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			ESUP

INDEX OF REVISIONS

REV.	*DESCRIPTION AND/OR AFFECTED SHEETS*
0	ORIGINAL

	REV. 0	REV.A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	JUL/22/2024								
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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

EEBD Emergency Escape Breathing Device

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
GTD	General Technical Description
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
SCBA	Self-contained Breathing Apparatus
SCC-CO_2	CO_2 Stress Corrosion Cracking
SIL	Safety Integrity Level
SLB	Strength Level Analysis
UEL	Upper Explosive Level
UPS	Uninterrupted Power Supply
VOC	Volatile Organic Compounds
WCT	Wet Christmas Tree
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, Buyer 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 - Regulating Standards – NRs;
    - NR 37 - Health and Safety in Oil Platforms and other applicable 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 14520 - Gaseous fire-extinguishing systems — Physical properties and system design — Part 1: General requirements, Part 5: FK-5-1-12 extinguishant and Part 15: IG-541 extinguishant;
  - 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: Standard for Low-, Medium-, and High- Expansion Foam;
  - NFPA 12: Carbon Dioxide Extinguishing Systems;
  - NFPA 14: Standard for the Installation of Standpipe and Hose Systems;
  - NFPA 15: Water Spray Fixed 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.
- NFPA 2001: Standard on Clean Agents Fire Extinguishing 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.
- IOGP - International Association of Oil & Gas Producers - Report 454 - Human factors engineering in projects.

1.3 APPLICABLE TECHNICAL SPECIFICATIONS

The Technical Specifications below are prescriptive and shall be considered for the Assessments described in Chapter 5. They can be checked in Annex VI.

- I-ET-3000.00-1300-98A-P4X-002 – Ship Collision Study
- I-ET-3000.00-1300-98A-P4X-003 – Dropped Objects and Swinging Loads Study
- I-ET-3000.00-5400-98G-P4X-001 - Explosion Study
- I-ET-3000.00-5400-98G-P4X-002 - Gas Dispersion Study
- I-ET-3000.00-5400-98G-P4X-003 - Fire Propagation and Smoke Dispersion Study
- I-ET-3000.00-5400-98V-P4X-001 - Preliminary Hazard Analysis (PHA)
- I-ET-3000.00-5400-98X-P4X-001 - Hazard and Operability Study - HAZOP
- I-ET-3000.00-5400-947-P4X-001 - Management of Change of Safety Studies

- I-ET-3000.00-5400-947-P4X-002 - Management of Safety Studies Recommendations
- I-ET-3000.00-5400-947-P4X-004 - Risk Assessment
- I-ET-3000.00-5400-947-P4X-005 - Escalation Analysis Due to Collapse of Equipment and Piping under Fire
- I-ET-3000.00-5400-98G-P4X-005 - CO_2 High Content Gas Leakage - Embrittlement Study
- I-ET-3000.00-5400-947-P4X-007 - Human Factors Engineering (HFE)
- I-ET-3000.00-5400-947-P4X-008 – Bow-Tie Analysis

2. LIFESAVING APPLIANCES

Adequate lifesaving appliances shall be provided for the crew that comes on board and shall be available in a safe place and comply with applicable Statutory Rules / Legislations. In addition, the provision of lifesaving appliances shall 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, clean agents 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.

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 II-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-11.

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 shall 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. Main deck escape routes shall preferentially be placed over hull's ballast tanks. In case main deck escape routes are partially or entirely located over cargo tanks, fixed firefighting system shall be designed to cover the entire cargo tanks area, regardless of the presence of the longitudinal coamings.

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.

For areas with the possibility of fires in flammable or combustible fluids, the foam concentrate to be used in the foam formation shall be of the type for hydrocarbons - AFFF 1% (Aqueous Film-Forming Foam 1% - AFFF 1%) or AFFF 3% (Aqueous Film-Forming Foam 3% - AFFF 3%). All foam system in the Unit shall be sized for the same concentration of foam concentrate.

For areas with the possibility of fires in flammable or combustible polar fluids, the foam concentrate to be used in the foam formation shall be of the type for polar solvents – AR-AFFF 3% (Alcohol Resistant Aqueous Film-Forming Foam 3% - AR-AFFF 3 %), 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-223 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-223.

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-223.

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 calculation of FWP's capacity shall consider the maximum demand for water from the firefighting system, which shall be the one required by the largest consumer system, with additional water demand for two hydrants outlet, connected to 2 ½" hoses for fire-fighting.

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 Unit operation.

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) LOCAL APPLICATION

The purpose of fixed carbon dioxide (CO_2) fire protection system is to extinguish fires in the protected systems and shall be specified, designed, installed and tested in accordance with the requirements of this technical specification and NFPA-12. Additionally, for floating units, the provisions of SOLAS, Chapter II-2 and FSS Code, where applicable, shall be complied with.

The fixed CO_2 system can only be used in systems and not in enclosed compartments, by means of local application, through local batteries of cylinders, which shall be packed in cabinets resistant to the marine environment.

All protected systems shall undergo an acceptance test for approval, using the extinguishing agent itself under the conditions provided for in the project, verifying compliance with the design and functional requirements, the specified standards and the manufacturer's maintenance and operation manuals. Acceptance tests for system approval shall be carried out during the onshore commissioning of the Facility.

The project shall provide means to enable inspections, tests and periodic maintenance of the systems, which shall be carried out in the operational phase, according to the standards and maintenance and operation manuals of the manufacturers.

Local batteries of CO_2 cylinders shall be provided to protect the atmospheric vent discharge and vent post discharge. 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 with

local manual activation (by pushbutton or mechanical) and automatic, by temperature sensors installed close to vent post discharge.

3.1.2.2 CLEAN AGENTS

The fixed firefighting system using clean extinguishant agents shall be applied in spaces or compartments occupied or possibly occupied with a risk of fire, with the objective of extinguishing.

The system shall be specified, designed, installed, and tested in accordance with the requirements of this guideline, NFPA-2001 and ISO 14520 Parts 1, 5 and 15. For Floating Units, the provisions of IMO MSC/Circ.848, MSC.1/Circ.1270, SOLAS Chapter II-2/10.4 and II-2/10.9 and FSS Code shall also be complied with.

Fixed firefighting system using clean extinguishant agents shall not use HFC, CFC and HCFC agents.

A full discharge acceptance test (performance test) using the clean agent itself is mandatory for all compartments and spaces protected by those agents. The full discharge test shall be done under real system operating conditions (to reflect the system operation in a real emergency scenario without system and compartment modifications) in order to verify the compliance with the design and functional requirements, the specified standards and the manufacturer's maintenance and operation manuals.

Seller shall define a methodology to measure the system performance as per system design, rules and standards. For enclosed compartments whereas are required to measure any type of gas or fluid concentration or any other parameter such as temperature, the methodology shall guarantee at least 3 measurements per compartment and at least two measurements per level for compartments with more than a single level. Those measurements shall be taken closer to the main fire risks of the protected compartment/space.

