation of the Pump Room drainage system. This calculation shall confirm the efficiency of the drainage including the equipment located in upper levels of the Pump Room. It shall also evidence the calculation for determination of the flow and pressure of the of emergency bilge system.

11.4 REMOTE MONITORING

In order to minimize Pump Room entry, further consideration needs to be given to the possible benefits to be obtained by installing a comprehensive remote surveillance system.

11.5 EXHAUSTS ARRANGEMENTS

The arrangement of the discharges of the exhausts fans of the Pump Room shall be according to item 5.4.1, Ch.II-2, Reg. 4 of IMO SOLAS and item 1.2 of Chapter 3, Part 4 of Circular Letter 1321 of the IMO.

11.6 GENERAL REQUIREMENTS

The location of the steam control valves (when applicable) to drive the stripping pump shall be located in the engine room.

The set point of the relief valves of the alternative oil transfer pumps shall be less than the maximum allowed work pressure (MAWP) of the discharge lines.

A second independent safety device shall be installed to prevent the overpressure in the discharge of the alternative oil transfer pumps that are installed in Pump Room.

It shall be prioritized the use of grid floor in the various levels of the Pump Room in order to facilitate the air flow in this environment, according to the Circular Letter of IMO 1321 (Part IV, Chapter 3).

12. EMERGENCY SHUTDOWN SYSTEM

An Emergency Shutdown System shall be provided to initiate appropriate shutdown, isolation and blowdown actions to prevent escalation of abnormal conditions into a relevant accidental process scenario and to limit the extent and duration of any such events which can occur.

For information purpose, the Emergency Shutdown System adopted by PETROBRAS is presented in Annex IV.

ANNEX I - FIRE DETECTION

(For information purpose the voting logic adopted by PETROBRAS)

INSTALLATION AREA	DETECTOR TYPE (Note 1)	LOGIC FOR ESD (Note 3)	LOGIC FOR OTHER ACTIONS (note 4)
- Storage area of flammable and/or combustible products, including alcohol	Flame (note 5)	2ooN (N ≥ 3)	1ooN (N ≥ 3)
- Risers connection area (upper riser balcony or turret internal areas) - Well Head area - Process areas - FPSO and FSO Main deck area, over cargo tanks (Note 10) - Cargo Pump Room - Offloading area	Fusible Plug and Flame (Note 5) OR Flame (Note 5)	2ooN (N ≥ 3) (Note 6)	1ooN (N ≥ 3)
- Areas near flare tower	Fusible Plug	(Note 7)	(Note 7)
- Essential Switchboard Room - Main Switchboard and Transformer Rooms	Smoke	2ooN (N ≥ 3) (note 11)	1ooN (N ≥ 3)
- Control and Electric Equipment rooms (panel, battery, battery charge, machinery space) - Telecommunication and Radio Rooms - Confined spaces with false floor and/or ceiling of Control Rooms		No ESD-3 required	2ooN (N ≥ 2)
- Cabins - Linen Room - Stairways - Cafeteria - Gymnastic Room - Access to Engine Rooms, Trunk and Pontoons - Offices - Recreation Room - Auditoriums - Crane Cabin			1ooN (N ≥ 1)
- Ventilation air intake of control rooms (CCR and radio room) and Muster Stations		No ESD-3 required	(Note 2)
- Warehouse - Food Deposits - Workshops - Laundry	Raise of Temperature Rate	No ESD-3 required	1ooN (N ≥ 1)
- Laboratories - Hospital / Infirmary - Paint Store - Galley - Crane Equipment Room			2ooN (N ≥ 2) (Note 4)
- Electric Power Generator and/or Gas Compressor Hoods	Flame (Note 8) and Fixed Temperature	2ooN (N ≥ 2) (note 12)	1ooN (N ≥ 2)
- Closed areas that contain internal combustion engines or daily use diesel tanks		2ooN (N ≥ 2)	
- Sauna	Fixed Temperature	No ESD-3 required	1ooN (N ≥ 1)

Notes:

1. Specification for fire detectors:

- Flame detectors to open areas: shall be **Multi Spectrum (IR3);**
- Smoke detectors to closed spaces and air intakes: shall be **Optical Type**;
- Fixed Temperature detectors to closed spaces: shall be **Electric-electronic Type**;
- Fixed Temperature detectors to open areas: shall be **Fusible Plug Type**, with fusion point equal to 70ºC;
- Raise of Temperature Rate detectors to closed spaces: shall be **Electric-electronic Type**.

