PETROBRAS	**TECHNICAL SPECIFICATION**	**Nº:** I-ET-3010.00-1225-323-P4X-001	
	CLIENT: SRGE		**SHEET:** 1 of 35
	JOB: -		
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SRGE	**TITLE:** **TECHNICAL SPECIFICATION FOR VAPOR RECOVERY UNIT**		**INTERNAL**
			ESUP

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1. DEFINITIONS AND ABBREVIATIONS

1.1 DEFINITIONS:

PETROBRAS	FPSO contracting and operating company.
PACKAGER	Company responsible for project, assembly, construction, fabrication, test of compressor and project, assembly, tests, integration and furnishing of all other main equipment in the skid, including the auxiliaries systems.
PURCHASER	EPC company responsible for project, assembly, erection, construction, fabrication, test and furnishing, lift, hook up, installation and integration of all Modules of FPSO, with complete and fully operative systems in accordance with the requirements of this specification, codes and standards referenced therein. PURCHASER matches Module Supplier, Bidder, Integrator and Automation Integrator from I-ET-3010.00-1200-940-P4X-002.
VENDOR	Company hired by the purchaser or packager to supply of equipment, components of equipment, instruments, control systems, etc. that will be part of the main system to be supplied.

1.2 ABBREVIATIONS:

AEPR	Automation & Electrical Panels Room
AMS	Asset Management System
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
AVM	Anti-Vibration Mounting
BDV	Blow Down Valve
CCR	Central Control Room (located in the Hull Accommodation)
CCR-ATR	Central Control Room – Automation and Turbomachinery Room
CGS	Compressor Governor System
CSS	Control and Safety System
Cv	Coefficient flow valve
DGS	Dry Gas Seal
DIO	Optical Internal Distributor
ESD	Emergency shutdown
FAT	Factory Acceptance Test
FGS	Fire and Gas System
FIT	Factory Integrated Test
FPSO	Floating Production Storage and Off-loading
FPU	Floating Production Unit
HMI	Human Machine Interface
IGCR	Inert Gas Compressor Running

I/O	Input/Output
LAN	Local Area Network
MCC	Motor Control Center
MMS	Machinery Monitoring System
MPA	Automatized Procedures Module (Portuguese: Módulo de Procedimentos Automatizados)
MPS	Machinery Protection System
MRT	Mechanical Running Test
OEM	Original Equipment Manufacturer
OPC UA	Open Platform Communications Unified Architecture
PAS	Package Automation System
PAT	Pulsation Acceptance Test
PCS	Process Control System
PLC	Programmable Logic Controller
PMS	Power Management System
PSD	Process Shutdown System
PSV	Pressure Safety Valves
PCV	Pressure Control Valves
PDCV	Pressure Differential Control Valve
P&ID	Piping and Instrument Diagram
RESD	Emergency Shutdown Relay
RFI	Radio Frequency Interference
RIO	Remote I/O Panel
SAT	Site Acceptance Test
SDV	Shut Down Valve
SGCS	Seal Gas Conditioning System
SGP	Seal Gas Panel
SLT	Sound Level Test
SIT	Site Integration Test
SOS	Supervision and Operation System
SYAT	Shipyard Acceptance Test
TAP	Performance Acceptance Test
TCP/IP	Transmission Control Protocol/Internet Protocol
UCP	Unit Control Panel
UCP_HMI	Human Machine Interface for Unit Control Panel

2. GENERAL

2.1 Rotary compressor for Vapor Recovery Unit package shall be dry screw type in accordance with API std 619, last edition.

2.2 The complete Vapor Recovery Unit package shall be designed for minimum 30 years of operation installed on the FPSO.

2.3 All documents listed in Material Requisition and specific project's "VAPOR RECOVERY UNIT PACKAGE SPECIFICATION", as stated in the DOCUMENT LIST, are mandatory, as well as the electrical, automation and safety requirements for Vapor Recovery Unit package unit described in these documents.

2.4 All components of the system shall be suitable for offshore environment, throughout the whole platform service life, under all operational conditions and submitted to Unit motions and accelerations described in PETROBRAS specifications.

2.5 PACKAGER and PURCHASER shall be entirely responsible for material selection on items not specified by PETROBRAS and shall inform material of all main parts according to ASTM code. All bolts and nuts shall be supplied with PACKAGER and PURCHASER certificates and fully marked according to applicable ASTM standard.

2.6 All shop punch lists shall be cleared before shipment.

2.7 Equipment shall be prepared for outdoor storage according to PURCHASER specifications.

2.8 PACKAGER and PURCHASER shall specify the products to be used for preservation of the equipment components and spare parts, their removal and reapplication methods and the application date. Such data shall be summarized on two tags to be securely fastened on all equipment and outside of each crate. If rust preventives are required, volatile products shall not be applied.

2.9 Hazardous and toxic materials with associated adverse health effects shall be avoided or minimized. PACKAGER, PURCHASER and VENDOR are encouraged to promote their replacement. Asbestos hazardous and toxic components shall not be used in the materials and equipment supplied for this project or for this plant or facility. As the use of such materials will not be tolerated, PETROBRAS strongly recommends PACKAGER, PURCHASER and VENDOR to take all necessary measures to ensure their use is fully avoided throughout this project. Material safety datasheets may be required by PETROBRAS any time, to demonstrate that a particular material has not been, is not and will not be used throughout all stages of this project.

2.10 All equipment, components and panels shall have a nameplate easy to access, to view and read. Nameplate shall be made in stainless steel AISI 316L and bolted (with stainless steel elements) to the equipment. Layout drawings shall be submitted to PURCHASER approval. Nameplates shall contain the following information, in Brazilian Portuguese language:

- Client name;
- Client job;
- Client area;
- Supplier name;
- Series number and model;
- Year of manufacturing;
- Main design and test data:
- Specific data;
- Tag number;
- Purchaser's requisition number (RM);
- Purchaser's request for quotation number (RFQ);
- Purchaser's order number (PO);
- Empty weight;

pressure, temperature, voltage, rotation, etc;

- Design code.

2.11 All safety signals shall be in Portuguese language.

3. CONSTRUCTION FEATURES

3.1 Compressor casing shall be made of cast steel. Rotors shall be solid type, made of forged steel. Ductile material will not be accepted.

3.2 Injection liquid for normal operation is not acceptable to avoid high discharge temperatures.

3.3 Compressor bearings shall be hydrodynamic type.

3.4 All bearings shall be designed to minimize oil foaming and prevent oil whirl at any operating speed.

3.5 The compressor train centerline shall be oriented in the fore/aft direction in case of installed on a FPSO (Floating Production Storage and Off-loading).

3.6 Connections between pipes flanges and suction and discharge nozzle flanges of compressor shall be provided by removable spools to facilitate compressor remove and disassembly. Removable spools shall not have any process connection for instruments. The removable spool shall have two borescope accesses (suction and discharge), closer to the compressor flanges. These access with blind flange connections shall be quick and easy to open and close.

3.7 Clamp connections are not acceptable.

3.8 PACKAGER and PURCHASER shall consider the presence of free water and corrosive agent (H2S 170 ppm or project datasheet value, whichever is greater and CO_2 5% vol. or project datasheet value, whichever is greater) even when not specified of all compressor operating cases, and its corrosive contents. In case of free water carry over, a chlorides content contamination shall be foreseen and considered during the compressor material selection.

3.9 PACKAGER and PURCHASER shall also consider, in addition to steady state operation, the transient conditions during: plant pressurization; compression system starts and stops; stopping compressor and depressurizing plant.

3.10 All materials that are exposed to hydrocarbons containing hydrogen sulphide shall follow the requirements of ISO 15156 for sour service for the lowest anticipated pH and the highest H_2S partial pressure.

4. ACCESSORIES AND AUXILIARIES

4.1 Piping

4.1.1 Except where indicated, all piping and accessories within equipment package limit shall be in accordance with PACKAGER piping specification and international standards.

4.1.2 All auxiliary piping requiring field connections shall be brought to the skid edge and shall be flanged.

4.1.3 Manual block valves and spectacle/blind flanges shall be provided at all battery limits such as inlet and outlet nozzles, drain lines, etc. PACKAGER and PURCHASER consider piping standards per each specific project's "PIPING SPECIFICATION FOR TOPSIDES" as stated in the DOCUMENT LIST. Manual valves shall be installed at the skid edge to be operated, especially valves for draining the compressor casing. Access to all manual valves shall be free.

4.1.4 All equipment shall have sufficient flexibility in all pipe and duct connections.

4.1.5 The interconnecting pipework between auxiliary skid and the main baseplate shall be provided by PURCHASER. The interconnections between the gas lines shall be routed above the skids. The pipes arrangement shall avoid the accumulation of liquid (siphon). Drainage shall occur in all lower parts of the piping regardless of FPSO motion under all operational conditions and submitted to Unit motions and accelerations described in PETROBRAS specifications.

4.1.6 T-type strainer shall be installed in the suction line, close to each stage of compression. It shall be removable type without disassembly of the piping.