Full discharge test procedure shall contain safety measures recommended by a previous risk assessment for all phases of the test (before, during and after the test and system reinstatement). Such recommendations shall not interfere with the system and the compartments/spaces design in order to perform the test.

The acceptance tests procedure shall be submitted to Buyer approval during the detailed engineering phase.

3.1.3 WATER MIST SYSTEM

The high-pressure water mist system can be used as fire protection for compartments with the objective of extinguishing. The 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, installed, 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 for protection of exhaust ducts, hood and kitchen cooking area, with the objective of extinguishing.

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

The system shall be specified, designed, installed, and tested 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 may not 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-201).

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.

Priority should be given to the use of portable fire extinguishers with a lower agent load, but with greater extinguishing capacity and that meet the three main classes of fire (ABC). These shall have a 5-year manufacturer's warranty.

3.3 PASSIVE FIRE PROTECTION - PFP

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

PFP shall 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 shall 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 actions and emergency shutdowns, see item 12 and 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 detector 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 Buyer 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 ≥ 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 Buyer 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 power generator hood, CH_4 detection shall comply with actions indicated in item related to HVAC System.

O_2 detectors shall be installed for continuous monitoring of breathable atmosphere in enclosed spaces containing central battery of Clean Agent extinguishing cylinders, compartments that have reserve cylinder storage (CO_2, clean agent, N_2) and in compartments with gas inert generator (CO_2, N_2). The monitoring shall be carried out by at least 3 O_2 detectors installed at a height not exceeding 2 m and not less than 1,5 m, with at least one being close to each of the access doors, inside the room.

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 item 12 and 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 item 12 and Annex IV.
Note 3: See Annex V.
Note 4: More stringent levels can be proposed by seller.
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 item 12 and 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 Buyer.

As minimum, the Risk Management Program shall 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.

According to Buyer Risk Matrix, presented in Annex III, Major Accidents Hazards shall be considered as all 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 other 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 Buyer 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 presented in Annex III.
- Quantitative Criteria – The risk assessment shall consider the following items:

  a) The possible loss or impairment of the Main Safety Functions 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, 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.

  NOTES:

  i) In cases where a Main Safety Function is impaired by other accidental loads, in addition to those described in item (b), the impairment frequency for each accidental load considered shall be the result of the division of $1x10^{-3}$ frequency value equally by the total number of accidental loads identified.

  ii) In no case, the value of impairment frequency of $2.5x10^{-4}$ occurrences per year, per individual accidental load may be exceeded.

  d) Each Main Safety Function 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 **Main Safety Functions.**

The objectives of the Main Safety Functions are:

a) To avoid the escalation of the accident, in order to preserve the people who are not in its vicinity.

b) Maintain the integrity of key structures to ensure that people can safely leave the Unit in the time frame.

c) Maintain the integrity of compartments and systems that are relevant to the emergency response, ensuring the integrity of the functions performed by them.

d) Ensure the maintenance of at least one escape route from each area to the Muster Station, Abandonment Stations and Accommodation.

The following items shall be considered as Main Safety Functions:

- Accommodations, Abandonment Stations, Muster Stations, control rooms and/or rooms containing essential equipment.
- Escape routes.
- FGS functions (system components, such as remote panels).

- Primary structures of process modules, utility modules and of flammable/combustible products storage area.
- Primary structures that support safety and lifesaving equipment.
- Primary structures from risers arrival area.
- Firewall adjacent to process areas.
- Pipe racks and support structures of hydrocarbon handling equipment.
- Safety equipment such as FWP, emergency generator, firewater and/or foam concentrate main, ADV, BDV, among others.
- Flare System structure and piping, including equipment and depressurization headers.
- For the hull: area on top of cargo tanks; hull of the FPSO and FSO; SS columns and pontoons.
- Unit positioning system (mooring system).
- Stability and floatability (hull / columns and pontoons integrity).
- Other items to be defined depending on the characteristics of each Project.

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 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 shall be verified during the Critical Elements of Operational Safety audit.

Comprehensive 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 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 study.

5.4.3 CONSEQUENCE ANALYSES

In this item are defined the minimum requirements for the Fire Propagation and Smoke Dispersion Study, Gas Dispersion, Explosion, Dropped Objects, Ship Collision Analysis and Embrittlement study due to CO_2 high content gas leakage that shall comply with the provisions below. All Safety Studies shall follow the Buyer Technical Specifications for each study.

- Selection, simulation and evaluation of all the accidental scenarios indicated in the PHA according to the criteria defined in item 5.2 and 5.3.
- 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.
- During the execution of each Study, an assessment shall be made to indicate the scenarios that shall be individually simulated, grouped or even discarded. In all cases they shall be documented, justified and approved by Buyer. During the development of the project, the need to include other scenarios to be simulated shall be evaluated in order to represent the updated conditions of the process and arrangement of the Unit.

- For segmentation of the sections to be analyzed and calculation of the inventory of combustible and/or flammable fluids of a fire or explosion scenario, the requirements of the Technical Specifications of each study shall be considered.
- To calculate the inventory of combustible and/or flammable fluids of a fire scenario, the effective closure time for the valves shall be considered:
    - For surface SDV valves, the closing time, for any SDV diameter, shall be considered as 45 seconds.
    - For isolation subsea valves of gas pipelines and gas production satellites well lines, 240 seconds may be considered as a first approach, which shall be ratified during the detailing project.
    - The time to be considered for the closure of the WCTs of the production, gas injection and gas lift lines shall be at least 600s. The "on/off" shut-off profile shall be considered for these valves, conservatively.
- Damage calculation to the Installation including evaluation of the impairment of Main Safety Functions.
- Consider existing fire passive and active protection.
- Proposal recommendations to reduce the risks when applicable. The effectiveness of the results of these measures shall be demonstrated through simulations. Such measures and evidence of effectiveness in reducing the risk shall be submitted to Buyer for approval.
- The scenarios of cold jets resulting from a loss of containment of a high content 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 50% 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 Buyer. 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.
- The leak frequency of equipment shall be set using as specialized reference database, such as: LEAK (DNV), International Association of Oil & Gas Producers (IOGP), AIChE or HSE (UK). Buyer shall be consulted in case seller 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 the definition of the Ignition Probability (immediate and/or late), shall be considered the correlations presented in one of the following references:
    - ENERGY INSTITUTE publication, Ignition Probability Review, Model Development and Look-Up Correlations - UK, Section 2 (Look-up Correlations) for Units Offshore. Each scenario shall be analyzed to determine the most appropriate correlation.
    - IOGP Report 434-06 - Ignition Probabilities - Risk Assessment Data Directory. Each scenario shall be analyzed to determine the most appropriate correlation.

      Ignition probabilities shall be applied in accordance with the Technical Specifications of Fire Propagation Study and Explosion Study.