2. Damper closure and alarm in CCR is required.
3. For adequate emergency shutdown level, see Annex IV as reference.
4. Besides the defined actions in item 5.4.2, other actions such as: alarm, close damper or stop equipment / switchboard shall also comply with items 6, 7, 8, 10 and 11.
5. Flame detector shall not be used in areas where the flame or radiation of flare could be in the field view of the detector.
6. In areas simultaneously protected by fusible plugs and flame detector the action shall be:
   a. Detection by fusible plug: Unit general alarm and opening of the respective ADV;
   b. Detection by only one (01) flame detector: Unit general alarm;
   c. Detection by fusible plug and one (01) flame detector OR by two (02) flame detectors: ESD-3P/3T and the opening of the respective ADV through the CSS and FWP start-up.
7. In areas near flare tower, where there are only fusible plugs detectors type, the activation of fusible plugs confers confirmed fire and shall lead to ESD-3 actuation and open respective ADV.
8. UV+IR detector can be used in these areas.
9. Restrooms do not require detection.
10. Fire detection in main deck area shall be dedicated to each coaming and shall not detect fire in other adjacent coamings.
11. ESD by confirmed fire in essential panels room does not shutdown essential equipment.
12. When activated, the system shall initiate an audible and visual alarm in the CCR and a general alarm in the Unit. Other actions, shall be done within the affected equipment / hood: shutdown equipment; shut off equipment fuel supply; depressurize the fuel gas supply piping located inside the hood; stop and inhibit restart of the ventilation fans and close dampers of hood; and activate the fire-fighting system inside the hood. In case of gas compressors units, it shall also close the process gas inlet and outlet, shutdown valves and, depressurize the affected compressor.

ANNEX II – GAS DETECTION

(For information purpose the voting logic adopted by PETROBRAS)

DETECTOR TYPE (NOTE 1)	**INSTALLATION AREA**	**VOTING LOGIC FOR ESD**	**VOTING LOGIC FOR ALARM**
CH_4 Point **OR** CH_4 Point and/or Open path	– Risers connection area – Process and hazardous areas – Well head areas – Turret area – Main deck, over cargo tanks	2ooN (n ≥ 3)	1ooN
	– Telecomunication equipment areas (note 7)		
	– Rooms with equipment handling hydrocarbons, such as: cargo pump room. (Note 2)		
	– Closed areas air intakes (Note 3) – Equipment air intakes (Note 3) – Electric Power Generator and/or Gas Compressor Hoods		
CH_4 Point	– Expansion tanks of the cooling water system – Water make-up tanks of the heating water system	No ESD required	1ooN (N≥ 2)
	– Crane cabin air intakes (Note 4)		
H_2S	– Risers connection area – Process and hazardous areas – Well head areas – Turret area	2ooN (N ≥ 3)	1ooN (N ≥2)
	– Closed areas air intakes (Note 5) – Equipment air intakes (Note 8, 9) – Electric Power Generator and/or Gas Compressor Hoods (note 9)		
	– Areas containing equipment or pipe with stagnated produced water	No ESD required	1ooN (N ≥2)
	– Crane cabin air intakes (Note 5)		
H_2	Battery room	No ESD required	1ooN (n ≥2)
CO_2	– Closed areas air intakes (Note 5)	2ooN (N ≥ 3)	1ooN (N ≥1)
	– Risers connection area – Process and hazardous areas – Well head areas – Turret area		
	– Process area containing equipment or pipes with rich CO_2 streams		
	– Crane cabin air intakes (Note 5)	No ESD required	1ooN (n ≥2)

Notes:

1. Specified gas detectors:

– H_2S shall be **Electro-chemical Type**;

– CO_2 and CH_4 point detectors and CH_4 open path detectors shall be **IR Type**;

– H_2 detectors shall be **Catalytic Type**.