4.1.7 Systems/equipment isolation shall comply with Isolation Guidelines requirements from specific project's document "DESCRIPTIVE MEMORANDUM – PROCESS".

4.2 Couplings and coupling guards

4.2.1 PACKAGER is responsible for all couplings within the package, including those for auxiliary equipment.

4.2.2 Coupling for main equipment shall be a stainless-steel flexible-element, non-lubricated type.

4.2.3 Couplings and coupling guards shall be according to API 671 latest edition. PACKAGER and PURCHAGER shall submit to PETROBRAS main equipment coupling data sheet according to API 671 latest Edition.

4.2.4 All coupling guards (including those for auxiliary equipment) shall be rigid, fully enclosed, in non-sparking material and solely fitted to equipment baseplates, not fastened. Safety coupling guards (without feet) are also acceptable. In case of failure, guards shall be able to retain broken parts, for personnel protection (OHSA 1910.219 shall be complied). Coupling guards shall be designed to allow removal without disassembling the coupling and shall be constructed so that routine inspections are performed by means of strobe light, with the equipment running.

4.2.5 Coupling guard drains shall have sight glasses in horizontal drain lines. The coupling guard shall not be used as a normal operating lube oil drain path.

4.3 Baseplate

4.3.1 Main baseplate shall be capable of supporting the stresses arising from platform motions and shall be provided with three (3) point supports and Anti-Vibration Mounting (AVM).

4.3.2 Baseplate shall be rigid enough to avoid permanent distortion during lifting, shipment and operation. When the baseplate is lifted, with all equipment mounted, beam deflection shall not exceed L/400 (L is the total baseplate length).

4.3.3 Driver, driven machine and transmission, oil system, seal panel and local panel shall be mounted on a single baseplate including auxiliaries. PACKAGER and PURCHASER shall submit layout to PETROBRAS comments and approval.

4.3.4 Baseplate shall be provided with nonskid decking covering all walking and work areas. Solid decking plate shall be removable where required for maintenance.

4.3.5 All furnished skids shall be sufficiently stiff to withstand all vibration loads induced by the equipment and transfer them to the deck beams.

4.3.6 Skid mounted assemblies shall be constructed in order to not allow equipment or parts be dismounted during lifting.

4.3.7 No equipment/component shall protrude beyond the skid limits. In cases where it cannot be avoided, required protection against mechanical damage shall be provided.

4.3.8 Each skid shall be provided with facilities (pad-eyes, lugs, bollards and spreader bar) for lifting, having suitable access for rigging. The estimated lifting load and safety factor for each point shall be informed in PURCHASER proposal. Main lifting points shall not be welded to the beam flange, unless the strength level is low enough or if the beam flange has a suitable thickness.

4.3.9 All equipment to be mounted on skids shall allow on-field leveling and alignment using jacking screws (in both plane directions) and precision type shims. Total shim thickness shall not exceed 6.35mm and the number of shims shall be kept to a minimum. Any additional height shall be made up of solid stainless-steel plate.

4.3.10 All skid mounted equipment containing liquids that shall be drained onto the skid area, shall be fitted with drip pan underneath the equipment and provided with flanged nozzle with sufficient slope. Drip pans draining system shall be designed considering the total deluge flow over the skid. Drain nozzles arrangements shall be provided at the skid edge with appropriate piping, blocking valve, strainer and water seal, in order to perform drainage regardless of FPSO motion.

4.3.11 Fasteners (including washers) and shims shall be constructed in stainless steel AISI 316L.

4.4 Support system

4.4.1 All required supporting system (including spring supports, structure, etc.) shall be supplied (for on-skid elements) or specified with all design requirements (such as loads, position, forces, etc.) by PACKAGER and PURCHASER.

4.5 Insulation

4.5.1 All required insulation for personnel protection or machine thermal efficiency shall be applied and provided by PACKAGER and PURCHASER.

4.5.2 Insulating shall ensure a temperature below 60˚C over the external surface for personnel protection.

4.5.3 To prevent corrosion under insulation, only non-hygroscopic insulation material shall be used.

4.5.4 In order to avoid damages during transportation and erection, insulation shall be carried out after final installation before sail away.

4.6 Oil system

4.6.1 The mineral lube oil system shall be designed per API 614 for special purpose (latest edition) to supply lubricating oil to the driver, gearbox and driven equipment. Special considerations shall be given to the FPSO motion in order to guarantee bearing lube and its oil drainage during normal operation and post-lube.

4.6.2 Special consideration shall be given to the presence of dirt, debris and any foreign matter in sensitive parts (bearings, for instance). Provisions shall be made for by-pass of sensitive parts while system flushing operations are performed.

4.6.3 PACKAGER and PURCHASER shall propose its standard oil system configuration, but the configuration of the coolers and filters shall be as Oil System Data Sheet.

4.6.4 Lube oil system shall be monitored with PACKAGER and PURCHASER specification, international standards for this system and Oil System Data Sheet.

4.6.5 PACKAGER and PURCHASER shall provide sampling points for oil analysis at reservoir, supply manifold and oil return line of each equipment. Sampling facilities shall be permanent, fitted with valves installed in T-type connections, oil spill and drip collectors and spillback lines to be routed back to oil reservoir. Sampling arrangement shall enable samples taken during operation.

4.6.6 Except for oil pumps, all piping, tubing, wetted metallic parts and appurtenance including lube oil and control oil systems shall be in stainless steel AISI 316L.

4.6.7 Socket welds for piping and tubing is prohibited.

4.6.8 Reservoirs:

- Reservoir shall be provided with filling connections (with filter), level indicator sight glass, antifoaming devices, accessible manholes, valve drain at skid edge and include provisions for nitrogen purges;
- All return lines shall be top entry type, extending inlet duct inside the reservoir to below minimum operating level in order to avoid foaming ;

- Reservoir shall be designed to facilitate air separation between the bearing return and pump supply;
- Vents shall be fitted with oil vapor separator in order to recover oil due to evaporation losses and environmental protection (PACKAGER and PURCHASER shall guarantee maximal oil losses of five (5) ppm). Vents shall be dimensioned with the same size as the oil return header, at least;
- An electric lube oil heater shall be provided, interlocked with a low-level and oil temperature control. This device shall be designed to facilitate removal without having to drain the reservoir or stop the equipment.

4.6.9 The configuration for pumps shall be:

- Main oil pump: Shaft-driven (preferable) or electric motor driven (AC power);
- Stand-by pump: Electric motor driven (AC power);
- Main and stand-by pumps shall have the same capacity;
- If the main pump is electrically driven, then main and stand-by pumps shall be identical.

4.6.10 Oil coolers shall be multi-plate duplex type with changeover valve. Cooler shall have provision for future increase of the number of plates. The cooling water pressure shall be lower than oil pressure at heat exchanger interior. The material shall be selected as following:

- Stainless steel AISI 316L, if closed loop cooling water system;
- Titaniun, if open loop cooling water system.

4.6.11 Oil filters shall be duplex (twin) with changeover valve. The canisters, transfer valves and piping for oil filter system shall be stainless steel AISI 316L construction. Filter element material shall be corrosion and water resistant. There shall be no by-pass around any filter.

4.6.12 Lube oil system shall have rundown tank for emergency conditions. The rundown tank shall have enough capacity for bearing cooling during coast-down time. The oil supply time by pumps and rundown tank shall not exceed fifteen minutes after the machine has stopped.

4.6.13 PACKAGER and PURCHASER shall inform all data and characteristics of electric load (as power, source, etc.) for each pump driver, heater, etc. in proposal phase. PURCHASER will furnish all electrical utilities required by PACKAGER, considering platform available voltages as stated in I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.

4.6.14 API data sheets for pumps and heat exchangers shall be included in proposal.

4.6.15 All oil vents shall be interconnected, fitted with flame arrestors and routed to a safe area. All oil drains shall also be interconnected and routed to oil reservoir. Flame arrestor material shall be compatible with vent line material.

4.6.16 Vent line shall be designed considering FPSO motion under all operational conditions and submitted to Unit motions and accelerations described in PETROBRAS specifications in order to avoid liquid seal.

4.6.17 PACKAGER and PURCHASER shall provide all data of oil system equipment and fluid as oil consumption, oil complete specification and filter elements life.

4.7 Gearbox

4.7.1 Gearbox shall be designed in accordance with API613 last edition. It shall be included a device to allow manually rotation of the shafts for maintenance purpose (such as shaft mechanical alignment or borescope inspection).

4.7.2 Gearbox shall be designed as a “stand-alone” unit whereby no external thrust loads shall be imposed upon the gearbox by other equipment.

4.7.3 Shaft oil seal shall be easily accessible for removal and re-installation without removing couplings.

4.7.4 All bearings shall be pressure lubricated and fully replaceable at field.

4.8 Pressure vessels

4.8.1 For nozzles less than 2” in nominal diameter, forged steel couplings may be used. Couplings shall be at least class 6000#, for socket weld.