- 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.
- Use software in accordance with Buyer's Technical Specifications for the correct estimation of the magnitude of fires, explosions and releases of toxic, asphyxiating, flammable and/or combustible substances, considering the specific conditions of the unit analyzed, such as: geometry, operating and meteoceanographic conditions.
- Consider the effective opening time of the BDV valves. The opening time cannot exceed 45 seconds.
- In the Fire Propagation and Smoke Dispersion, Gas Dispersion and Explosion Studies, possible escalation effects shall be analyzed.
- The software for simulation of leaks to be used shall be able to simulate the decay of the leakage rate due to the operation of the Emergency Shutdown systems and the influence of the automatic depressurizing. The automatic depressurizing shall be considered only in fire propagation simulations.
- Consequence studies shall be integrated with each other to ensure that the premises and recommendations are coherent and consistent among them, considering the characteristics and objectives of each study. In the same way, there shall be an integration between the studies performed by the different types of contracts that a project can have (hull, topside, integrator, packages, among others). The Project shall submit a final report containing all the conclusions and recommendations that substantiate such integration. The purpose of integration is the evaluation of the Unit as a whole, not as isolated parts.

5.4.4 METEOROLOGICAL DATA

The Consequence Studies shall use the specific Meteoceanographic Data for the region in which the Unit is planned to be installed.

Data such as the relative frequency of occurrence of velocities, wind direction, temperature and humidity of the air shall be used as input data for the simulations of consequence studies.

Eight wind directions shall be considered. For each of them, at least the two wind speeds shall be analyzed and simulated using a CFD type numerical model for all studies:

- The wind speed corresponding to the calm weather condition (0.5 m/s).
- Another speed between the calm weather speed and the most frequent speed shall be simulated in order to characterize the consequences as a function of the cloud sizes.

In the Gas Dispersion Studies, for each direction and wind speed, dispersions in distinct modules can be included in the same numerical simulation, as long as the clouds observed in the modules do not interfere with each other.

According to the characteristics of each Consequence Study, simplifications in the amounts of wind directions and speeds to be simulated can be indicated, these simplifications will be defined in the Technical Specifications of each study.

Any simulation reduction, which excludes leak scenarios, shall be justified and approved by Buyer.

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.

The leak rates to be used in the CFD simulations shall be ones indicated in the Technical Specifications of each Safety Study where applicable.

In order to define the leakage rates to be used in the Gas Dispersion Study for the allocation of flammable/toxic/asphyxiating gas detectors, the methodologies indicated in the Technical Specification of this study shall be followed.

To decide whether use flammable gas or CO_2 detectors:

In modules and/or areas where there can be concentrations of CO_2 higher than flammable gas, the requested analysis on this item shall be performed for the case which has higher concentration of flammable gas and another for the higher concentration of CO_2. For the case where there is CO_2 concentrations higher than flammable gas, this analysis shall determine whether the contour of 30,000 ppm of CO_2 is bigger than the 60% LII of flammable gas one. In affirmative case, this leak rate shall be used to allocate dedicated CO_2 gas detector on this contour. For the other case, there shall be installed dedicated flammable gas detectors.

To decide whether add H_2S detectors:

In modules and/or areas where there can be streams with concentrations of H_2S higher than 50 ppm, the requested analysis on this item shall be performed. This analysis shall determine whether the contour of 20 ppm of H_2S is bigger than the 60% LII of flammable gas one, or whether the contour of 20 ppm of H_2S is bigger than the 30,000 ppm of CO_2 one. In cases that the contour for H_2S is bigger, these leak rates shall be used to allocate dedicated H_2S gas detector on these contours.

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 LEAKS FREQUENCY

Each item / equipment has a "Frequency of Leak vs. Leak Rate" relation to be determined based on information from Databases. For each segment to be analyzed, the frequency associated with a given leak rate will be the sum of the frequencies for that same leak rate considering all existing components (flanges, valves and special items such as line

filters, dresser joints etc.), as well as the equipment that compose that segment, that can cause leaks with the specified rate.

This calculation shall be performed for all leak rate ranges, which is, the leak frequency that a component can have shall be calculated, starting from 0,1 kg/s until the maximum possible rate. The leak frequency shall be grouped by leak rate categories (small, medium and large).

5.4.7 SELECTION OF LEAK POINTS

The representative leakage points shall be defined considering the updated arrangement of the Unit. Leakage points shall be analyzed for each item /equipment of the identified scenario. The choice of the items / equipment shall be carried out in a way that guarantees the coverage of possible areas of the module that can be affected by the leaks, avoiding partial analysis, in only one region of the module, and partial detectors location, leading to areas without analysis and without detection coverage.

5.4.8 LEAKING DIRECTION

For each leak point four leak directions shall be considered.

There shall be at least one scenario with the leakage direction oriented against the prevailing wind direction.

Scenarios where leakage and wind are aligned and directed to the outside of the Unit do not need to be modeled as long as they do not cross areas of the Unit.

5.4.9 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.

The minimum 3D model completeness to be used is at least 60%, plus the congestion factor for each area, according to engineering evaluation.

The geometric model shall be presented for approval by Buyer prior to the beginning of CFD analysis.

5.4.10 GAS DISPERSION STUDY

The study shall assess the dispersion of flammable, toxic and asphyxiating gases arising from gas leakage scenarios and operational gas discharges to provide consistent information for:

- Design of gas detection systems.
- Adequate positioning of equipment vents, Vent Post and machine discharge exhausts, in order to avoid contamination of enclosed compartments (air intakes), operational areas, support vessels and flotels, and other places of passage or permanence of personnel in the Unit, avoid undesired interferences in the gas detection system in the case of operational gas discharges.
- Evaluation of escape routes impairment frequency due to the scenarios of toxic and asphyxiating gas leaks.

The concentrations for escape routes impairment due to H_2S and CO_2 leakage shall be as follows:

- H_2S: 50ppmv.
- CO_2: 30000 ppmv.

In carrying out the Study, the leakage scenarios indicated in the PHA shall be considered, as well as the voting logic and the type of detector to be used.

The Study shall consider, among others, the following aspects:

- Determination of gas leakage points.
- Inventories and conditions of the released gas, such as composition, temperature, pressure.
- Leakage directions and wind directions.
- The dispersion of gases by computational simulation, using CFD model.

The final definition of the location of the detectors shall consider information coming from updated documentation, as well as the characteristics and limitations of the detectors to be adopted.

In addition, the final position of the detectors shall consider frequent access for testing and maintenance of these, as well as interference with structures and equipment.

5.4.11 STEPS FOR GAS DETECTOR LOCATION STUDY

The Study shall consider, as a minimum, the steps described below:

a) Determination of leak points:

Leak points shall be selected by considering the inventory and process variables of the released gas to ensure that there is no area of Fire Zones whose leaks are not detectable. For this selection, P&IDs, arrangement, 3D model, etc. shall be used. To determine leak points in piping sections or equipment, the most likely leak location shall be considered.

