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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
AS	Anti-surge
ASV	Anti-surge Valve
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
CGS_HMI	Human Machine Interface for 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
FPFLFS	Full pressure, full load, full speed test

FPSO	Floating Production Storage and Off-loading
FPU	Floating Production Unit
FST	Factory Stability Test
HMI	Human Machine Interface
HVSD	Hydraulic Variable Speed Drive
IGCR	Inert Gas Compressor Running
I/O	Input/Output
LAN	Local Area Network
MCC	Motor Control Center
MLO	Mineral Lube Oil
MMS	Machinery Monitoring System
MPA	Automatized Procedures Module (Portuguese: Módulo de Procedimentos Automatizados)
MPS	Machinery Protection System
MRT	Mechanical Running Test
OPC UA	Open Platform Communications Unified Architecture
PAS	Package Automation System
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. Centrifugal compressor for Motocompressor package units shall be in accordance with API std 617 last edition.

2.2. The complete Motocompressor packages shall be designed for minimum 30 years of operation installed on the FPSO and at least 5 years of uninterrupted operation.

2.3. All documents listed in Material Requisition and specific project's "CENTRIFUGAL GAS MOTOCOMPRESSORS PACKAGE SPECIFICATION", as stated in the DOCUMENT LIST, are mandatory, as well as the electrical, automation and safety requirements for Motocompressor package units described in this document.

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 any particular material has not been used 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 PETROBRAS approval. Nameplates shall contain the following information, in Brazilian Portuguese language:

- Client name;
- Client job;
- Client area;
- Specific data;
- Tag number;
- Purchaser's requisition number

- Supplier name;
- Series number and model;
- Year of manufacturing;
- Main design and test data: pressure, temperature, voltage, rotation, etc.;
- (RM);
- Purchaser's request for quotation number (RFQ);
- Purchaser's order number (PO);
- Empty weight;
- Design code.

2.11. All safety signals shall be in Portuguese language.

3. CONSTRUCTION FEATURES

3.1. Centrifugal compressors shall be radially split case (barrel type) in accordance with API std 617 last edition.

3.2. Compressors with mounted tie-bolt impellers are not acceptable.

3.3. Compressors with sidestream are not acceptable.

3.4. Compressor bearings shall be hydrodynamic tilting pads type.

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

3.6. 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).

3.7. Connections between pipe flanges and suction and discharge nozzle flanges of compressor shall be provided with removable spools to facilitate compressor removal and disassembly. Removable spools shall not have any process 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.

3.8. Clamp connections are not acceptable.

3.9. PACKAGER and PURCHASER shall consider the presence of free water and corrosive agent (H_2S 170 ppm or compressor datasheet value, whichever is greater and CO_2 5% vol. or compressor datasheet value, whichever is greater) even when not specified in any compressor operating case. In case of free water carry over, a chlorides content contamination shall be foreseen and considered during the compressor material selection.

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

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

3.12. In case of a skid with two compressor casings, it shall be provided the required maintenance area on the skid and appropriate fixtures in order to allow the procedure for bundle removal from any casing with no need of removing any of the casings

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, if any, and the main skid 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. A removable T-type strainer without disassembly of the piping, shall be installed in the suction line, close to each stage of compression.

4.1.7. In case of water content in gas, an analysis shall be made to verify the possibility of hydrate formation in the recycle line. Hot recycle (ASV upstream of the heat exchanger) shall be used.

4.1.8. 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 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, 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 require equipment or parts to be dismounted for 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 applications (last edition). 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:

- for HVSD, the MLO system shall be integrated and provided for lubricating driver, HVSD and driven equipment;
- for gearbox, the MLO system shall be integrated, if possible, and provided for lubricating driver, gearbox, and driven equipment. When MLO system is not possible to be integrated, an independent mineral oil (lube) package system shall be provided for lubricating driver, gearbox and driven equipment, installed nearest main equipment baseplate.

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 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 specification, international standards for this system and Oil System Data Sheet.

4.6.5. PACKAGER 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 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 allow removal without having to drain the reservoir or stop the equipment.

4.6.9. The configuration for pumps is:

- 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 rundown tank shall not exceed fifteen minutes after the machine has stopped.