4.8.2 All nozzles having a nominal diameter of 2” or greater, shall be flanged, except when specified for butt weld in the piping.

4.8.3 The minimum nominal diameter of nozzles intended for any purpose shall ¾”.

4.8.4 Only full penetration welds are permitted.

4.8.5 All shell reinforcements, integral or not, shall always have the same shell P-number.

4.8.6 The minimum degree of radiographic examination for weld inspections according table UW-12 shall be full or spot.

4.9 Enclosure

4.9.1 If necessary, according to noise control requirements item, each vapor recovery unit shall have its own enclosure and shall be stainless steel AISI 316L.

4.9.2 Enclosure shall consist of removable panels and doors supported on a heavy-duty frame. The enclosure shall be fabricated and bolted so that it can be completely disassembled. Open roof sections (meshed plate) shall also be removable. Enclosure shall consist of removable panels and doors, open roof sections (meshed plate), all supported on a heavy-duty frame. The enclosure shall be fabricated and bolted so that it can be completely disassembled. No enclosure pressurizing system or internal fire fighting system are to be installed. Fire fighting system shall be the one for the module.

4.9.3 Joints between panels, skid, floor, piping, ducts, cabling and shaft penetrations shall be properly sealed to prevent noise propagation.

4.9.4 Enclosure shall be provided with wide full-opening side doors to allow adequate maintenance access, assembly and disassembly of all parts of the equipment. Hinges shall be strong enough to withstand constant use and wear.

4.9.5 Enclosure doors shall be fitted with lockable handles and, in service, these doors shall be kept locked. Door locations shall be clearly marked, both inside and outside the enclosure.

4.9.6 Access doors shall be fitted with viewing windows.

4.9.7 Enclosure shall be provided with internal lighting adequate inspection and maintenance in the any area into the enclosure.

4.9.8 Gas (heavy hydrocarbons and H2S) detection system shall be provided.

4.9.9 Enclosure material, bolts, fasteners, nuts, door hinges, locks and latches shall be stainless steel AISI 316L.

4.10 Dry Gas Seal (DGS) system

4.10.1 All dry gas seal system and components shall be provided by the DGS manufacturer in accordance with API 692 (latest edition), considering all operating conditions (including pressurizing start-up, normal and emergency shutdown, in settling-out, etc.) and site available utilities.

4.10.2 The seal gas supply shall be available before starting compressor package pressurization and continue to operate as long as the pressure in the process plant is greater than 0.3 barg.

4.10.3 PACKAGER and PURCHASER shall furnish all technical details about DGS system during proposal phase, including seal leakage detection method.

4.10.4 PACKAGER and PURCHASER shall include in proposal a reference list showing his experience with proposed DGS system, highlighting the units with similar services.

4.10.5 DGS system shall always assure that the seal gas pressure is positive in relation to the balance line pressure and a minimum seal gas flow across the final labyrinths to avoid seal contamination for all operations conditions such as: pressurizing, starting, operating, normal stop or emergency shutdown during depressurization.

4.10.6 DGS shall be bi-directional tandem type with intermediate seal gas labyrinth for each shaft end. Primary and secondary seals rotating faces material shall be made of silicon carbide, at least. The conditioned fuel gas (normal operation) and process gas (during normal operation when fuel gas is not available due to fuel gas system upset) and high pressure nitrogen (for commissioning) shall be used as primary seal gas supply. The high pressure nitrogen as primary sealing gas source shall take into account the primary seal gas requirement (pressure and flowrate) and available utilities.

4.10.7 Conditioned nitrogen shall be used as secondary seal and separation gas supply. Separation seals type selection shall minimize nitrogen consumption in running and stop condition. Available nitrogen flow rate shall be consulted prior to separation seal type selection, and if possible, carbon ring non-contacting is the preferred separation seal type. Labyrinth seal for separation seal type shall not be acceptable.

4.10.8 Where different seal designs or pressure ratings are employed in adjacent casings on the same compressor package, the seal cartridge shall be designed to prevent the incorrect mounting in different casings.

4.10.9 All DGS include piping, Pressure Safety Valves (PSV), Pressure Control Valves (PCV), check valves, orifice plates, valves (including internals components) and the other devices shall be made from stainless steel AISI 316L and shall be supplied by PACKAGER and PURCHASER.

4.10.10 PACKAGER and PURCHASER shall provide a dedicated Seal Gas Panel (SGP) for each compressor set.

4.10.11 All PSV and check valves on venting piping, downstream each seal, control valves and other necessary valves for DGS system shall be provided by PACKAGER and PURCHASER. PSV shall be sized to assure venting capacity during a seal failure and minimize potential damage and uncontrolled leakage to atmosphere. PACKAGER and PURCHASER shall conduct a Vent Study according to Annex A of API 692 Part I to demonstrate venting capacity.

4.10.12 All lines connected to flare system shall be capable to be isolated for maintenance of upstream equipment/accessories by means of an isolation valve (locked open) supplied by PACKAGER and PURCHASER.

4.10.13 PACKAGER and PURCHASER shall supply the DGS system fully fitted with piping and support on main equipment baseplate.

4.10.14 All piping, valves and fittings shall have insulation and/or heating, where applicable.

4.10.15 PACKAGER and PURCHASER must guarantee nitrogen supplying for seal system during all compressor cases including pressurization, pressurized, depressurization and lube oil running conditions. Therefore, the nitrogen supply capacity shall be defined during the detailed design in accordance with the Flare System depressurization strategy. Complete high pressure nitrogen storage system including intensifier is acceptable by means to be defined by PURCHASER (nitrogen bottles or pressure vessel). A buffer vessel storage system at tie-in pressure is acceptable for fuel gas.

4.10.16 The Nitrogen shall be also conditioned by Seal Gas Conditioning System (SGCS).

4.10.17 DGS system shall be provided with all control, monitoring and safeguarding instrumentation, including monitoring primary vent by pressure or flow (trip) and secondary vent by pressure (alarm only) to identify DGS damage.

4.10.18 PACKAGER and PURCHASER shall supply any pressure control valves if necessary to guarantee minimum back-pressure at DGS primary vent line.

4.10.19 A Seal Gas Conditioning System (SGCS) shall be furnished by DGS supplier and shall be designed to remove all particles and liquids from the fuel gas system, high pressure nitrogen system and main compressor discharge gas. This conditioned gas will supply primary seal, avoiding any kind of failure. PACKAGER and PURCHASER shall guarantee a clean gas flow, at least 20ºC to the right of depressurized curve tangent to the dew point line (see Figure B.1 – Annex B – API-692), and at least 15 kPa (at upstream of primary seal) higher than compressor end with the higher sealing pressure inboard of the process side labyrinth. The SGCS shall include as a minimum:

- Pressure Differential Control Valve (PDCV) to control seal gas supply;
- Seal gas K.O. Drum to collect the condensate with automatic drain by LV and LSH;
- Twin filter arrangement (2x100%) for solids retention with on-line changeover capability;
- Electric heater with 10% spare electrical resistance elements. Sensors for seal gas temperature control shall be installed as close as possible to the DGS inlets. Heater power panel, complying with I-ET-3010.00-5140-741-P4X-004 - SPECIFICATION FOR LOW-VOLTAGE GENERIC ELECTRICAL PANELS FOR OFFSHORE UNITS. When eletric heater is not being demanded (depressurized compressor) it shall be kept energized (warmed) by heater panel to avoid low insulation in the resistive elements; Heater panel temperature indications shall be provided at HMI;
- The SGCS components shall be installed according to the sequence stated above (PDCV, KO drum, filters and heater);
- All seal gas lines between the heater and DGS inlets shall be thermally insulated for heat conservation (HC);
- If other valves (PCV or PDVC) are supplied, beside the required at the inlet of the seal gas treatment system, coalescer filters downstream of the valves shall also be provided. These coalescer filters shall have automatic drain by LV and LSH;
- The SGCS logic control shall be designed to ensure a safe and reliable operation for each compressor casing mounted on the main baseplate for all operating conditions (pressurizing, starting, operation, normal stop and emergency shutdown;
- Automatic drains shall only be opened when the compressor is pressurized.

4.10.20 PACKAGER and PURCHASER shall provide a dedicated seal gas conditioning skid for each compressor casing mounted on the main baseplate.

4.10.21 In order to minimize the DGS system footprint, PACKAGER and PURCHASER may propose keeping all the appurtenances described above a solution integrating the SGP (Seal Gas Panel) with the SGCS (Seal Gas Conditioning System) to be submitted in the technical proposal to PETROBRAS´s approval.

4.10.22 Drains shall be provided for seal gas KO Drum, filters and all seal lines, including primary and secondary vent lines. Drainage shall occur in all lower parts of the piping. The pipes arrangement shall avoid liquid accumulation (siphon).

4.10.23 The design of Seal Gas Conditioning System (SGCS) shall also consider the starting condition case where seal gas (fuel gas or process gas) has lower temperature and pressure when compared to normal condition.