2. Actions upon detection at cargo pump room are specified in item 4.2.1.
3. Whenever grouping air intakes, a minimum of three detectors shall be used ($N \geq 3$). Open path detectors shall be preferable. For air intakes in the process areas, will only be accepted grouping of adjacent air intakes.
4. Air intakes of crane cabins shall have 2 detectors. The action upon confirmed gas shall be: close dampers, turn off fans 2oon ($N \geq 2$) and activate cabin internal alarm.
5. In compartments where continuous or occasional permanence of people is foreseen, the need for detection of H_2S and CO_2 in air intakes shall be confirmed by the Gas Dispersion Study.
6. It is not necessary to allocate CO_2 detectors at turbines hood air intakes.
7. Installation of open path detectors shall be preferable.
8. Equipment such as: air compressors and nitrogen generation system compressors.
9. The monitoring of H_2S in equipment air intakes and turbine hoods shall be evaluated only regarding flammability limits.

ANNEX III – RISK TOLERANCE MATRIX

(For information purpose the Risk Tolerance Matrix adopted by PETROBRAS)

Consequences Severity Categories		Description / Characteristics				Frequency categories				
						A Extremely remote	**B Remote**	**C Not likely**	**D Probable**	**E Frequent**
		People	**Asset / operational continuity**	**Environment (see Note 1)**	**Image**	Conceptually possible, but with no references in the industry	Not expected to occur, although there are references in similar facilities in the industry	Not likely of occurring during the life time of a group of similar facilities	Possible of occurring once during the facility life time	Possible of occurring many times during the facility life time
V	Catastrophic	Multiple fatalities on-site or off-site fatality (see Note 2)	Catastrophic damages which can lead to the loss of the industrial facility	Catastrofic damages	International impact	M	M	NT	NT	NT
IV	Critical	Onsite fatality or severe injuries off-site (see Note 3)	Severe damage to systems/equipment (slow repair)	Severe damages	National impact	T	M	M	NT	NT
III	Medium	Severe on-site injuries or light off-site injuries	Moderate damage to systems	Moderate damages	Regional impact	T	T	M	M	NT
II	Marginal	Light injuries	Light damages to systems / equipment	Light damages	Local impact	T	T	T	M	M
I	Negligible	First aid cases or no injuries	Light damages to equipment without compromising the operational continuity	Insignificant damages	Insignificant impact	T	T	T	T	M

NOTE 1 In the case of leakage of oil or products, Tables B.1 or B.2 (respectively for leakages in the water and land) can be used to define the categories of severity, according to the degree API of the product, to the leaked volume and to the environment harmed. **[Recommended practice]**

NOTE 2 The catastrophic scenario for people consists of large scale accidents, with potential of a larger number of fatalities, including people from the workforce that not necessarily has any direct relation with the accident.

NOTE 3 The critical scenario for people consists of accidents of localized scope in a unit or process plant, with potential of a small number of fatalities (up to 3 people), usually related to the specific task and to the accident scenario.

NOTE 4 The frequency categories aim to allow an evaluation of the frequency of the accidental scenario, which shall be estimated considering the action of preventive safeguards existing or provided in the design.

NOTE 5 The categories of severity aim to allow an evaluation of the magnitude of the consequences of physical effects (overpressure, toxic concentration, thermal radiation etc.), which must be estimated considering that the presence of mitigating safeguards, existing or provided in the current revision of the design, shall reduce such severity. This consideration regarding the mitigating safeguards does not apply to LOPA.

NOTE 6 The approach for risk classification shall comply with criteria from the state or federal Governmental Body, such as CETESB, INEA, IBAMA.