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

4.7. Gear Units

4.7.1. Hydraulic Variable Speed Drive (HVSD)

4.7.1.1 When specified on the compressor datasheet, HVSD shall be designed as a “stand-alone” unit, whereby no external thrust loads shall be imposed upon the HVSD by other equipment.

4.7.1.2 HVSD shall be designed for all operating cases defined in the compressor datasheet. There is no predominant operating case. The certified point does not represent the most frequent operating point. The hydraulic variable speed driver shall be designed to operate continuously and for a long period at any point in the speed and torque range.

4.7.1.3 Nitrogen purge connection for preservation propose of HVSD shall be included on equipment.

4.7.2. Gearbox

4.7.2.1 When specified on the compressor datasheet, the gearbox shall be double helical, single stage 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).

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

4.7.2.3 The use of one or two gearboxes shall be defined by vendor. However, dimension limitations for compressor package defined on the compressor datasheet must be accomplished.

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

4.7.2.5 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 be 3/4”.

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. Dry Gas Seal (DGS) system

4.9.1. 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.

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

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

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

4.9.5. 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, emergency shutdown, pressurized stopped and during depressurization.

4.9.6. 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 discharge process gas shall be used as primary seal gas supply and conditioned nitrogen shall be used as secondary seal gas supply.

4.9.7. Conditioned nitrogen shall be used as 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.

4.9.8. Air and nitrogen utilities consumption shall be minimized due FPSO capacity production restriction. Seal and labyrinth shall be designed in order to minimize gas consumption. XV valves with limiter switch and any other required protection layer shall be used in order to automatically reduce consumption whenever not required.

4.9.9. 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.

4.9.10. 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.

4.9.11. PACKAGER shall provide a dedicated Seal Gas Panel (SGP) for each compressor casing.

4.9.12. 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. PSV, or rupture disk, shall be sized to assure venting capacity during a seal failure and minimize potential damage and uncontrolled leakage to atmosphere. PACKAGER shall conduct a Vent Study according to Annex A of API 692 Part I to demonstrate venting capacity.

4.9.13. 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.

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

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

4.9.16. PACKAGER and PURCHASER must guarantee instrument air for booster and 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).

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

4.9.18. 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.

4.9.19. PACKAGER shall supply any pressure control valves if necessary to guarantee minimum backpressure at DGS primary vent line.

4.9.20. A Seal Gas Conditioning System (SGCS) shall be furnished by DGS supplier and shall be designed to remove all particles and liquids from the compressor discharge gas. This conditioned gas will supply primary seal, avoiding any kind of failure. PACKAGER 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 separator and coalescer filter arrangement (2x100%) for solid and liquid retention with on-line changeover capability and automatic drain by LV and LSH;
- Twin pneumatic pressure boosters (2x100%) shall be provided to ensure seal gas pressure at 15 kPa (upstream primary seal) above balance line pressure under any operating condition of compression system. Migration of the seal gas to the instrument air and vice versa cannot occur at any time. Standby boosters shall start automatically in case of operating booster failure.
- Electric heater exchanger 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 electric 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, boosters and heater exchanger).
- All seal gas lines between the heater exchanger and DGS inlets shall be thermally insulated for heat conservation (HC);
- If other valves (PCV or PDCV) 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, during depressurization or when stopped pressurized);
- Automatic drains shall only be opened when the compressor is pressurized.

4.9.21. PACKAGER shall provide a dedicated seal gas conditioning skid for each compressor casing mounted on the main baseplate. However, 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.

4.9.22. 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. Pressure Relief and Drainage

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

4.10.2. PACKAGER shall inform maximum allowable pressure for each shaft-end seal casing.

4.10.3. Compressor shall be able to stop and remain pressurized, at settle-out condition. Compressor shall also be able to restart from settle-out condition. If restart is not possible due to driver sizing, an operational XV valve (different from BDV) shall be used automatically to reduce system pressure. However, this pressure relief (different from settle-out condition) shall be submitted to PETROBRAS approval.

4.10.4. The elastomers applied to compressors and auxiliary systems components such as DGS (Dry Gas Seal), SGP (Seal Gas Panel), SGCS (Seal Gas Conditioning System) 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.