The accidental scenarios to be considered in the analysis shall be those from small leaks, but capable of generating clouds at relevant concentrations of toxic and/or flammable gases. All gas leakage scenarios identified in the PHA shall be included in the analysis, regardless of the severity category of the scenario.

To eliminate clouds that have been simulated, it shall be considered that their contribution will be negligible for the detection strategy. All justifications for the elimination of some scenario of gas leakage shall be registered and approved by Buyer.

b) Quantities and Properties of Gases

The study shall include the inventory calculation and the determination of thermodynamic and physical-chemical characteristics of the hazardous gases present in the Unit.

If the composition of the gas has a significant amount of components heavier than air, two gases shall be considered for simulation, as follows: a simulation considering all components lighter than air, and the other considering all the components heavier than air.

c) Gas Dispersion Model

The dispersion analyzes shall be performed through an appropriate CFD tool, as defined in item 8.5.

d) Design Criteria

The location and quantification of gas detectors shall be based on the use of three-dimensional modeling for gas concentrations. The detectors shall be positioned so as to allow the detection of all cases selected and simulated as representative of the scenario.

5.4.12 GAS DISPERSION STUDY FOR VENT POST AND PROCESS VENT LOCATION

A study for vent post and P/V breaker vent location shall be performed, evaluating flammable gases dispersion through the same CFD model used in detection system design. Vent Post and P/V breaker vent 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.

A study for process vents location shall be performed, evaluating flammable gases / toxic and/or asphyxiating dispersion through the same CFD model used in detection system design. This study shall ensure that vented gases do not interfere with Gas Detection System of Unit and do not increase the risks for personnel. The limits of exposition to toxic/asphyxiating gases shall be evaluated according to the limits established in Brazilian Regulation. 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.

5.4.13 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.

Discharges of machinery shall be positioned in such a way that exhaust gases from such discharges do not reach air intakes with CO_2 concentrations above 1000 ppm.

5.4.14 EXPLOSION STUDY

Overpressure levels in Main Safety Functions 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 providing, when necessary, measures to maintain their integrity.

The Explosion Study shall be developed using a numerical model using CFD software as defined in Buyer Technical Specification. The use of any other software shall be previously approved by Buyer.

For the segments between emerged part of production risers and BSDVs, and between production BSDVs and their choke valves, the leak frequencies / explosion frequencies calculation shall also be performed considering the shut-in pressure at the choke valves and other pressures that are provided in the design phase. This evaluation shall be performed respecting the leak categories provided in item 5.4.5 of small, medium, and large leaks.

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 5.4.9 Geometry Modeling.

b) Leaks

The leakage rates and frequencies shall be determined as per the Technical Specification I-ET-3000.00-5400-98G-P4X-001 - Explosion Study. 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.

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) Explosion Modeling

Scenarios shall be selected with variation in cloud sizes, cloud location, and ignition location. Results in terms of pressure on panels, overpressure monitoring points and impulses in the area shall be obtained for each scenario and then combined to define pressure versus associated frequency curves, for each point of interest.

The Dimensioning Accidental Loads (DALs) of the MSF shall be obtained from the exceedance curves, according to the risk tolerability criterion.

Figures showing the distribution of the overpressure contours due to the explosion at different time steps shall be presented for some scenarios previously selected. The DAL to be considered for the module or area shall be the one in which the monitoring point obtained the highest explosion load (overpressure, drag, impulse etc.).

e) Explosion Assessment

An approach that results in curves showing the annual frequency as a function of the overpressure due to the explosion (exceedance curves) shall be applied. The input data

shall consist of the CFD analysis results obtained from the ventilation, dispersion and explosion simulations, in terms of ventilation rates, cloud size and explosion loads (overpressures, drag, impulse, etc.) respectively.

The probability distributions of the dependent variables shall be applied as input data for the probabilistic evaluation. The wind probability shall be obtained from the wind rose, and the frequency of leakage shall be calculated considering the contribution of all the components that may contribute to the analyzed leak.

The DAL considering explosions affecting each of the MSFs shall be presented as pressure curves (point overpressures, panel overpressure and dynamic pressure), as well as the corresponding duration of the triangular impulse. If necessary, reduction of the cumulative frequencies of the scenarios or overpressure levels shall be sought through design modifications, rather than maintaining integrity through the use of structural reinforcement. For this reason, it is recommended to identify the factors that most affect the results.

5.4.15 FIRE PROPAGATION STUDY AND SMOKE DISPERSION ANALYSIS

The purpose of the Fire Propagation Study is to assess the fire consequences in the Unit under analysis, considering the scenarios defined in the Preliminary Hazard Analysis (PHA). This evaluation consists in obtaining the thermal effects and smoke dispersion effects.

In this Study, at least the following items shall be checked:

- Impairment of the Main Safety Functions.
- Possibility of propagation and escalation of the fire.
- Consequences for the integrity of the structure, equipment and supportation of piping and equipment with inventories of flammable fluids, as well as structure, equipment and supportation of piping and equipment of flare system.
- Simultaneous impairment of the main escape routes (access to accommodations, Muster Stations and Abandonment Stations) caused by radiation, smoke and toxic fumes generated in the fire scenarios, determining the frequency associated with this impact.

The Study shall propose alternative solutions, which shall be implemented in the respective phase of the project, to ensure the escape, shelter and evacuation of people.

For the scenario escalation analysis, it is necessary to identify the mechanisms by which the initiating event can trigger new fire scenarios, staggering the initial scenario.

The analysis of fire propagation shall be carried out in an integrated way, considering in the same study the fire scenarios originated in the hull and the topside. In this way, fire loads originating in an area shall have their impact evaluated in all adjacent areas directly or by escalation.

In the evaluation of the Fire Propagation and Smoke Dispersion Study, in addition to the scenarios indicated in the PHA, the relevant ones defined by the project team analyzed shall be considered, such as accidental indoor scenarios that contain potential sources of flammable product leakage.

METHODOLOGY

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

a) Characterization of Fire Scenarios

Fire scenarios can be characterized as jet fires and pool fires for purposes of consequence analysis. Flash fire scenarios will not be considered in the simulations:

- Jet Fire

Flames dimension and geometry shall be calculated through CFD model. Initial leakage rates for each range determined in item 5.4.5 shall be simulated. Immediate ignition shall be considered and flame properties variation with time shall be included in calculations.

The variation of the dimensions of the flame in function of the reduction of the internal pressure / inventory shall be considered. Thus, the inventory available for burning is a function of the initial volume contained in the system; of the closing time of SDVs; pressure and temperature at each instant of time; and of the possible action of the depressurizing system (via BDVs), where applicable.

- Pool Fire

The leakage rates of the liquid to be analyzed shall be such that they produce evaporation rates equal to those defined in item 5.4.5. The largest pool fire to be simulated shall not extrapolate the containment of the module.