Risk category	Description of the necessary control level
Tolerable (T)	There is no need for additional measures. Monitoring is necessary to ensure that the controls are kept.
Moderate (M)	Additional measures shall be assessed with the purpose of obtaining a risk reduction and to implement those considered practicable (ALARP region – "As Low As Reasonably Practicable").
Not Tolerable (NT)	The existing controls are insufficient. Alternative methods shall be considered to reduce the probability of occurrence or the severity of consequences, so as to bring the risks to regions of lower magnitude of risks (ALARP or tolerable regions).

ANNEX IV – EMERGENCY SHUTDOWN

(For information purpose the Emergency Shutdown adopted by PETROBRAS)

1. GENERAL

The Emergency Shutdown System shall permit an effective and safe shutdown of the process and other equipment aboard the Unit in order to limit risks caused by undesired effects.

The shutdown hierarchy shall comprise 4 levels representing a staged response to increasing hazard levels, Level 1 being the lowest and Level 4 the highest and most severe. The 4 levels are summarized as follows:

Level 4 – Preparation for Abandonment (ASD);
Level 3 – Emergency Shutdown (ESD);
Level 2 – Process Shutdown (PSD);
Level 1 – Equipment Shutdown (USD).

The manual activation of ESD 2, 3 or 4 shall be only by physical push button.

2. CONFIGURATION OF EMERGENCY LEVELS

a) Level 4 (ESD-4)

The level will be activated in preparation for abandonment. Activation of ESD-4 emergency level without initiation of the sound alarm of prepare to abandon shall be possible. The sound alarm shall be activated through the CSS or by a specific push-button located next to ESD-4 push-button.

b) Level 3 (ESD-3)

The level will be the result of detection of Fire & Gas. It may be divided in two levels: Partial (ESD-3P) and Total (ESD-3T), where:

- ESD-3P Keeping the main electric power supply on.
- ESD-3T Main electric power supply or distribution off.

Adoption of division of ESD-3 partial (ESD-3P) and total (ESD-3T) shall be defined during the design.

The two levels of ESD-3 shall be used only for Units that operate at the following conditions:

- Main electrical power supplied by other Unit or;
- Diesel or dual fuel main electric power generation. In this case, main electrical power generation is supplied by diesel during ESD-3P.

During ESD-3P, in Units that have dual fuel main power generation, the residual gas inventory of the fuel gas system shall be the minimum necessary to allow the switching from gas to diesel.

Note:

The scenario of fuel switching shall be incorporated in the consequences studies (gas dispersion and fire propagation) to evaluate the safety implications involved.

Auxiliary power generation, when applicable, shall be considered as main electrical power generation for all interlocking effects with the Emergency Shutdown System, and its start-up shall only be inhibited in case of fire or gas in the corresponding affected area.