4.10.5. The compressor casing draining operation shall be carried out with either pressurized or depressurized compression plant. Drains with valves shall be provided for all compressor stages (impeller-diaphragm cavity) and inlet and discharger volutes, installed on the edge of the skid. The drain valves shall be configured with double block to closed and opened drains. If drainage of individual stage cannot be accomplished due to design limitations, it shall be demonstrated during the proposal phase (by means of drawings) that all inner parts will have an effective drainage. Manual pressurized drainage piping shall be connected to a liquid collector vessel located under the main baseplate.

4.10.6. 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 drain shall be configured with double block to closed and opened drain. The primary and secondary vents valves shall be configured with double block to opened drain. All valves shall be installed on the edge of the skid. Manual pressurized drainage lines shall be connected to a liquid collector vessel located under the main baseplate.

4.10.7. 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 liquid collector vessel located under the main baseplate. 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.

4.10.8. All drains for compression system, like vessels, compressor casings, 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).

4.10.9. The liquid collector vessel shall be provided to receive liquids from drainage of the compressor casing and seal gas system through restriction orifices. The vessel shall be installed under the main baseplate, and it shall have the same pressure class of compression plant suction. The vessel shall be connected to the flare system via locked open valve and locked close manual valves to perform manual drainage of the vessel to closed drain system. Drain arrangements shall provide access sight glasses in order to verify flow and leakage and to confirm whether the drainage operation is being accomplished or not. The vessel shall be equipped with LG, LSH and LSL.

4.10.10. PDITs associated with SDVs shall be able to indicate positive and negative values to avoid SDV opening when downstream pressure is larger them upstream pressure.

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 and 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, pressurized stopped, 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. Depressurized Emergency Shutdown events shall be minimized.

5.1.7. The Package depressurization must be requested to CSS-PSD. In case of depressurized ESD event, PAS shall immediately stop the machine and request CSS-PSD to open the BDV. The Package shall be able to be kept pressurized up to the time to be defined during the detail design in accordance with the Flare System depressurization strategy, especially in black shutdown. The BDV shall be used only for safety purpose. For other necessities, such as package purge sequence, the XV parallel to the BDV shall be used.

5.1.8. The PAS shall be designed according to the requirements described in specifications I-ET-3010.00-1200-321-P4X-001 – TECHNICAL SPECIFICATION FOR CENTRIFUGAL COMPRESSOR DRIVEN BY ELECTRIC MOTOR and I-ET-3010.00-1200-800-P4X-002 - AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGE UNITS 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-514001 - POWER MANAGEMENT SYSTEM (PMS) FOR OFFSHORE;
- 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-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;
- 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-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-DE-3010.00-5140-797-P4X-002 ELECTRICAL SYSTEM AUTOMATION TYPICAL ACTUATION DIAGRAMS

5.1.9. 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

5.1.10. 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.

5.1.11. 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.

5.1.12. 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.

5.1.13. 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".

5.1.14. 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.

5.1.15. The PACKAGER/PURCHASER shall perform dynamic simulation to at least confirm Settle Out Pressure (SOP), calculate purge, pressurization and depressurization times, to size anti-surge valve and throttle valves (when specified). The simulation shall evaluate protection from surge during steady state operation, start-up and normal/emergency stop (pressurized or depressurized), considering possible interactions with other packages. The dynamic simulation shall also be used to identify any additional required valves for antisurge system and to avoid compressor rotation during depressurization after the compressor stopped. Supply of additional valves is the responsibility of the PACKAGER/PURCHASER, and their installation is the responsibility of the PURCHASER.

5.1.16. 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.

5.1.17. 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.

5.1.18. PACKAGER 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.

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

5.1.20. 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.

5.1.21. 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.

5.1.22. 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.

5.1.23. 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:

- Capacity control;
- Load-sharing control;
- Anti-surge controls;
- Automatized Procedures Module (MPA) interface;
- Human Machine Interface of Compressor Governor System (CGS_HMI), loose item for installation in CCR.

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 PETROBRAS documents (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 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, ESD signals from CSS and ESD from MPS shall actuate the RESD and be used as input for UCP safety PLC. ESD from UCP safety PLC shall also actuate the RESD.

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 I-ET-3010.00-1200-800-P4X-002 – AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGE UNITS.

5.4.6. 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.