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, limited to 60 minutes.

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 Main Safety Functions.

d) Fire Propagation and Escalation Analysis

The possibility of fire escalation shall be checked for other equipment or pipelines with significant inventory (eg process plant vessels and pipelines with a diameter of 6” or greater), which may result in a greater severity of the scenario involving other areas / equipment of the Unit. Escalation analyzes shall consider existing protections in design for systems impacted by the original scenario.

e) Elastoplastic Structural Analysis

The objective of this analysis is to evaluate the behavior of the structure considering the mechanical loading of the structure plus the thermal incident fire loads and to define which structural elements shall be protected, the type and the extent of PFP necessary and sufficient to guarantee the integrity of the elements, according to collapse criterion. The type of protection shall be according to the scenario that leads to the collapse of structure: pool or jet. The protection time specification shall meet the minimum duration of the scenario leading 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 shall be applied transiently to represent the evolution of the fire over time for 60 minutes.

The elastoplastic analyzes shall contemplate the scenarios whose temperature in the primary structures reaches values equal or greater than 450 °C.

In the case of the main structural elements that can be directly impacted by jet flares, with sufficient duration and intensity to promote their collapse, the PFP shall be applied to the full 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 the support of 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, reaches the 450°C.

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.
- Process equipment, which have an inventory of flammable / combustible liquid above 4000 Kg, shall have their supports evaluated, in order to avoid failure of the support.

The collapse analysis shall consider stress, strain, buckling and excessive displacements.

g) Mechanical Integrity Analysis for Vessels and Pipe under Fire

The heat rate caused by fire incident on vessels and tubing piping resulting from the CFD simulation shall be fed into software suitable for the dynamic simulation of the plant in order to evaluate if the stresses reached by the items exceed the vessel or pipe resistance limit conditions, according to vessel manufacturer data and line specifications. In the specific case of vessels, which necessarily receive deluge, the collapse analysis shall be performed only for jet fire scenarios directly affecting the equipment.

The study shall comply with the methodology described in I-ET-3000.00-5400-947-P4X-005 - Escalation Analysis Due to Collapse of Equipment and Piping under Fire.

5.4.16 SMOKE DISPERSION STUDY

For each fire scenario considered, an analysis of the smoke dispersion shall be carried out, informing the concentration of the cloud as a function of time, verifying the radius of visibility and the breathable atmosphere.

The impairment of all primary escape routes and consequently access to accommodation, Muster Stations Abandonment Stations shall be analyzed. In cases where the impairment of escape routes to the above areas is verified, a recommendation shall be generated to enable the maintenance of at least one escape route, considering all scenarios evaluated.

The impairment criterion to be applied to escape routes shall provide a minimum visibility of 3,0 m for well-defined routes, provided with good visibility or illumination signaling and breathable atmosphere assurance, taking into account CO and CO_2 concentrations and time exposure during escape.

5.4.17 DROPPED OBJECTS

The purpose of this study is to evaluate the impairment of MSF, such as hydrocarbon process plant areas, depressurizing lines, chemical storage areas and others, due to the drop or impact of cargo handling by the installation cranes. The study shall be carried out according to Buyer Technical Specification.

5.4.18 SHIP COLLISION

The purpose of this Study is to assess the impairment of MSF defined in Technical Specification I-ET-3000.00-1300-98A-P4X-002 – Ship Collision Study that may be impacted by collision of service vessels, shuttle tanks and passing vessels. The study shall be developed according to the Technical Specification mentioned above.

5.4.19 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.

The study shall be carried out according to Buyer's Technical Specification.

5.4.20 CO_2 HIGH CONTENT GAS LEAKAGE - EMBRITTLEMENT STUDY

The study of embrittlement by low temperature due to leakage of currents with high CO_2 content aims to evaluate the scenarios identified in the PHA, of medium and large leakage of currents with high CO_2 content to assess the risk of fragilization of structural elements, equipment and their supports, and the possible consequences for the Unit.

The leakage of CO_2 at low temperatures shall be considered as an additional accidental load for those MSF that may be impacted.

The study shall be carried out according to Buyer's Technical Specification.

5.5 SAFETY INTEGRITY LEVEL (SIL)

The design of Safety Systems shall full comply with API 14C standard requirements. Some critical Safety Instrumented Systems of systems as closed flare, HIPPS and HC blanketing, can have reliability analysis (SIL) in accordance with IEC 61508/511. For any other loop that might be required the reliability assessment, that shall be done with prior approval from Buyer.

5.6 HUMAN FACTORS ENGINEERING (HFE)

Human factors engineering design principles shall be considered in the design, according to IOGP Report 454 and Buyer specification I-ET-3000.00-5400-947-P4X-007 - Human Factors Engineering (HFE).

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 item 12 and 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.
- Clean Agents cylinders battery rooms and areas protected by gaseous fixed 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 at 10% of LEL shall initiate an audible and visual alarm in the CCR. 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.
- Start stand by fan, to increase exhaust air exchange rate.

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 Buyer.

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. At least one main escape route shall be available on Topsides at first level of process plant.

Escape routes 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.

Compartments with central batteries of clean agent cylinders, compartments protected by clean agents and compartments with inert gas generators shall have at least two access doors.

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 to 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 BLANKETING SYSTEM FOR CARGO TANKS ON FPSO

10.1 GENERAL REQUIREMENT

All FPSOs and FSOs Units shall have an Inert Gas System, as required by the IMO, FSS Code and Classification Societies rules, for the inertization of cargo tanks, offspec oil tanks, produced water, slop tank or any other structural tank installed in the hull area, which may have volatile organic compounds (VOC) in its atmosphere.

The inert gas generation system shall have a configuration of two units at 100% (2x100%).

The supply of inert gas shall have oxygen concentration monitoring to ensure that the gas is adequate, before it is sent to the cargo tanks, in accordance with the limits established

in the project. The concentration of O_2 inside the tanks shall not exceed 8%, as required by the FSS Code.

The gas dispersion analysis for the vent posts shall consider representative scenarios for the gas composition in the cargo tanks, in concentration and discharge flow ranges that reflect the presence of hydrocarbons in the atmosphere of the tanks and the different modes of operation of the system. The criteria to be considered in the dispersion simulations for the vent posts are described item 5.4.10 / 5.4.12.

Vent post(s) shall have a flame arrestor protection device, in addition to fire protection, according to item 3.1.2.1.

10.2 HYDROCARBON BLANKETING SYSTEM - HC GAS BLANKETING

In addition to the Inert Gas System, a Hydrocarbon Blanketing System (HC Gas Blanketing), associated with a recovery system for volatile organic compounds, shall be foreseen, as defined in GTD, in order to reduce the emission of VOC to the atmosphere.