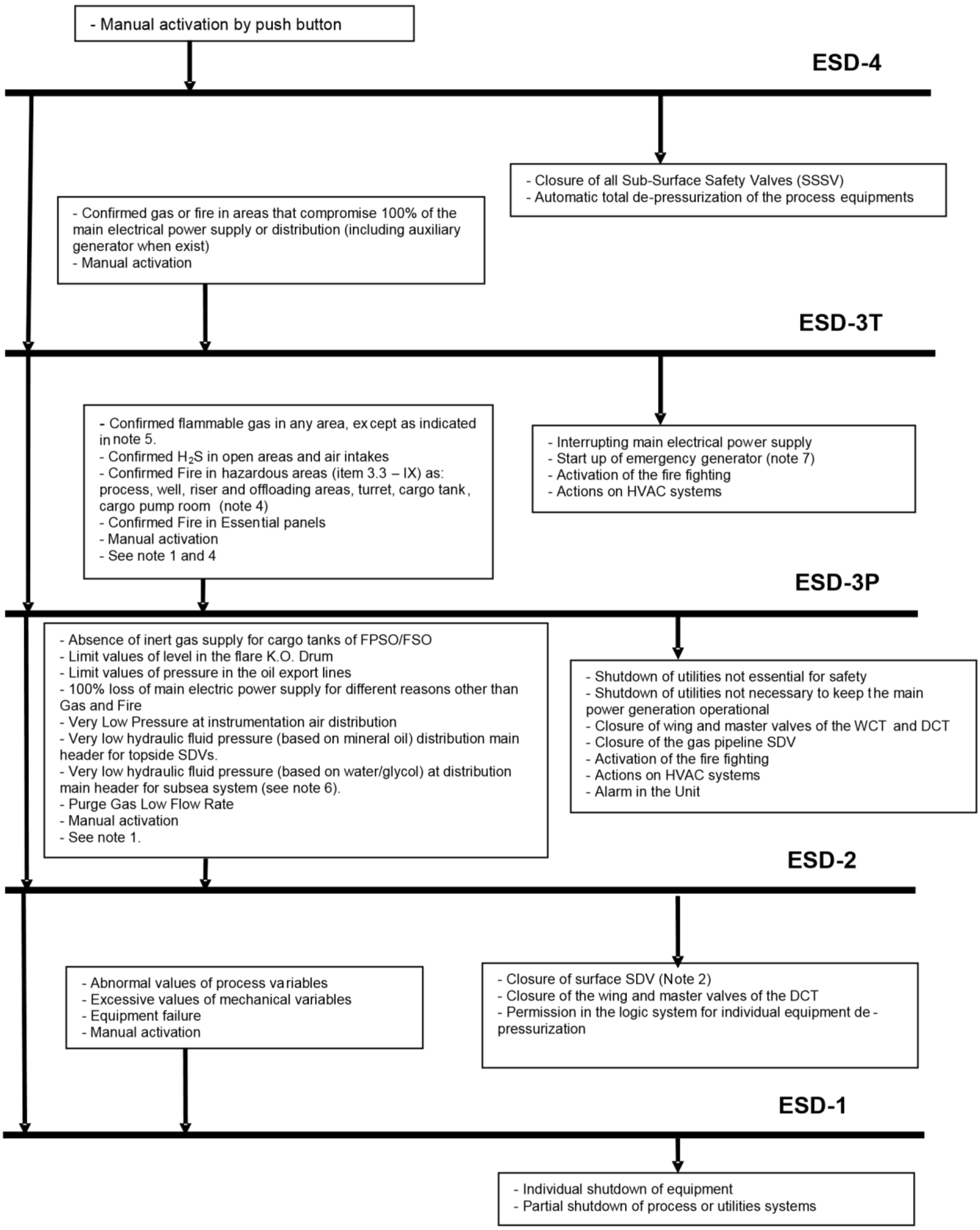
c) Level 2 (ESD-2)

Consist of the total shutdown of the process without affecting the utilities. It will occur if a process variable such as pressure, temperature, level, exceeds the designed limits.

d) Level 1 (ESD-1)

Is the individual shutdown of equipment or a Partial shutdown of process or utilities systems.

Emergency Shutdown Diagram



Notes:

1) Others variables that lead to shutdown other than those presented in the Emergency Shutdown Diagram shall be defined during the design.

2) Automatic closing of surface SDV, except the SDV feeding the turbo-generators (combustible gas and hot water systems). Other exceptions shall be evaluated during the design and may be accepted as long as the operational risks of these systems are evaluated and characterized as tolerable.

3) The activation of a single smoke detector in rooms that contain essential equipment shall initiate an alarm only in the CCR. The need for emergency shutdown actions due to smoke confirmation by two (02) smoke detectors shall be evaluated during design. Exception is made for essential switchboard rooms where a confirmed fire by two (02) smoke detectors shall initiate ESD-3P.

4) Fire in other areas shall activate ESD-3P, however this decision shall be considered in FES.

5) Confirmed flammable gas at the ventilation air outlet or inside the turbine hood shall alarm in the CCR and initiate the turbine shutdown. Other actions shall follow Item 8 (HVAC).