5.4.7. 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.

5.4.8. 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.

5.4.9. Connectivity to external system through open communication protocols shall be MODBUS and OPC UA by Ethernet TPC/IP Protocol. All I/O digital/analogic variables, alarms and trips, controllers signals and parameters (including performance, load sharing, anti-surge and MPS) and events including first-out shall be available.

5.4.10. The UCP interface with Asset Management System (AMS) shall be as described in the specific project's "AUTOMATION INTERFACE OF PACKAGE" as stated in 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 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 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 the specific project's "AUTOMATION NETWORK DESCRIPTION" as stated in 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. Probe 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: Two (2) accelerometers for gearbox casing (one (1) over the input and one (1) over the output shaft centerline, near radial bearings); four (4) accelerometers for electric motor (two (2) for each bearing housing) for motors equipped with journal (or hydrodynamic tilting pads) bearings or two (2) accelerometers for electric motor (one (1) for each bearing housing) for motors equipped with roller bearings;

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 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 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) shall be available with buffer signal output.

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

5.7.4. In addition to the signal available through the MPS Communication Card, PACKAGER 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.

5.7.5. 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: Capacity, Load sharing and Anti-surge controls and a specific HMI for Compressor Governor System (CGS_HMI). 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 Capacity, Load Sharing and Anti-surge controls systems shall be implemented by dedicated system and segregated from the Control system and the Safety system PLCs of UCP, with hardwired interlock and network for communication purpose, complying with API670 (5th ed.) item 9.3.5.

5.8.1.3. Special attention shall be given to low gas temperatures, including in recycle line, and possibility of ice formation outside piping and valves. Compressor shall be able to continuously operate with process gas mass flow varying from zero to value presented on datasheet.

5.8.1.4 Anti-surge and throttle (when specified) valves shall be sized according to process dynamic simulation and submitted to PETROBRAS approval.

5.8.1.5 The suction throttle valve (when applicable), shall be installed upstream of the scrubber and located outside of the recycle loop. Whenever throttle valve is associated to speed variation for capacity control, throttling process shall initiate only after speed reaches minimum value.

5.8.1.6 The antisurge valves, throttle valves (when specified) with their associated devices (positioners, air boosters, limit switches and solenoids), pipelines, tubings, instrumentation (flows, pressures and temperatures), orifice plates, and check valves associated with CGS shall be specified by Compressor Governor VENDOR. The design of controllers, valves, instrumentation, tubings and pipelines associated with CGS shall be submitted to PETROBRAS together with the certificate of approval issued by the Compressor Governor VENDOR.

5.8.1.7 PACKAGER shall furnish the anti-surge valves, throttle valves (when specified) with their associated devices such as, positioners, air boosters, limit switches and solenoids, all instrumentation of CGS, including transmitters (flows, pressures and temperatures) and orifice plate.

5.8.1.8 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 the flow transmitter may not exceed 3 meters, and for pressure transmitter may not exceed 5 meters.

5.8.1.9 All analog and digital variables and events shall be available for CGS_HMI and UCP_HMI.

5.8.1.10 CGS shall have fallback strategies to allow the capacity, load-sharing and anti-surge system to continue operation in the event of transmitter failure.

5.8.1.11 A detailed system operation and maintenance manual shall be provided, including detailed description of all control strategies, and configuration information for all control blocks, I/O assignments, and any other parameters. The system shall allow modification of the control blocks configurations, I/O assignments, and parameters by Petrobras, allowing complete operation, maintenance, and modifications/upgrades.

5.8.2. **Capacity control**

5.8.2.1 Each compression service type shall have a Capacity control.

5.8.2.2 Capacity control shall maintain the suction pressure and limit the maximum discharge pressure of compressor trains. If the discharge pressure exceeds the set point, system shall switch from suction pressure control to discharge pressure limit. The control shall operate in automatic and manual modes. Capacity control output is input to load sharing controls. 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 Capacity control shall be mounted on Unit Control Panel (UCP) at Automation and Electrical Panels Room (AEPR).

5.8.2.4 When the compression train operating in parallel, capacity control and load sharing control shall provide appropriate distribution of loads between compression units, so that they keep their Operating Point (OP) proportionally equidistant from their respective Surge Control Line. Special attention shall be given to compression units operating closer to the surge line.