4.10.24 Nitrogen consumption shall be minimized at FPSO normal operation and at emergency condition. Automatic isolation valves with end-course positioning key, pressure transmitter and associated logic shall be included for nitrogen lines.

4.10.25 SDV and associated logic shall be included to isolate seal gas (fuel gas or process gas) line tie-in when compressor is not pressurized.

4.11 Pressure Relief and Drainage

4.11.1 The seal gas system design pressure shall be at least the same of compressor suction vessel or the pressure and temperature at the seal gas system when seal gas PDCV fails (fail open), whichever is greater.

4.11.2 PACKAGER and PURCHASER shall inform maximum allowable pressure for each shaft-end seal casing.

4.11.3 The elastomers applied to compressors and auxiliary systems components such as DGS (Dry Gas Seal), SGP (Seal Gas Panel), SGCS, (Seal Gas Conditioning Skid) etc, in contact with process gas, shall be select from the requirements recommendations and procedures of qualification and testing in according with the criteria established in ISO 23936-2, to prevent explosive decompression of internal components, as well as to exhibit long term resistance behavior under thermal and dynamic cycle conditions, including the depressurization rate recommended in the API 521 standards.

4.11.4 Seal gas supply lines drainage operation shall be carried out with either pressurized or depressurized compressor. The primary vent lines and secondary vent lines drainage shall be performed only with depressurized compressor. The seal gas and primary vents valves shall be configured with double block to closed and opened drain. The secondary vents valves shall be configured with simple block to opened drain. All valves shall be installed on the edge of the skid. Manual pressurized drainage lines shall be connected to a closed drain system.

4.11.5 Seal gas KO Drum and Coalescer filters drains of SGCS (Seal Gas Conditioning System) and SGP (Seal Gas Panel) shall be carried out with either pressurized or depressurized compressor. The valves shall be configured with double block to closed and opened drains. All valves shall be installed on the edge of the skid. Manual pressurized drainage line shall be connected to a closed drain system. Automatic drainage liquid of seal gas KO Drum and Coalescer filters shall be drained to the same piping that will receive the liquid from the compressor suction process KO Drum.

4.11.6 All drains for compression system, like vessels, seal gas KO Drum, filters, seal gas supply lines, primary and secondary vent lines, shall be installed in all lower parts of the piping to enable liquid removal during start-up procedures. The pipes arrangement shall avoid the accumulation of liquid (siphon).

4.12 Silencers

4.12.1 Silencers (acoustic isolation) on suction and discharge piping lines shall be provided. The silencers shall also be pulsation suppressors.

4.12.2 All Silencers (inlet and discharge) shall be in stainless steel AISI 316L.

4.12.3 Analysis of pulsation, noise suppression and all related mechanical analysis shall be performed according to Annex C.

5. AUTOMATION

5.1 General requirements

5.1.1 Package Automation System (PAS) shall supervise and control the compression service that include motocompressor and auxiliaries as well as its compression process plant.

5.1.2 PACKAGER will be responsible for all required control interlocking interface and communications architecture with the systems/process plant outside its scope of supply, in order to guarantee the proper start-up, operation, pressurized and depressurized shutdown.

5.1.3 Unit Control Panel (UCP), Remote I/O Panel (RIO), Machinery Protection System (MPS), Machinery Monitoring System (MMS) interface, Compressor Governor System (CGS), Asset Management System (AMS) interface and Device and Field Instrumentation are part of Package Automation System (PAS).

5.1.4 Package Automation System (PAS) shall be designed to ensure safe and reliable operation, performing sequencing, interlocking, protection, control and monitoring during pressurizing, starting, operation, normal stop, emergency shutdown, during depressurization and depressurized stop. The PAS shall not allow undesirable nor unsafe operations. PAS shall be furnished functionally assembled and tested.

5.1.5 Each compression package shall have its own PAS. Each PAS shall operate independently, so a failure of any component in the compression package train does not affect the availability of any other compressor package train.

5.1.6 Compressor will be controlled by means of a suction pressure controller. The compressor capacity control system shall be provided by PACKAGER and PURCHASER and shall operate in the range of 0 to 100% of maximum flowrate for each stage. The control shall be done through the recycle valve (spillback valve).

5.1.7 The PAS shall be designed according to the requirements described in specifications I-ET-3010.00-1225-323-P4X-001 – TECHNICAL SPECIFICATION FOR VAPOR RECOVERY UNIT and I-ET-3010.00-1200-800-P4X-002 - AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGE UNITS and specifications required by international standards and Classification Society's requirements, as well as the following specifications:

- I-DE-3010.00-5140-700-P4X-003 - GROUNDING INSTALLATION TYPICAL DETAILS;
- I-DE-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM;
- I-ET-3010.00-1200-800-P4X-010 - CRITERIA FOR ESTABLISHING CABLE CODES AND CABLE GLAND CODES;
- I-ET-3010.00-1200-800-P4X-013 - GENERAL CRITERIA FOR INSTRUMENTATION PROJECTS;
- I-ET-3010.00-1200-850-P4X-002 - ASSET MANAGEMENT SYSTEM (AMS);
- I-ET-3010.00-5140-700-P4X-001 - SPECIFICATION FOR ELECTRIC DESIGN FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-700-P4X-003 - ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-700-P4X-004 – PN-5140001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-700-P4X-005 - REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS;
- I-ET-3010.00-5140-712-P4X-001 - LOW-VOLTAGE INDUCTION MOTORS FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-712-P4X-002 - MEDIUM-VOLTAGE INDUCTION MOTORS FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-741-P4X-001 - LOW-VOLTAGE MOTOR CONTROL CENTER AND SWITCHGEAR FOR OFFSHORE UNITS;

- I-ET-3010.00-5140-741-P4X-004 - SPECIFICATION FOR LOW-VOLTAGE GENERIC ELECTRICAL PANELS FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE;
- I-ET-3010.00-5143-700-P4X-001 – ELECTRICAL SYSTEM PROTECTION CRITERIA;
- I-ET-3010.00-5500-854-P4X-001 - MACHINERY MONITORING SYSTEM (MMS);
- I-ET-3010.00-5520-800-P4X-004 - AUTOMATION NETWORK REQUIREMENTS;
- I-LI-3010.00-5140-797-P4X-001 - ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST;
- I-DE-3010.00-5140-797-P4X-002 - ELECTRICAL SYSTEM AUTOMATION TYPICAL ACTUATION DIAGRAMS;
- I-ET-3010.00-5140-700-P4X-007 - SPECIFICATION FOR GENERIC ELECTRICAL EQUIPMENT FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-772-P4X-002 - SPECIFICATION FOR LOW-VOLTAGE FREQUENCY CONVERTERS, SOFTSTARTERS AND INVERTERS FOR OFFSHORE UNITS.

5.1.8 Additionally, the PAS shall also be designed according to the requirements described in each specific project's documents stated in the DOCUMENT LIST:

- AUTOMATION INTERFACE OF PACKAGED UNITS
- AUTOMATION AND CONTROL ARCHITECTURE
- INSTRUMENTATION ADDITIONAL TECHNICAL REQUIREMENTS
- FIELD INSTRUMENTATION
- EQUIPMENT LIST
- AUTOMATION AND CONTROL SYSTEM FUNCTIONS
- AUTOMATION NETWORK DESCRIPTION

5.1.9 All instrumentation and alarms/trips mentioned in the data sheets and process plant P&IDs are the minimum required by PETROBRAS. PACKAGER and PURCHASER may indicate other instrumentation and alarms/trip for general protection and monitoring according to their experience and for compliance with Classification Society's requirements and submit in technical proposal to PETROBRAS for approval.

5.1.10 PACKAGER shall supply Unit Control Panels (UCP) and Remote I/O (RIO) panels. UCP will be installed at the Automation and Electrical Panels Room (AEPR) and RIO will be installed in the field by PURCHASER.

5.1.11 All requirements for PAS shall be checked during Factory Acceptance Test (FAT), Shipyard Acceptance Test (SYAT) and Site Acceptance Test (SAT) according to IEC 62381.

5.1.12 PAS shall have its package classification according to Technical Specification I-ET-3010.00-1200-800-P4X-002 - AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGE UNITS, and per each specific project, the following documents stated in the DOCUMENT LIST: “AUTOMATION INTERFACE OF PACKAGE UNITS” and “AUTOMATION AND CONTROL SYSTEM FUNCTIONS”.

5.1.13 PACKAGER and PURCHASER shall provide to PETROBRAS all keys, drivers, manuals, installation media and licenses of all software inside package, including all development tools and comply with requirements from specific project’s document “DESCRIPTIVE MEMORANDUM – AUTOMATION AND CONTROL SYSTEM - SCOPE DEFINITION”. No software access restrictions will be accepted by PETROBRAS.

5.1.14 All proper means of electrical and environmental protection shall be applied to all instruments and electrical equipment, particularly those located in hazardous areas and/or an aggressive saline air environment. Instruments and electrical equipment shall comply with IEC-60079 and they shall be at least IP-56.