The HC gas blanket system shall meet the following requirements, as a minimum:

- Installation of O_2 analyzers (2oo3 voting logic) in Hull HC distribution header for monitoring and interlocking, to shutdown cargo pumps and the SDVs with SIL requirement for isolation of gas inventory in tanks.
- Installation of O_2 analyzer in each cargo tank, slop tank and any other structural process tank for monitoring and interlocking with the respective SDVs at the inlet of each tank and pump.
- Installation of two SDVs between the process plant and the hull distribution system. One SDV shall be located on the topside and the other near the hull HC distribution header.
- Installation of SDVs in the fuel gas lines at the inlet of each tank (cargo tanks, offspec oil tanks, produced water, slop tank or any other structural tank that has its atmosphere controlled by the use of inert gas or HC Gas Blanketing), for its automatic isolation in the event of gas confirmation, fire confirmation in the Unit or pressure increase in the fuel gas lines that feed the HC Gas Blanketing system.

- The design of the HC Gas Blanketing system shall provide means for isolating the inert gas system when the inert gas system is in operation and vice versa.
- The fuel gas lines of the HC Gas Blanketing system shall not pass-through safe areas of the Unit aft of the Engine Room forward bulkhead, or through closed compartments of the installation. All lines shall be grounded.
- The design shall provide means for the tanks to always be purged with inert gas before starting the operation with hydrocarbons and using the HC Gas Blanketing system.
- Process gas used in the HC Gas blanketing shall be treated to H_2S, with 5 ppmv maximum.
- H_2S monitoring (2oo3 voting logic) for monitoring/interlocking with SDVs.
- Means shall be provided to avoid air ingress through the tip of the Vent Post(s). An O_2 analyzer shall be provided in vent gas header, as close as possible to vent posts.
- Installation of PITs (2oo3 voting logic) to shut off hydrocarbon gas supply to the tanks and cargo pumps shutdown, in case of low pressure.
- Installation of PITs (2oo3 voting logic) to shut off hydrocarbon gas supply to the tanks, in case of high pressure.
- Installation of TITs (2oo3 voting logic) at vent post to shut off hydrocarbon gas supply to the tanks, in case of high temperature due to fire at vent post.
- Connection of cargo tanks to the Unit's flare system or any other torch system is not allowed.
- The PV break vent and vent post shall be directed to a safe location, above the process plant, and assessed at Gas Dispersion Study.
- All scenarios of hydrocarbon gas leaks from the HC Gas Blanketing system and from the tanks to the external area shall be included in the Fire Propagation, Gas Dispersion and Explosion Studies, regardless of the risk classification of the scenarios in the PHA.
- In addition to the risk analysis and consequences studies already provided for in this Guideline (item 5), the FMECA/FMEA technique shall be applied to evaluate the interaction of possible failures of the process plant's fuel gas systems in the hull systems and vice versa.

- CH_4 detectors shall be installed in the main deck area, on cargo tanks area, with the function of alarm and safety interlock. The location of the detectors shall be based on the Unit's Gas Dispersion Study. The implementation of a gas detection system for the main deck area is mandatory.

10.3 SAFETY REQUIREMENTS FOR OPERATION WITH SETTLING TANKS

Measures to reduce the risk of loss of containment / release of H_2S shall be foreseen in the Project, specifically for Units that operate with settling tanks and reservoir fluid containing H_2S.

Areas with potential loss of containment / accidental release of H_2S shall be identified through the risk analyses described in item 5. Scenarios of loss of containment in the process plant, as well as in the main deck region, especially related to the operation of the settling tanks, shall be considered.

A gas dispersion study shall be carried out to map the H_2S clouds supporting the Unit's H_2S exposure strategy and assess the need for allocation of H_2S detectors. Detection of H_2S gas by any detector at concentrations equal to or greater than 8 ppm v/v in open areas shall alarm in CCR. Two detectors at concentrations equal to or greater than 8 ppm v/v in open areas shall trigger a continuous visual and audible alarm in the affected area as defined in item 4.

In case of use of P/V Breakers to protect the settling tanks, their vents, as well as the vent posts dedicated to the settling tanks and their header, shall be directed to a safe place, and their geometry, location and height shall be defined based on the Gas Dispersion Study, according to item 5.4.10/5.4.11/5.4.12/5.4.13.

Settling tanks shall have their safeguards defined in accordance with the Marine System requirements and in accordance with API 14C. Scenarios that may cause overpressure / low pressure shall be considered in the risk analyses and safeguards shall be provided for the settling tanks. In addition, analyses shall consider the possibility of gas blow-by, indicating safeguards as necessary.

Units operating with settling tanks that contain H_2S in the reservoir fluid shall be provided with self-contained breathing apparatus (SCBA) in areas with the potential for loss of

containment / accidental release of H_2S. People accessing the process area shall carry the escape mask (EEBD) and the portable H_2S detector.

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 saltwater 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 Buyer is presented in Annex IV.

ANNEX I - FIRE DETECTION

(For information purpose the voting logic adopted by Buyer)

	INSTALLATION AREA	DETECTOR TYPE (Note 1)	VOTING LOGIC FOR ESD (Note 2)	VOTING LOGIC TO OTHERS ACTIONS (Note 3)	UNIT GENERAL ALARM
1	- Storage area of flammable and/or combustible products, including alcohol.	Flame (Note 4)	2ooN (N ≥ 3)	1ooN (N ≥ 3)	2ooN (N ≥ 3)
2	- Risers connection area (upper riser balcony, hang-off region, BSDVs connections or turret internal areas) - Well head areas - Process areas - FPSO and FSO Main deck area, over cargo tanks (Note 5) - Cargo pump room - AFT offloading area	Fusible Plug and Flame (note 4) OR Flame (note 4)	2ooN (N ≥ 3) (Note 6)	1ooN (N ≥ 3)	(Note 6)
3	- Area near Flare - Top floor of process plant modules (Note17) - FWD offloading area	Fusible Plug	2oo3 (Note 7)	(Note 7)	1oo3
4	- Electric essential panels rooms - Normal panels room (Note 18) - Transformers room	Smoke	2ooN (N ≥ 3) (Note 13)	1ooN (N ≥ 3)	2ooN (N ≥ 3)
5	- Control rooms and electric equipment rooms (panels, battery, battery recharger, machinery space) - Telecommunication and Radio Rooms - Confined spaces with false floor and/or ceiling of Control Rooms		No ESD 3 required	2ooN (N ≥ 2)	Note 16
6	- Cabins - Linen Room - Stairways - Messroom - Gymnasium - Access to Engine Rooms, EIT and exhaustion ducts trunk, Pontoons - Offices - Recreation Room - Auditoriums - Crane Cabin			1ooN (N ≥ 1)	Note 16
7	- Ventilation air intake of control rooms (CCR and radio room), Muster Stations, FWD Temporary Refuge		No ESD 3 required	(Note 8)	No
8	- Warehouse - Food storage - Workshops - Laundry	Raise of Temperature Rate	No ESD 3 required	1ooN (N ≥ 1)	Note 16
9	- Laboratories - Hospital / Infirmary - Paint Store (Note 11) - Galley - Crane Equipment Room			2ooN (N ≥ 2) (Note 3)	Note 16
10	- FWP compartments - Emergency generator compartment	Flame (Note 9) and Fixed Temperature	No ESD 3 required	1ooN (N ≥ 2) (Note 15)	Note 16
11	- Electric Power Generator hood	Flame (Note 9) and Fixed Temperature		1ooN (N ≥ 2) (Notes 12, 14)	No