5.8.3. **Load sharing control**

5.8.3.1 Each compression train shall have its Load sharing control.

5.8.3.2 The variable speed driver and/or throttle valve shall be included in Load sharing control loop.

5.8.3.3 Load sharing control will command speed and/or throttle valve (when specified) to maintain the desired suction pressure determined in capacity control. If Capacity control is unavailable or a compression train will work at a different suction pressure than the other compression train of the same service, then the Load sharing control shall perform suction pressure control and limit the maximum discharge pressure.

5.8.3.4 In the motocompressor the load sharing control shall also limit electric motor current.

5.8.3.5 Load sharing control shall operate individually or in parallel with others Load sharing controls at same compression service. Load sharing shall operate with automatic and manual modes. Set points shall be monitored and defined UCP_HMI from UCP at AEPR.

5.8.3.6 The control system shall have anti-reset windup action when the Driver is in limitation and strategies to allow bump less transfer when the Driver leaves the limitation or when the control system returns from manual to automatic.

5.8.4. **Anti-Surge (AS) control**

5.8.4.1 Each compression stage (section) shall have its anti-surge control.

5.8.4.2 For design purpose, PACKAGER shall consider one AS recycle line for each stage in its proposal. Overall recycle line shall not be accepted.

5.8.4.3 PACKAGER/PURCHASER shall furnish the anti-surge control valves with their instrumentation including transmitters (flow, pressure and temperature) for each stage (section). Diaphragm seal shall not be used for these instruments. The antisurge valves, instrumentation and associated piping shall be specified by Anti-surge System VENDOR. The design of the anti-surge valves, instrumentation and associated piping shall be submitted to PETROBRAS together with the certificate of approval issued by the Anti-surge VENDOR, including check valves.

5.8.4.4 The volume between discharge compressor, check valve (installed immediately after the "T" of the recycle pipe) and AS valve shall be the smallest possible. A double check valve shall be provided separating each compressor stage.

5.8.4.5 AS valves shall be sized to perform their function in all operating conditions, including transients, avoiding choke zone but not oversized in order to maintain their controllability.

5.8.4.6 The anti-surge valve shall be open at failure type, with linear response, class 5 balanced cage globe, body material according to the AS recycle line material specification for each Gas Compression 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 AS valve material selection subjected to the galling nor any other wear/corrosion mechanism will be accepted;

5.8.4.7 The anti-surge valve shall be mounted with high speed intelligent positioner and high flow booster to increase the precision and speed of actuation.

5.8.4.8 The use of quick exhaust, or similar system that opens the anti-surge valve in an uncontrolled mode, is not allowed.

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

5.8.4.10 The maximum anti-surge valve opening stroke time (0 to 100%) shall be up to 1 second for valves smaller than or equal to 4 ", up to 2 seconds for valves larger than 4" and less than 12 " and up to 3 seconds for valve larger than 12".

5.8.4.11 The minimum anti-surge valve closure stroke time (100% to 0) shall be up to 3 seconds for a valve smaller than or equal to 4 ", up to 5 seconds for valve larger than 4" and less than or equal to 12 " and up to 8 seconds for valve larger than 12”.

5.8.4.12 AS control system shall be furnished with:

- A maximum scan time of 50 milliseconds;
- Compressor surge detector;
- Supervision so that in case of two (2) surge events within fifteen (15) seconds, the AS valve shall be opened through current analog output and three-way solenoid deenergizing, installed between booster and actuator;
- Supervision so that in case of four (4) surge events within thirty (30) seconds, the AS control shall stop the compressor;
- Closed loop control signal with Proportional (P) and Integral (I) action for anti-surge control. P+I controller response shall be started when the Operation Point reaches the Surge Control Line. P+I controller shall be anti-reset windup action;
- Adaptative actions to allow the Surge Control Line to change as a function of the displacement of the operating point, with automatic return to the original position (when operating point reaches the Surge Control Line). The faster the Operation Point moves towards the Surge Control Line the faster the Surge Control Line shall move towards the Operation Point. The Surge Control Line offset rate is a function of Operation Point offset and shall be an adjustable parameter;
- An adaptive open loop response to large and fast disturbances, when Operating Point reaches the line (Trigger Line), located between Surge Control Line and Surge Line. In this case the AS valve opening response shall be immediate;
- AS valve opening shall be proportional to the displacement rate from the Operating Point towards the Trigger Line;
- Maximum opening of the valve shall be an adjustable parameter;