5.1.15 In order to guarantee adequacy to IEC-61892-7, all instruments, electrical equipment and panels installed in field open areas shall be certified to operate in Zone 2, including certified enclosures against explosive atmosphere are mandatory.

5.1.16 PACKAGER and PURCHASER shall provide a local instrumentation board (rack) installed on the equipment baseplate, as mentioned on data sheets and process plant P&IDs. Oil filled gauges shall be provided for analogical instruments subject to high vibration levels.

5.1.17 PAS shall not be restarted without manual acknowledgement of the shutdown conditions.

5.1.18 PAS shall send a “Start Request” hardwired output signal from UCP to PMS to request automatic field forcing in main generators, in order to reduce voltage drop during starting. PAS shall receive “Starting Permission” hardwired input signal from PMS to UCP after the voltage at busbar that feeds the load reach the pre-selected adjustable value, according to Electrical Studies.

5.1.19 The FPSO electrical system will supply electric power to compression system according to the I-ET-3010.00-5140-700-P4X-003 – ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.

5.1.20 The 220 Vdc power to the PAS must be guaranteed during black shutdown event in the time required to complete package depressurization. This time shall be defined during detail design in accordance with the Flare System depressurization strategy.

5.1.21 PURCHASER and PACKAGER shall not supply any components (including hardware, firmware, software etc.) for PAS that are obsolete or that has Declaration of Obsolescence.

5.2 PAS hardware

5.2.1 The Unit Control Panels (UCPs), to be located in the Automation and Electrical Panels Room (AEPR), shall have front and rear access doors, IP22 protection level and cable entry from the bottom of the panel. The internal temperature shall be kept bellow 30 ºC. Each UCP shall include, at least:

- One dedicated safety system and one dedicated control system, each system shall be implemented using Programmable Logic Controllers (PLC);
- HMI hardware (UCP_HMI);
- Ventilation exit at the top;
- Network switch and DIO optical fiber;
- Acknowledgment and reset push-buttons;
- Compressor start and stop push-buttons in the HMI. Compressor start and stop and lamp status push-buttons can also be by hardware on the panel front door;
- Emergency shutdown retentive push-button in the HMI. Emergency shutdown retentive push-button shall also be by hardware on the panel front door;
- Auxiliaries devices start-up and stop push-buttons and switches (to define main and stand-by) in the HMI. Auxiliaries devices start-up and stop push-buttons and switches can also be by hardware on the panel front door;
- Sound alarm;
- Start counter and hourmeter in the HMI. Start counter and hourmeter shall also be by hardware in the panel front door;
- Asset Management System (AMS) interface;
- Emergency Shutdown Relay (RESD).

5.2.2 The Remote I/O Panel (RIO), to be located in the field, shall be made of stainless steel AISI 316L and installed in shelters protected from rain, wind and sunlight in the respective compression modules. The panels shall have front and rear access doors, cable entry from the bottom of the panel and IP56 protective level. The panel internal temperature shall be kept bellow 40 ºC. Each RIO shall include, at least:

- I/Os safety system and I/Os control system;
- Network switch and DIO optical fiber;
- Machinery Protection System (MPS);
- Machinery Monitoring System (MMS) interface;
- Asset Management System (AMS) interface;
- Start and stop lamp status;
- Emergency shutdown retentive push-button;
- Emergency Shutdown Relay (RESD).

5.2.3 Compressor Governor System (CGS), located inside the UCP Panel, shall include, at least:

- Pressure control (spillbacks valve control);
- Load-sharing control;
- Automatized Procedures Module (MPA) interface.

5.2.4 The network switches shall be industrial manageable type. A package entry switch shall be supplied and installed complying with requirements shown in AUTOMATION NETWORK DESCRIPTION.

5.2.5 Networks for control, safety and monitoring shall be segregated from each other and redundant.

5.2.6 Unit Control Panel (UCP) and the Remote IO Panel (RIO) controlling this package shall be limited to the number of sections and size presented in the EQUIPMENT LIST. The panels provided shall not exceed these size limitations.

5.2.7 Safety System PLC shall receive all process variables related to emergency shutdown logics, execute these logics and perform hardwired actuation on final elements in abnormal situation. Control System PLC is responsible for control and monitoring functions of the process variables.

5.3 PAS software

5.3.1 PAS shall enable changes of set points, timer presets and control parameters, input by-passing and output override with the system in operation, without damage to the process.

5.3.2 The control system programming and configuration shall be carried out by the UCP_HMI through a laptop computer not provided by PACKAGER/PURCHASER. The software editors shall be provided by PACKAGER/PURCHASER.

5.3.3 HMI software (with runtime and development licenses) shall be provided.

5.3.4 Access to configuration and programming shall be protected by change management tools, including specific passwords with several levels, such as: general, operation, maintenance and engineering. All passwords shall be delivered to PETROBRAS with NO access restrictions.

5.3.5 The control system programming shall be in accordance with PETROBRAS specifications. PACKAGER and PURCHASER proposal shall inform the programming languages used in the system.

5.3.6 HMI alarm annunciation shall comply with ISA-18.1, according to the sequence F2M-1 (manual reset first out with no subsequent alarm flashing and silence pushbutton). Alarm Management Systems shall comply with ISA-18.2.

5.4 PAS system

5.4.1 The PAS shall be capable of carrying out control, interlock, process, start-up, shutdown, normal operation and safety procedures for main machinery and auxiliary equipment, including all the necessary interfaces to connect with Motor Control Center (MCC) and other controls and PETROBRAS security systems, such as: Control and Safety System (CSS), Power Management System (PMS), Asset Management System (AMS) and Machinery Monitoring System (MMS).

5.4.2 Emergency Shutdown Relay (RESD) shall be provided to actuate directly on the Driver and on the process plant SDVs.

5.4.3 The Emergency shutdown retentive push buttons, external stop signal from CSS, and MPS, shall actuate the RESD and be used as input for UCP safety PLC.

5.4.4 PAS shall include, at least, the following functions:

- Automatic and manual start-up, loading, normal/emergency stop, purge and shutdown sequences without causing any damage to equipment or process instability;
- Indication and recording of unit malfunction/shutdown, event signals and all machinery sequences (such as start-up, normal stop, etc.);
- Monitoring and control of all variables, alarms and shutdown signals with UCP indication as described in PETROBRAS specification (such as temperature, pressures, etc. indicated in P&IDs and data sheets);
- Independent hourmeter and starts counter;
- Suction gas flow for each compressor stage in m3/h.

5.4.5 PAS shall send and receive hardwire signals to/from Control and Safety System (CSS) according to each specific project's "AUTOMATION INTERFACE OF PACKAGE UNITS" as stated in the DOCUMENT LIST.

5.4.6 PAS shall send and receive hardwired signals to/from Electrical System according to I-LI-3010.00-5140-797-P4X-001- ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

5.4.7 PAS shall have high reliability, integrity and availability for operation in fail safe mode in order to avoid, whenever possible, an unnecessary shutdown or loss any process variable with safety function.

5.4.8 PAS shall include on-line testing and self-diagnosis facilities, in order to allow the maintenance technician to identify failures, enabling corrective maintenance without causing unit shutdown and avoiding operation without any safety function.

5.4.9 In case of power failure, system shall retain all programs and data as well as interface software for a minimum of six months, not being necessary to reconfigure the system after power restore. During a power failure, all outputs shall be automatically changed to their safe position.

5.4.10 Connectivity to external system through open communication protocols shall be MODBUS and OPC (Open Platform Communications) by Ethernet TPC/IP Protocol. All I/O variables, from all controllers (including pressure, load sharing and MPS) and first-out events shall be available.

5.4.11 The UCP interface with Asset Management System (AMS) shall be as described in each specific project's "AUTOMATION INTERFACE OF PACKAGE UNITS" as stated in the DOCUMENT LIST. UCP controllers shall be HART compatible, without the need for multiplexers.

5.5 Human Machine Interface (HMI) of UCP

5.5.1 UCP_HMI shall allow the operator to view and acknowledge alarms and trips, protections reset, status of each I/O and intermediate variables, software monitoring/modification, system configuring, first-out of alarms and shutdowns, list of set points and parameters, analog variables, variables performance and trend, recording of all relevant data and periodic reports, events, number of starts and operation hours, by-pass of inputs and override of outputs.