	- Gas Compressor hoods	Flame (Note 9) and Fixed Temperature		1ooN (N ≥ 2) (Note 12)	No
	- Enclosed spaces with internal combustion engines or daily use diesel tanks - Diesel Purifier and Centrifugal Room	Flame (Note 9) and Fixed Temperature		1ooN (N ≥ 2) (Note 15)	Note 16
12	- Sauna	Fixed Temperature	No ESD 3 required	1ooN (N ≥ 1)	Note 16

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. For adequate emergency shutdown level, see item 12 and Annex IV.
3. Besides the defined actions in the table, other actions such as: alarm, close damper or stop equipment / panel shall also comply with items 7, 12 and Annex IV.
4. Flame detector shall not be used on the top floor of process plant modules, or in areas where it could detect the flame of flare.
5. Fire detection on main deck shall be dedicated to each coaming and shall not detect the fire in the regions of the other coamings.
6. In areas simultaneously monitored 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: indicates confirmed fire, actuating the emergency shutdown level ESD-3P/3T; 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 indicates confirmed fire (PIT voting logic 2oo3), actuating the emergency shutdown level ESD-3P.
8. Close dampers and alarm in CCR are necessary.
9. UV+IR detector can be used in these areas.
10. Restrooms do not require detection.

11. In cases where the paint store is open (or surrounded by grade) and ventilated, IR3 type flame detectors can be used.
12. When activated, the system shall initiate an alarm in the CCR. 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; close dampers 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.
13. ESD by confirmed fire in essential panels room does not shutdown essential equipment.
14. The ESD-3T is only required in cases that simultaneously compromise all the main generators, according to item 12 and Annex IV.
15. In the case of FWP and emergency generator driven by diesel engines, the actions resulting from the fire confirmation are indicated in item 12 and Annex IV.
16. Fire confirmed in FWP and emergency generator compartments, as well as in the recreation areas, offices, accommodation and other areas of the accommodation module shall initiate a general alarm in the Unit only if, after two minutes, there is no acknowledgement at CCR, with the exception of paint stores, which shall start the general alarm immediately.
17. The fusible plugs network in the top floor of the modules shall be installed at a height between 2.10m and 3.0m from the floor, so that the plugs are able to cover any area that presents a risk of fire, such as: areas of piping, areas with PSVs, BDVs.
18. In case of impairment of all main power distribution, it shall be activated ESD-3T.

ANNEX II – GAS DETECTION

(For information purpose the voting logic adopted by Buyer)

DETECTOR TYPE (NOTE 1)	INSTALLATION AREA	VOTING LOGIC FOR ESD	VOTING LOGIC FOR ALARM
CH_4 Point OR CH_4 Point and Open path	- Process areas and hazardous areas (Note 2, 10) - Well head areas - Turret area - Main deck, over cargo tanks area - Risers connection area	2ooN (n ≥ 3)	1ooN
	Telecomunication equipment areas (note 8)		
	Rooms with equipment handling hydrocarbons, such as: cargo pump room. (Note 3)		
	- Closed areas air intakes (Note 4) - Equipment air intakes (Note 4, 9) - Electric Power Generator and/or Gas Compressor Hoods (Note 4)		
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 5) - Crane Equipment Room air intakes (Note 5)	2ooN (N ≥ 3)	1ooN (N ≥2)
H_2S	- Process areas and hazardous areas (Note 2) - Well head areas - Risers connection área - Turret area	2ooN (N ≥ 3)	1ooN (N ≥2)
	- Closed areas air intakes (Note 6)		
	Areas containing equipment or pipe with stagnated produced water	No ESD required	1ooN (N ≥2)
	- Crane cabin air intakes (Note 6)		
H_2	Battery room	No ESD required	1ooN (n ≥2)
CO_2	Closed areas air intakes (Note 6)	2ooN (N ≥ 3)	1ooN (N ≥1)
	- Process areas and hazardous areas (Note 2) - Well head areas - Risers connection area - Turret area		
	Process area containing equipment or pipes with rich CO_2 streams		
	- Crane cabin air intakes (Note 6)	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. Process plant areas and others areas in which a flammable atmosphere may be present, such as main deck area of FPSOs and FSOs on cargo tanks area; aviation kerosene storage area and other liquid fuels having a flash point below 60°C; areas delimited by the offloading containment basins; cargo pump room.
3. Actions upon detection at cargo pump room are specified in item 4.2.1.
4. Whenever grouping air intakes, a minimum of three detectors shall be used (N ≥ 3). Open path detectors shall be preferable. For air intakes in the process areas, will only be accepted grouping of adjacent air intakes.
5. Air intakes of crane cabins and crane equipment room shall have at least 2 detectors. The action upon detected gas, 1ooN (N ≥ 2), shall be: close dampers, turn off fans and activate cabin internal alarm.
6. 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.
7. Cancelled.
8. Installation of open path detectors shall be preferable.
9. Equipment such as: air compressors and nitrogen generation system compressors.
10. At the top floor of the process plant modules that contain flammable and/or combustible fluids, in addition to the options listed in the table, coverage of the area may be done only by open path detectors.

ANNEX III – RISK TOLERANCE MATRIX

			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
Consequences Severity Categories	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 Buyer)

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.