- The open loop response signal shall return to zero proportionally to the inverse function of an exponential;
- The coefficients of the open loop response signal decay function shall be adjustable;
- The delay time for the start of signal return to zero shall be an adjustable parameter;
- An adaptive detection algorithm in order to protect the compressor by establishing new safety margins (more conservative than previous one) when a surge event occurs;
- Decoupling gains to reduce interaction between anti-surge controls of different compression sections and among the other control loops of compression system. Decoupling gains shall be adjustable parameters;
- Control strategy that makes the Surge Line and Surge Control Line independent of variations in gas composition (molecular weight), suction pressure and suction temperature;
- Even when in manual operation, AS control shall be capable to switch-over to automatic operating if close to surge condition;
- Capacity of limiting the maximum pressure and/or maximum discharge temperature and/or minimum suction pressure of compressor through anti-surge valve opening, independently of Capacity control. The performance of these limits shall not affect Anti-surge Control. Limit values shall be adjustable parameters;
- Fallback strategies shall be also available to allow the anti-surge system to continue operation in the event of transmitter failure. In case of flow transmitter failure, AS valve shall be fully opened.

5.8.4.13 In order to achieve good controllability, PACKAGER shall recommend and review AS line layout.

5.8.4.14 AS control and Capacity control/Load sharing controls from compression service shall have a decoupling capability in order to temporally reduce the Capacity control action when the AS control is performed, especially when opening the valve.

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 in the specific project's "AUTOMATION INTERFACE OF PACKAGED UNITS" as stated in 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.

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

5.8.5.4 PACKAGER shall be able to receive 4-20mA input signals at Capacity Control for the compressor suction and discharge 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 shall be able to receive for each AS recycle valve a 4-20mA input signal in AS control system. This signal will go to a low value selector (override) with the output of the anti-surge (AS) control algorithm. In this way, the MPA or the operator can command the opening of the recycle valve, even if the AS control does not need to open the valve. This override selector shall be implemented in AS control system, but the override signal (4-20mA) will be provided by the Process Control System (PCS is scope of the PURCHASER). At UCP_HMI, operator shall select if this remote ASV command will be enabled or not.

5.8.5.6 PACKAGER shall properly monitor the 4-20 mA input signals from remote setpoints and AS valves opening, so that the failure of these signals disables the action of the MPA on the respective controller.

5.8.6. **Human Machine Interface of Compressor Governor System (CGS_HMI)**

5.8.6.1 PACKAGER/PURCHASER shall supply a dedicated HMI of Compressor Governor System (CGS_HMI) for all compressors services. This CGS_HMI shall be a 19" rack-mounted PC (at maximum with 2U height), shipped loose.

5.8.6.2 CGS_HMI shall have at least the following functionality:

- Programming and configuration interface of Capacity, Load sharing and Anti-surge control systems and Automatized Procedures Module (MPA);
- Historic log:
  a. Daily files - Recording and storing of all analog and digital variables, alarms and events Capacity, Load Sharing and Anti-surge Control Systems and MPA. with 200 milseconds 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 40 milliseconds), of all analog and digital variables, alarms and events Capacity, Load Sharing and Anti-surge Control Systems and MPA. Storage shall be at least 120 files (24 days x 5 days).
- Event and trigger log:

a. Storing all variables at the minimum sample time (40 miliseconds) 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. Surge and ESD Compressor are events that shall already be programmable in CGS_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 variabels logs in the CSV standard (data separated by semicolon);
- Simplified PI&Ds with all CGS parameters and variables;
- Compressor performance maps of all Operational Cases included in the compressor datasheet (API-617) showing the Operation Point, Surge Line, Trigger Line and Surge Control Line. The following maps are required: Rc x Q (m3/h), Pd (bar) x Q (m3/h), Td (ºC) x Q (m3/h), Hp (kJ/kg) x Q (m3/h), ηp (%) x Q (m3/h), Pot (kW) x Q (m3/h), Rc x QN (Sm3/d at 15.6 ºC and 1 atm);
- Compressor performance map Rc x Invariant flow of suction conditions showing the Operation Point, Surge Line, Trigger Line and Surge Control Line.