5.5.2 UCP_HMI shall comply, at least, with the following requirements:

- Industrial microcomputer installed inside the panel housing;
- Access to HMI shall be provided for onshore access, in accordance with AUTOMATION NETWORK DESCRIPTION. Additional Ethernet network card shall be available for package LAN if necessary. Remote access shall be password protected;
- Read and write access to removable data storage devices shall be disabled. Enabling this access shall be possible with password protection.
- HMI screen shall be on front door of the panel. Minimum 20 inch widescreen LCD color touch screen display. The CPU of HMI shall be independent from the display screen of HMI;
- Historical log:
  a. Daily files - Recording and storing of all digital and analog variables, alarms and events of PAS system with 1 second sample time. Storage shall be at least 72 files (24 days x 3 months);
  b. Hourly files - Recording and storing, in high speed (minimum sample time shall be less than 120 milliseconds), of all analog and digital variables, alarms and events of PAS system. Storage shall be at least 72 files (24 hours x 3 days).
- Event and trigger log:
  a. Storing all variables in the minimum sample time (less than 120 milliseconds) during 15 minutes, 10 minutes before and 05 minutes after the programmable event/trigger. Storing at least 150 files per programmable event/trigger;

b. All events and all analog/digital variables (trigger is reaching a preset value) must be programmable to start storage. ESD or Normal Stop are events that shall already be programmable in UCP_HMI to start storage.

- Trend with capable of playback any stored variables and showing a set of minimum 12 variables at the same time;
- Capable of export of stored variables logs in the CSV standard (data separated by semicolon);
- Listing in chronological order of all alarms, trips,events, and user-defined actions with PLC timestamps with milliseconds time resolution. The message of first trip of SD sequence shall be emphasized;
- Display of process plant and auxiliaries PI&Ds with all variables and variables from Compressor Control;
- Display of equipment schematic layout with all variables from Machinery Protection System.

5.5.3 PACKAGER and PURCHASER shall provide UCP_HMI supervisory software (runtime and development tool) running on Windows environment, compatible with the size of the application and in its latest version (preferably at 64 bits). Software shall be supplied, installed, configured in the UCP_HMI and provided with complete manuals/electronic media. Software licenses shall also be provided.

5.5.4 Access to configuration and programming shall be protected by change management tools, including specific passwords with several levels, such as: general, operation, maintenance and engineering. All passwords shall be delivered to PETROBRAS with NO access restrictions.

5.5.5 If, for any reason, HMI have some malfunction, the control system shall continue with all its function normally. PACKAGER and PURCHASER shall provide a hardware interface (such as a laptop computer connection) in order to establish an external communication with PLC.

5.5.6 English and Brazilian Portuguese languages shall be used on all UCP_HMI screens installed on UCP.

5.5.7 Each UCP_HMI must also be able to allow operation of any further compression train in this compression service, including remote UCP_HMI. All Data (historical trend, event and trigger and alarm and trip logs) shall be synchronized among all HMIs.

5.5.8 All PLCs, HMIs, MPS shall be synchronized. Time synchronism shall be sent from Time Servers, see each specific project's "AUTOMATION NETWORK DESCRIPTION" as stated in the DOCUMENT LIST.

5.5.9 UCP_HMI software must be compatible with OSI "Plant Information-PI" software.

5.5.10 One remote UCP_HMI for each compression service shall be provided, with the same functionalities of the UCP_HMI, to be installed at Central Control Room (CCR). This UCP_HMI shall be a 19" rack-mounted PC (at maximum with 2U height). The PC shall have three Ethernet ports, and each port must be connected to the PAS system switch of each compression train.

5.6 Machinery Protection System (MPS)

5.6.1 Machinery Protection System (MPS) shall be according to the API 670 latest revision.

5.6.2 Sensors arrangement for driven equipment, gearbox and driver:

- Radial vibration: Two (2) non-contact probes for each radial bearing (X-Y signal);
- Axial position: Two (2) non-contact probes for each axial bearing;
- Phase: One (1) phase reference transducer for every different shaft speed;
- Casing vibration: Accelerometers for gearbox casing: one (1) over the input and one (1) over each output shaft centerline, near radial bearings; four (4) accelerometers for electric motor (two (2) for each bearing housing) for motor equipped with journal or hydrodynamic tilting pads bearings or two (2) accelerometers for electric motor (one (1) for each bearing housing) for motor equipped with roller bearings;
- Pulsation: One (1) dynamic pressure sensor for each suction (upstream of silencer) and discharge (downstream of silencer) stage, connected to dynamic monitor at MPS rack (only for monitoring);

5.6.3 Probes shall allow gap adjustment.

5.6.4 All bearings must have metal temperature monitoring (two sensors installed, one spare). Only where metal bearing temperature measure is not feasible, PACKAGER and PURCHASER shall propose a bearing oil outlet temperature sensor with the same alarm and shutdown signals as indicated for metal bearing temperature in data sheets. Two temperature sensors at active side and two temperature sensors at inactive side shall be provided for thrust bearings. All bearing temperatures shall be directly connected to MPS rack.

5.6.5 Monitors shall be mounted on Remote I/O Panel (RIO) in the field.

5.6.6 RIO shall have internal space for temporary installation of a Machine Data Acquisition System, with minimum dimensions 70 cm x 70 cm x 15 cm (LxWxH). Shall also be provided a 220 Vac plug socket and an ethernet port with connection to AEPR.

5.6.7 All vibration and temperature protection systems shall be according to Original Equipment Manufacturer (OEM) standards and API 670 compliant.

5.6.8 Each monitor channel shall be capable of continuously comparing the input signal to warning set points. The warning system shall comprise at least two (2) levels: alarm and shutdown. The exception is axial position monitor, for which shall be supplied with four (4) independent alarms and shutdown adjustable limits (two (2) for each direction).

5.6.9 The vibration signals (including displacement and accelerometers) of the whole train shall have an unfiltered output at the UCP (one per channel) for recording and maintenance purposes.

5.6.10 Each channel shall be supplied with an electronic configurable time delay to avoid activation of alarm during transient signals.

5.6.11 All wiring shall be protected by flexible conduits to a stainless steel AISI 316L junction box (at skid edge), neatly routed to allow machine maintenance without damaging probes and wire leads.

5.6.12 Extension cables shall be armored.

5.6.13 Oscillator-demodulators shall be mounted in an intrinsically safe junction box, if applicable.

5.6.14 Paired channels (XY) from the two transducers mounted at each bearing for radial shaft vibration monitoring shall be allocated at the same MPS I/O card.

5.6.15 A controlled access set point multiplier function shall be provided with actuation by an external contact closure which causes the alarm (alert) and shut down (danger) set points to be multiplied by a factor.

5.6.16 All vibration signals channels shall be allocated at the same MPS monitor of the corresponding phase reference signal channel.

5.6.17 MPS x MMS interface shall not use internal control panel switches. MPS shall be connected directly to MMS panel.

5.7 Machinery Monitoring System (MMS)

5.7.1 The MMS (provided by PURCHASER) shall be designed in according to the requirements described in the items below and in the specification I-ET-3010.00-5500-854-P4X-001 – MACHINERY MONITORING SYSTEM.

5.7.2 Besides the control and supervisory UCP system, Machinery Protection System shall be integrated in the Machinery Monitoring System (MMS) of the FPSO, provided by PURCHASER, for maintenance purposes. PACKAGER and PURCHASER shall provide interface cards installed in the Machinery Protection System to allow the interconnection with the MMS (software and hardware). All vibration signals (including displacement and accelerometers) and dynamic pressure shall be available with buffer signal output.

5.7.3 For a basic description, the primary function of this system is to perform analysis of the mechanical parameters: all machinery protection system signals (with possibility to make analysis like FFT, full spectrum, Bode plot, cascade and waterfall diagrams, shaft average center line, orbit, X-Y plot and experience-based vibration analysis) and auxiliary system signals (lube, seal, etc.).

5.7.4 All signals from MPS monitoring cards shall be available to send data to MMS.

5.7.5 In addition to the signal available through the MPS Communication Card, PACKAGER and PURCHASER shall make available the required process variable signals presented in the I-ET-3010.00-5500-854-P4X-001 – MACHINERY MONITORING SYSTEM, through the Package Fast Ethernet Network to perform the functions above in the Machinery Monitoring System.

5.7.6 Packager shall provide all documentation of vibration signals and configuration files of the Machinery Protection System to be implemented by the MMS Supplier for Monitoring System configuration.

5.8 Compressor Governor System (CGS)

5.8.1 General requirements

5.8.1.1 Compressor Governor System (CGS) consists of the following controls: Pressure and Load sharing control. These controls shall be integrated (so any individual corrective action taken by one loop shall not degrade a response from other). CGS shall enable adjustment of all parameters and perform inputs by-pass without causing process disturbances, keeping the plant in safe condition.

5.8.1.2 PACKAGER/PURCHASER shall furnish the spillbacks valves with their associated devices such as, positioners, air boosters, limit switches and solenoids, all instrumentation of CGS including transmitters (flows, pressures and temperatures).

5.8.1.3 All pressure, flow transmitters and positioner of CGS shall be smart with HART protocol and maximum response time of 100 milliseconds. Transmitters must be installed above the process connection and piping routing must not form siphons. The length of the tubing for pressure transmitter may not exceed 5 meters.