6) In addition to ESD-2, the production and gas lift wing valves shall be closed.

7) Emergency Generator start-up shall be initiated whenever loss of power in the main bus-bar occurs.

8) In case the essential switchboard installed in the same environment as the Emergency Generator and its respective diesel tank, the smoke detection by one or more detectors shall not initiate ESD-3P.

9) ESD-3P action “alarm in the Unit” refers to automatic PA/GA.

ANNEX V – ACUTE HEALTH EFFECTS OF HIGH CONCENTRATIONS OF CARBON DIOXIDE

Carbon Dioxide Concentration (Percent)	Time	Effects
17 - 30	Within 1 minute	Loss of controlled and purposeful activity, unconsciousness, convulsions, coma, death
>10 – 15	1 minute to several minutes	Dizziness, drowsiness, severe muscle twitching, unconsciousness
7 – 10	Few minutes	Unconsciousness, near unconsciousness
	1.5 minutes to 1 hour	Headache, increased heart rate, shortness of breath, dizziness, sweating, rapid breathing
6	1 – 2 minutes	Hearing and visual disturbances
	<16 minutes	Headache, dyspnea
	Several hours	Tremors
4 – 5	Within a few minutes	Headache, dizziness, increased blood pressure, uncomfortable dyspnea
3	1 hour	Mild headache, sweating, and dyspnea at rest
2	Several hours	Headache, dyspnea upon mild exertion

Sources:

(1) “Carbon Dioxide Capture and Storage”, prepared by Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2005.

(2) Interim guidance on conveying CO2 in pipelines in connection with carbon capture, storage and sequestration projects, UK Health and Safety Executive, Hazardous Installations Directorate, 12 Aug.2008, UK HSE Interim Guidance.

(3) EPA.

ANNEX VI – IMPAIRMENT CRITERIA

Main Safety Functions and Relevant Safety Items	Description	Impairment Criteria								
		Parameters to be checked	**H2S (ppm)**	**CO (ppm)**	**CO2 (ppm) (note 2)**	**Visibility (m) (note 5)**	**Smoke temperature (°C) to 30 min. (note 4)**	**Heat Flux (KW/m²) (note 1)**	**Temperature at structures (°C) (note 6)**	**O_2 Depletion (%) (note 9)**
Accommodation Muster Station (primary and secondary refuge) CCR	Accommodation (including: Central Control Room (CCR) and Radio Room) Muster stations	- External bulkheads collapse; - Gas contamination (hydrocarbons, toxics and asphyxiates) (note 7)	8 (note 10)	100 (note 3)	30.000	3	90	NA	450	>19,5
Embarkation Stations	Embarkation Stations SB	- Primary structures temperatures; - Capacity of people stays waiting for evacuation.	8 (note 10)	100 (note 3)	30.000	3	90	1,58	450	>19,5
	Embarkation Stations PS			100 (note 3)	30.000	3	90	1,58	450	>19,5
Escape Routes	Escape Routes SB	Impossibility to escape due to the simultaneous impairment of primary escape routes, considering: - Floor collapse; - Asphyxia, toxicity, radiation, temperature or visibility. (note 8)	50 (note 10)	1.200	30.000	3	90	4,73	450	17
	Escape Routes PS		50 (note 10)	1.200	30.000	3	90	4,73	450	17
	Central Escape Routes		50 (note 10)	1.200	30.000	3	90	4,73	450	17
Modules Division	Division Modules Plates	Integrity of division modules plates.	NA	NA	NA	NA	NA	NA	450	NA
Primary Structures	Primary Structures that Supports Process Modules	Primary structures elements collapse.	NA	NA	NA	NA	NA	NA	450	NA
	Main Deck over cargo tanks	Primary structures elements collapse and top tank plate.	NA	NA	NA	NA	NA	NA	450	NA
Fireproof bulkheads	Open Areas (Process Areas) Fire Walls	Primary structures elements collapse.	NA	NA	NA	NA	NA	NA	450	NA
Structures that supports equipment handling HC	Equipment containing significant HC inventory and its supporting structures.	Primary structures elements collapse.	NA	NA	NA	NA	NA	NA	450	NA
	Risers (Production, Gas Lift, Gas Exportation and Gas Injection)	Primary structures elements collapse.	NA	NA	NA	NA	NA	NA	450	NA
	Primary Structures that Supports Riser Balcony	Primary structures elements collapse.	NA	NA	NA	NA	NA	NA	450	NA
Pipe-racks	Central Pipe-rack	Primary structures elements collapse.	NA	NA	NA	NA	NA	NA	450	NA
	Riser Pipe-rack	Primary structures elements collapse.	NA	NA	NA	NA	NA	NA	450	NA
Safety Equipment	FWP SB	External bulkhead collapse	NA	NA	NA	NA	NA	NA	450	NA
	FWP PS	External bulkhead collapse	NA	NA	NA	NA	NA	NA	450	NA
	Water Main Ring	Primary structures elements and piping supports collapse.	NA	NA	NA	NA	NA	NA	450	NA
	Foam Main Ring	Primary structures elements and piping supports collapse.	NA	NA	NA	NA	NA	NA	450	NA
	ADV (automatic deluge valves)	Impossibility to reach the valves due to high levels of radiation.	NA	NA	NA	NA	NA	4,73	NA	NA
	Emergency Generator	External bulkhead collapse	NA	NA	NA	NA	NA	NA	450	NA
	Local Equipment Room (LER)	- External bulkhead collapse. - Gas contamination.	8 (note 10)	100 (note 3)	30.000	3	90	NA	450	>19,5
Structures and Piping (LP and HP Headers) of Flare System / High	Piping (LP and HP Headers) and Flare System / High Velocity Vent Structures	Primary structures elements and piping supports collapse.	NA	NA	NA	NA	NA	NA	450	NA