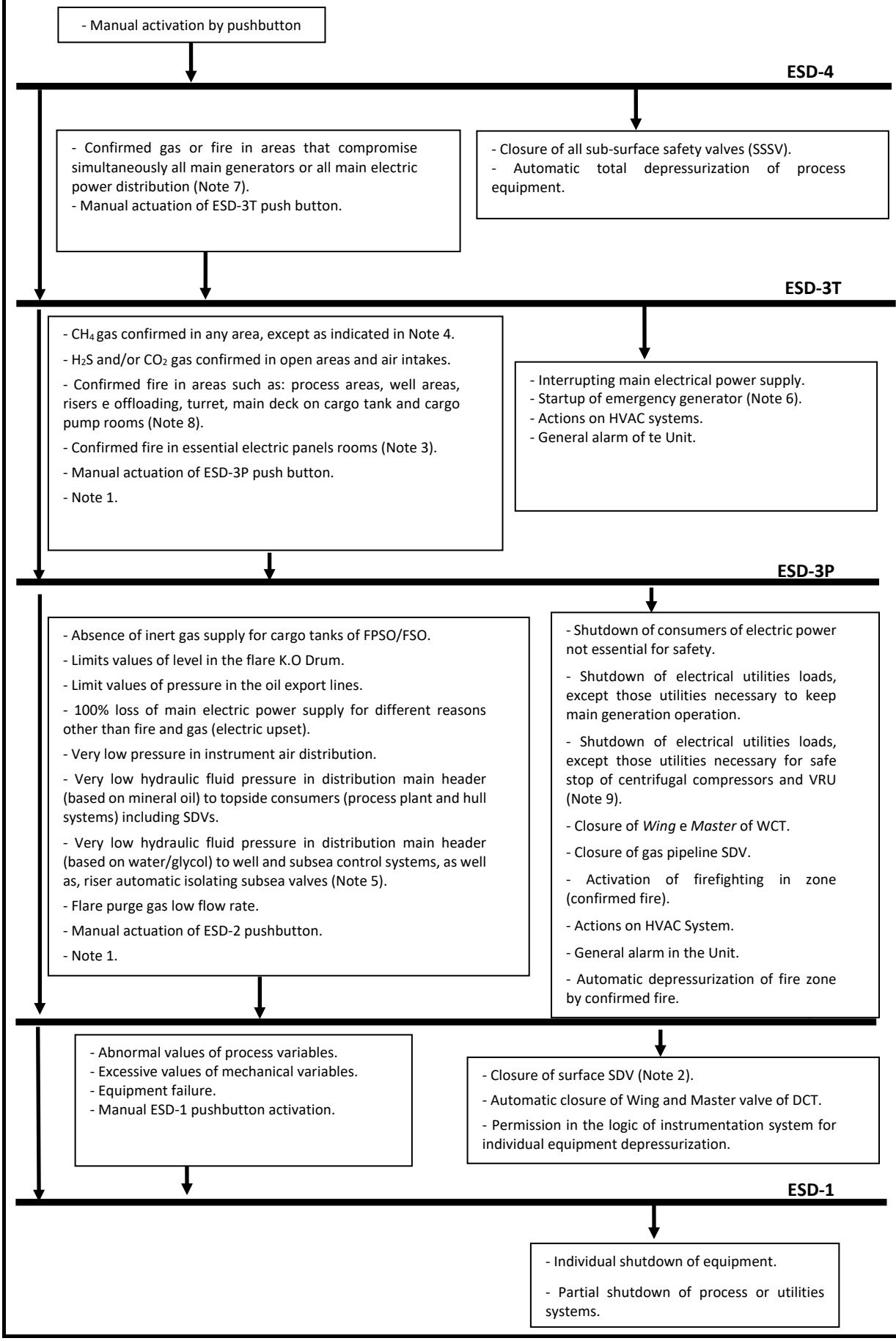
c) Level 2 (ESD-2)

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


- Manual activation by pushbutton
ESD-4
- Confirmed gas or fire in areas that compromise simultaneously all main generators or all main electric power distribution (Note 7).
- Manual actuation of ESD-3T push button.
- Closure of all sub-surface safety valves (SSSV).
- Automatic total depressurization of process equipment.
ESD-3T
- CH_4 gas confirmed in any area, except as indicated in Note 4.
- H_2S and/or CO_2 gas confirmed in open areas and air intakes.
- Confirmed fire in areas such as: process areas, well areas, risers e offloading, turret, main deck on cargo tank and cargo pump rooms (Note 8).
- Confirmed fire in essential electric panels rooms (Note 3).
- Manual actuation of ESD-3P push button.
- Note 1.
- Interrupting main electrical power supply.
- Startup of emergency generator (Note 6).
- Actions on HVAC systems.
- General alarm of te Unit.
ESD-3P
- Absence of inert gas supply for cargo tanks of FPSO/FSO.
- Limits values of level in the flare K.O Drum.
- Limit values of pressure in the oil export lines.
- 100% loss of main electric power supply for different reasons other than fire and gas (electric upset).
- Very low pressure in instrument air distribution.
- Very low hydraulic fluid pressure in distribution main header (based on mineral oil) to topside consumers (process plant and hull systems) including SDVs.
- Very low hydraulic fluid pressure in distribution main header (based on water/glycol) to well and subsea control systems, as well as, riser automatic isolating subsea valves (Note 5).
- Flare purge gas low flow rate.
- Manual actuation of ESD-2 pushbutton.
- Note 1.
- Shutdown of consumers of electric power not essential for safety.
- Shutdown of electrical utilities loads, except those utilities necessary to keep main generation operation.
- Shutdown of electrical utilities loads, except those utilities necessary for safe stop of centrifugal compressors and VRU (Note 9).
- Closure of *Wing* e *Master* of WCT.
- Closure of gas pipeline SDV.
- Activation of firefighting in zone (confirmed fire).
- Actions on HVAC System.
- General alarm in the Unit.
- Automatic depressurization of fire zone by confirmed fire.
- Abnormal values of process variables.
- Excessive values of mechanical variables.
- Equipment failure.
- Manual ESD-1 pushbutton activation.
- Closure of surface SDV (Note 2).
- Automatic closure of Wing and Master valve of DCT.
- Permission in the logic of instrumentation system for individual equipment depressurization.
ESD-1
- Individual shutdown of equipment.
- Partial shutdown of process or utilities systems.

Notes:

(1) Other variables that lead to the emergency stop, in addition to those presented in the Emergency Shutdown Diagram, shall be defined during the Project and approved by Buyer.

(2) Automatic and immediate closure of all surface SDV valves, except the fuel gas turbine power supply SDV. Other exceptions shall be evaluated during the Project and can be accepted through the evaluation and risks characterization as tolerable of the operational continuity of these systems.

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

(4) Confirmed gas in the air outlet or inside the turbine hood shall alarm in the CCR and start the shutdown of the same (ESD-1).

(5) In addition to the ESD-2, the production and gas lift wing valves of the WCTs shall be closed.

(6) The start of the emergency generator shall be trigged only from the loss of power in the main busbar.

(7) For the ESD-3T initiator, only the fire or gas scenarios that simultaneously affect all the main generators shall be considered, disregarding the auxiliary generator.

(8) The actuation of the firefighting system foreseen in shutdown level 3P shall only be started in case of confirmation of fire.

(9) In case of confirmed fire in the fire zone where these equipment are located these loads shall be immediately de-energized.

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 CO_2 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 – TECHNICAL SPECIFICATIONS

I-ET-3000.00-1300-98A-P4X-002_A.PDF

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I-ET-3000.00-5400-98G-P4X-001_D.pdf

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I-ET-3000.00-5400-98G-P4X-005_E.pdf

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I-ET-3000.00-5400-98X-P4X-001_E.pdf

I-ET-3000.00-5400-947-P4X-001_C.pdf

I-ET-3000.00-5400-947-P4X-002_A.PDF

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