5.8.2 Pressure control

5.8.2.1 Each stage of each compression service type shall have a Pressure control.

5.8.2.2 Pressure control shall maintain the suction pressure and limit the maximum discharge pressure of compressor trains. If the discharge pressure exceeds set point, system shall switch from suction pressure control to discharge pressure limit. The control shall operate in automatic and manual modes. These set points shall be monitored and defined from UCP_HMI of Unit Control Panel (UCP) at Automation and Electrical Panels Room (AEPR).

5.8.2.3 Pressure control shall be implemented in the Unit Control Panel (UCP) at Automation and Electrical Panels Room (AEPR).

5.8.3 Load sharing control

5.8.3.1 The load sharing control supplier shall be supplied according to the OEM standards.

5.8.3.2 Load sharing control shall operate when the compression trains are in parallel and will command the pressure controls to maintain the desired suction pressure. Load sharing shall operate with automatic and manual modes. Set points shall be monitored and defined UCP_HMI from UCP at AEPR.

5.8.3.3 When the compression train is operating in parallel, pressure control and load sharing control shall perform an appropriate distribution of loads between compression trains.

5.8.4 Spillback valves

5.8.4.1 Spillback valves shall be sized to perform their function in all operating conditions, including transients and not oversized in order to maintain their controllability.

5.8.4.2 The spillback valve shall be fail open type, with linear response, class 4 balanced cage globe, body material according to the spillback recycle line material specification at Process Flow Diagram, as minimum, stainless steel AISI 316L seat material with “Stellite” or equivalent hardness material, no chromium coating shall be accepted and with anti-noise technology to attenuate up to 90 dBA @ 1m. No spillback valve material selection subjected to the galling nor any other wear/corrosion mechanism will be accepted.;

5.8.4.3 The spillback valve shall be mounted with high speed intelligent positioner and high flow booster to increase the precision and speed of actuation;

5.8.4.4 The use of quick exhaust, or similar system that opens the spillback valve in an uncontrolled mode, is not allowed;

5.8.4.5 A three-way solenoid shall be used, between the Booster and the Actuator, with high Kv to allow spillback valve smallest stroke. The solenoid shall be energized to allow modulation of the spillback valve.;

5.8.4.6 The maximum spillback valve opening stroke time (0 to 100%) shall be up to 1 second for valves less than or equal to 4 ", up to 2 seconds for valves greater than 4" and less than 12 " and up to 3 seconds for valve greater than 12";

5.8.4.7 The minimum spillback valve closure stroke time (100% to 0) shall be up to 3 seconds for a valve less than or equal to 4 ", up to 5 seconds for valve greater than 4" and less than or equal to 12 " and up to 8 seconds for valve greater than 12”;

5.8.5 Automatized Procedures Module (MPA)

5.8.5.1 The MPA (Automatized Procedures Module) shall be designed in according to the requirements described in the items bellow and in the specification for each specific project’s “AUTOMATION INTERFACE OF PACKAGE UNITS” as stated in the DOCUMENT LIST.

5.8.5.2 MPA will be defined by PETROBRAS during the detail design, or during operation phase. These systems may use PETROBRAS software package, or third part packages when required, and run on computers in the automation network. The goal of MPA is to assist operators in integrating and coordinating the various compressors in the unit's gas treatment system. MPA system will not be supplied for PACKAGER and PURCHASER.

5.8.5.3 PACKAGER and PURCHASER shall provide connectivity through MODBUS and OPC for the MPA to read all critical variables of the compressor (pressures, temperatures, power, current, speed, etc.).

5.8.5.4 PACKAGER and PURCHASER shall be able to receive 4-20mA input signals at Pressure Control for the compressor suction pressure remote set points. These remote set point signals (4-20mA) will be provided by Process Control System (PCS is scope of the PURCHASER). At UCP_HMI, operator shall select if set points will be defined locally (at UCP_HMI) or remotely (from MPA signals). In this way, the MPA or the operator can command the suction pressure set points.

5.8.5.5 PACKAGER and PURCHASER shall properly monitor the 4-20 mA input signals from remote setpoints, so that the failure of these signals disables the action of the MPA on the controller

6. ELECTRICAL

6.1 Electrical equipment and materials shall comply with requirements of:

- I-ET-3010.00-5140-700-P4X-002 - SPECIFICATION FOR ELECTRICAL MATERIAL FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-700-P4X-007- SPECIFICATION FOR GENERIC ELECTRICAL EQUIPMENT FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-700-P4X-009 - GENERAL REQUIREMENTS FOR ELECTRICAL MATERIAL AND EQUIPMENT FOR OFFSHORE UNITS;
- I-ET-3010.00-5140-772-P4X-002 - SPECIFICATION FOR LOW-VOLTAGE FREQUENCY CONVERTERS, SOFTSTARTERS AND INVERTERS FOR OFFSHORE UNITS.

6.2 Electrical installations inside the package and the voltages to be supplied for electrical loads (motors, heaters, control panels, etc.) shall comply with requirements of I-ET-3010.00-5140-700-P4X-003 - ELECTRICAL REQUIREMENTS FOR PACKAGES FOR OFFSHORE UNITS.

6.3 Electrical motors shall comply with requirements of I-ET-3010.00-5140-712-P4X-001 - LOW-VOLTAGE INDUCTION MOTORS FOR OFFSHORE UNITS and I-ET-3010.00-5140-712-P4X-002 - MEDIUM-VOLTAGE INDUCTION MOTORS FOR OFFSHORE UNITS. The electrical motors shall be fed from platform normal panels.

6.4 The electrical communications interfaces of the package shall comply with requirements of I-DE-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE DIAGRAM, I-ET-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION ARCHITECTURE, I-DE-3010.00-5140-797-P4X-002 - ELECTRICAL SYSTEM AUTOMATION TYPICAL ACTUATION DIAGRAMS and I-LI-3010.00-5140-797-P4X-001 – ELECTRICAL SYSTEM AUTOMATION INTERFACE SIGNALS LIST.

6.5 Equipment, accessories, piping and structures shall be grounded according to requirements of I-DE-3010.00-5140-700-P4X-003 - GROUNDING INSTALLATION TYPICAL DETAILS, I-ET-3010.00-5140-700-P4X-001 – SPECIFICATION FOR ELECTRICAL DESIGN FOR OFFSHORE UNITS, IEC 61892-6 and IEC-60092-502. Besides these standards, for installations in hazardous area, the grounding requirements of IEC 61892-7 shall be complied.

6.6 Heater panels shall comply with I-ET-3010.00-5140-741-P4X-004 - SPECIFICATION FOR LOW-VOLTAGE GENERIC ELECTRICAL PANELS FOR OFFSHORE UNITS.

6.7 Other panels, except MCC, shall comply with requirements of I-ET-3010.00-5140-741-P4X-004 - SPECIFICATION FOR LOW-VOLTAGE GENERIC ELECTRICAL PANELS FOR OFFSHORE UNITS.

6.8 All electrical panel shall comply with I-ET-3010.00-5140-700-P4X-005 - REQUIREMENTS FOR HUMAN ENGINEERING DESIGN FOR ELECTRICAL SYSTEMS OF OFFSHORE UNITS.

6.9 Motocompressor auxiliary loads shall be fed by auxiliary MCCs, provided by PURCHASER (out of scope of PACKAGER). However, PACKAGER shall provide all necessary information about auxiliary loads for Integrator, in order to allow complete and suitable fabrication of auxiliary MCCs. Auxiliary MCCs (Motor Control Center) shall comply with I-ET-3010.00-5140-741-P4X-001 - LOW-VOLTAGE MOTOR CONTROL CENTER AND SWITCHGEAR FOR OFFSHORE UNITS.

7. OPERATION AND MAINTENANCE REQUIREMENTS

7.1 PACKAGER and PURCHASER shall make the applicable recommendations to optimize operation and maintenance, taking into account the remote location and platform general conditions. Any changes to equipment design, materials or specific spares that may improve the equipment operability, availability or reliability shall be submitted to PETROBRAS for review and approval. But PACKAGER and PURCHASER shall always comply with PETROBRAS requirements before suggest any modification.

7.2 The packages shall be designed so that all maintenance can be carried out with standard tools as much as possible.

7.3 Equipment layout shall enable easy and safe access for maintenance to all components and parts. PACKAGER and PURCHASER shall provide suitable walkways, ladders and handrails for all packages, including auxiliaries. All equipment and peripherals, especially oil reservoirs, shall have full access and inspection doors/hatches.

7.4 Instruments and piping accessories shall be arranged in proper location in order to allow easy access by maintenance and operation personnel. Installation of piping and cable supports next to couplings, bearings and seals shall be avoided, for instance.

7.5 PACKAGER and PURCHASER shall prepare detailed assembly, disassembly and maintenance procedures, describing the use of all involved lifting apparatus and including all required preventive and corrective maintenance tasks. PACKAGER and PURCHASER shall inform the need for disassembling any component or equipment in order to facilitate access for maintenance. Suitable maintenance routes shall be provided to remove the main components and auxiliaries, avoiding interference with structures, piping, cabling, electric conduits and supports, equipment, etc. This plan shall be submitted to PETROBRAS for approval.