Velocity Vent										

Legend:
NA – Not Applicable

Notes:
1 – Threshold allowed to personal exposure of 2 (two) to 3 (three) minutes, already considering solar radiation. Reference: API Std 521.
2 – Reference: NIOSH. The amount of 30.000 ppm is related to STEL (*Short Term Exposure Limit*) and the value of 40.000 ppm is related to IDLH (*Immediately Dangerous for Life and Healthy*).
3 - Considering 50% of the threshold presented at NIOSH (200 ppm).
4 - Threshold allowed to an exposure time up to 30 (thirty) minutes. Reference: "*Methods of approximation and determination of human vulnerability for offshore major accident hazard assessment*" HSE Publication, at *http://www.hse.gov.uk/foi/internalops/hid_circs/technical_osd/spc_tech_osd_30/spctecosd30.pdf*
5 – Reference: OGP *Risk Assessment Data Directory - Report No. 434 – 14, March 2010 – Vulnerability of Humans.*
6 – At the screening step of the structural probabilistic analysis it shall be considered the value of 450 °C as the temperature design criteria for the impairment of the structures.
7 – Air intakes gas monitoring.
8 – According to definition of IDLH presented at NIOSH: *"The purpose for establishing an IDLH value in the Standards Completion Program was to determine the airborne concentration from which a worker could escape without injury or irreversible health effects from an IDLH exposure in the event of the failure of respiratory protection equipment. The IDLH was considered a maximum concentration above which only a highly reliable breathing apparatus providing maximum worker protection should be permitted. In determining IDLH values, NIOSH considered the ability of a worker to escape without loss of life or irreversible health effects along with certain transient effects, such as severe eye or respiratory irritation, disorientation, and incoordination, which could prevent escape."*
9 – Reference: NR 33.
10 - Reference: NR 15.

ANNEX VII – FIRE-STRUCTURE ANALYSES FOR PASSIVE FIRE PROTECTION DESIGN

ANNEX VII -
I-ET-3010.00-1300-14