7.6 PACKAGER and PURCHASER shall provide lifting/handling devices and external structure components enabling assembly, disassembly and removal all components inside the package (compressor, gearbox, electric motor rotor, etc) with adequate and certified capacity to handle maximum maintenance weight and/or dimensions. Lifting and handling devices shall be according to each specific project's "TOPSIDE´S MECHANICAL HANDLING PROCEDURES" as stated in the DOCUMENT LIST.

7.7 PACKAGER and PURCHASER shall include in proposal a schedule stating the expected time between major overhauls.

7.8 The packages shall be designed so that all maintenance can be carried out with standard tools as much as possible.

7.9 PACKAGER and PURCHASER shall provide special tools for all maintenance activities including tools for compressor, gearbox, driver and driver rotor, to assembly, disassembly and removal.

7.10 PACKAGER and PURCHASER shall provide a gearbox shaft end with an adaptor in order to allow manual turning for maintenance purposes, if applicable.

7.11 Noise control requirements

7.11.1 Noise control analysis is a mandatory item to be carried-out. PACKAGER and PURCHASER shall present noise data regarding items included in scope of supply.

7.11.2 The maximum allowable sound level shall be 90 dB(A) at one (1) meter around the unit and up to two (2) meters from the floor.

7.11.3 The noise control system for the package shall consider the noise radiated by inlet/outlet piping, equipment enclosure and equipment casings.

7.11.4 Whenever electric motor drivers are used, it shall be verified if motor fan design can be modified (e.g., use of unidirectional blades, etc.) before any apparatus are applied for noise attenuation.

7.11.5 In case of expected noise are higher than allowable limits, the equipment must be furnished with some noise control reduction measure and the maximum noise allowable value will be 85 dB(A). PACKAGER and PURCHASER may consider the best solution, which may include acoustic walls (open roof) and safety system requirements. In this case (open roof) no ventilation systems are acceptable. The use of device to comply with noise requirement must be proved to be efficient and submit to PETROBRAS approval.

7.11.6 For all equipment installed without acoustical enclosure, the following data will be required during proposal phase:

- Sound power level of the equipment;
- Sound pressure level, in each of the four main directions and in one point of the top;
- Acoustic isolation on suction and discharge piping lines shall be provided.

7.11.7 For all equipment installed inside acoustic enclosure, the following data will be required during proposal phase:

- Sound power level of the equipment without enclosure;
- Sound pressure level, in each of the four main directions and in one point of the top, for the equipment plus enclosure;
- Acoustical data of enclosure and silencers (when applicable).

8. INSPECTION AND TESTS

8.1 General requirements

8.1.1 PETROBRAS is entitled to inspect the package anytime during fabrication to ensure that material and workmanship are in accordance with the specifications.

8.1.2 Inspection of materials and/or equipment will be made by PETROBRAS or its authorized representatives.

8.1.3 Unless otherwise specified, all witnessed tests shall be informed, at least, 90 days before the scheduled dates.

8.1.4 Unless otherwise established by PETROBRAS inspector, all equipment shall be available for inspection in an unpainted state.

8.1.5 All PAS shall be functionally tested at supplier facilities. All control sequences and shutdown logics shall be simulated and tested against the requirements. Details of supplier standard functional test procedures shall be submitted to PURCHASER approval.

8.1.6 PETROBRAS inspector shall have the right to request inspections to ensure that the equipment complies with the relevant classification society requirements.

8.1.7 In case any defects and/or shortcomings are found, PACKAGER and PURCHASER shall bear the full cost of such inspection and replacement as necessary. Any repair shall previously be approved by PETROBRAS. The subsequent inspection necessary to confirm the satisfactory results will be at PACKAGER and PURCHASER cost.

8.1.8 All process gas system welds shall be 100 % radiographically inspected and submitted to magnetic particle examination.

8.2 Hydrostatic test (HT)

8.2.1 For all trains, parts being tested shall be externally coated with a layer of white lead carbonate or any other suitable powder to help leakage detection.

8.2.2 No vises or clamping devices shall be used for pressing of nozzle flanges.

8.2.3 PTFE tape or thread compounds shall not be used to prevent leakage of threaded plugs and connections.

8.3 Performance Test (PT)

8.3.1 Performance Test shall be performed on each unit and spare casings according to ISO 1217 last Edition.

8.3.2 The performance test procedure shall be agreed with PETROBRAS

8.4 Mechanical Running Test (MRT)

8.4.1 MRT shall be performed on each unit and spare casings according to API STD 619 last Edition.

8.4.2 PACKAGER shall submit to PURCHASER and PETROBRAS digital files (storage type to be mutually agreed during detailed design) with vibration data recorded during MRT and all test information, including, at least: failed tests, with sweeping, starting/stopping ramp, equipment vibration signature, diagram for all bearing signals and phase angle versus speed.

8.4.3 The MRT procedure shall be agreed with PETROBRAS

8.5 Sound Level Test (SLT)

8.5.1 The sound pressure meter shall be class I, according to IEC 61672. The characteristics of the octave filter shall be in accordance with IEC 61260. The sound pressure reading shall be made as equivalent continuous level, for 60 seconds sampling time. The recorded values shall be corrected to the nearest entire value within 1dB. A maximum deviation of 2dB will be allowed, both for the A scale weighted value and for the octave bands between 31.5 Hz and 8000 Hz.

8.5.2 The procedures for sound measurement assume a condition of free field over reflecting floor. This implies that the tests will be preferably performed in an outside area, with a smooth floor made of concrete, asphalt, etc. If this condition is not satisfied, then the correction for measurements in rooms shall be applied.

8.5.3 If the difference between the background noise level and the equipment sound level plus the background is less than 10dB, the measurements shall be corrected.

8.5.4 If the normal operating condition cannot be reached in the test facilities, PACKAGER, PURCHASER and PETROBRAS shall agree with measurements methods and values.

8.5.5 If the values measured and reported during the shop test are higher than the limits submitted by PACKAGER or PURCHASER to approved by PETROBRAS in proposal, PACKAGER and PURCHASER shall provide, without extra cost, sound attenuation methods in order to reach this limit, if required by PURCHASER.

8.6 Factory Integrated Test (FIT)

8.6.1 PACKAGER shall execute one FIT in their installations per compressor service. FIT shall be a functional test including the following contract parts, at least: main electric motor, HVSD/gearbox, compressor, PAS, oil system and seal gas system including seal gas treatment system.

8.6.2 The FIT procedure, with the steps and duration, shall be similar to the MRT, and shall have, at least, three starts and three stops.

8.6.3 Vibration requirements (limits, acceptance, etc.) shall be the same used for MRT.

8.6.4 Motors will be tested according to electrical standards references and PETROBRAS specification.

8.6.5 Control check shall be done during FIT, as part of functional test.

8.6.6 The FIT procedure shall be agreed with PETROBRAS

8.7 Shipyard Acceptance Test (SYAT)

8.7.1 Shipyard Acceptance Test (SYAT) is inert gas (N2) functional test onshore, performed on each unit.

8.7.2 Shipyard Acceptance Test (SYAT) shall be performed in the shipyard facilities after compressor and process plant complete commissioning (including N2He leakage test of piping system been executed) and complete integration with all systems of FPSO that support the operation of compression system.

8.7.3 PURCHASER shall provide all facilities, support and technical procedures to execute a SYAT, according to Annex B - Inert Gas Screw Compressor Running Test. PACKAGER and PURCHASER shall provide technical assistance for all SYAT.

8.7.4 PURCHASER and PACKAGER will perform a SLT during SYAT.

8.7.5 The SYAT procedure shall be agreed with PETROBRAS including acceptance criteria.

8.8 Pulsation Acceptance Test (PAT)

8.8.1 Pulsation Acceptance Test (PAT) is an offshore acceptance test to be performed at one set when the motocompressor is able to operate after all commissioning is completed and not pending.

8.8.2 The maximum pulse values, during PAT, shall comply with item 6.9.4 of API-619 latest version.

8.8.3 The PAT procedure shall be agreed with PETROBRAS.

8.9 Site Acceptance Test (SAT)

8.9.1 Site Acceptance Test (SAT) is an offshore acceptance test to be performed on each unit when the motocompressor is able to operate after all commissioning is completed and not pending.

8.9.2 SAT shall be performed according to “Annex A” (Rotating Equipment Reliability Test).

8.9.3 PURCHASER and PACKAGER and PURCHASER shall provide all facilities, support and technical assistance for SAT. PURCHASER is responsible for any repairs required during the SAT that are not caused by factors external to the motocompression system.

8.9.4 The SAT procedure shall be agreed with PETROBRAS. However, the acceptance criteria stated at Annex B shall be complied.

9. ANNEXES

9.1 Annex A: Rotating Equipment Reliability Test.

9.2 Annex B: Inert Gas Screw Compressor Running Test.

9.3 Annex C: Acoustic Pulsation and Mechanical Analysis Guidelines and Technical Requirements.