5.8.6.3 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.

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

5.8.6.5 A fiber optic port shall be available in one of the UCPs of the compression system for this HMI interconnection.

5.8.6.6 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.

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 and 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 Motor Control Center (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 present 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 inside the skids and inside de module, 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 and handling 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, HVSD, electric motor rotor, etc.), including internal parts such as compressor bundle, electric motor rotor and HVSD core runner with adequate and certified capacity to handle maximum maintenance weight and/or dimensions. Lifting and handling devices shall be according to the specific project's "TOPSIDE´S MECHANICAL HANDLING PROCEDURES" as stated in the DOCUMENT LIST.

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

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

7.9. PACKAGER and PURCHASER shall provide a HVSD shaft end with an adaptor in order to allow manual turning for maintenance purposes.

7.10. Noise control requirements

7.10.1. 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.

7.10.2. 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.

7.10.3. The noise control system for the package shall consider the noise radiated by inlet/outlet piping, equipment enclosure including ventilation system (if specified) and equipment casings.

7.10.4. 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.

7.10.5. 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 blanket or acoustic walls (open roof) and safety system requirements. The use of device to comply with noise requirement must be proved to be efficient and submit to PETROBRAS approval.

7.10.6. 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.

7.10.7. 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 PETROBRAS 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.

8.1.9. Hydrodynamic Bearings, if required, and DGS shall be removed by PACKAGER after Factory Acceptance Test of Compressor (FAT) or Factory Integrated Test (FIT) and package separately with clear identification to be delivered with the main equipment in a packing suitable for long term storage for posterior PACKAGER assembly.

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 bundles according to ASME PTC 10 (type 2).

8.3.2. PACKAGER shall measure balance line flow and division wall flow calculation during performance test.

8.3.3. 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 all spares bundles according to API STD 617 last Edition.

8.4.2. PACKAGER shall submit to 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. Full Pressure Full Load Full Speed Test (FPFLFS)

8.5.1. According to the requested by each Compressor Service Data Sheet, Full-pressure, Full-load, Full-speed Test (FPFLFS) shall be performance as per API 617 per compressor type. As a PT and MRT items, the FPFLFS shall also be witnessed. During this test, shop driver may be used.

8.5.2. When requested, one full-pressure, full-load, full-speed test shall be performance as per API 617 item 4.3.8.6 per compressor type during the Mechanical Running Test. As a MRT item, the full pressure/load/speed shall also be witnessed. During this test, shop driver may be used.

8.5.3. The FPFLFS procedure shall be agreed with PETROBRAS including acceptance criteria.

8.6. Factory Stability Test (FST)

8.6.1. According to the requested by each Compressor Service Data Sheet, FST per compressor type shall be performed as described in “Annex B”.

8.6.2. The FST procedures shall be agreed with PETROBRAS.

8.7. Sound Level Test (SLT)

8.7.1. 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.

8.7.2. 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.

8.7.3. 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.

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

8.7.5. If the values measured and reported during the shop test are higher than the limits submitted by PACKAGER and 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 PETROBRAS.

8.8. **Factory Integrated Test (FIT)**

8.8.1. 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.

8.8.2. The FIT procedure, with the steps and duration, shall be similar to the MRT, and shall have, at least, three starts and three stops. The test is without process plant, and therefore the compressor shall be under vacuum. It is not necessary to perform the unbalance test.

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

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

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

8.8.6. The FIT procedure shall be agreed with PETROBRAS.

8.9. **Shipyard Acceptance Test (SYAT)**

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

8.9.2. Shipyard Acceptance Test (SYAT) shall be performed in the shipyard facilities after compressor and process plant complete commissioning (including N2 and He leakage test of piping system been executed) and complete integration with all systems of FPSO that support the operation of compression system.

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

8.9.4. PURCHASER and PACKAGER shall perform a SLT during SYAT.

8.9.5. The SYAT procedure shall be agreed with PETROBRAS including acceptance criteria. However, the acceptance criteria stated at Annex C shall be complied.

8.10. **Site Acceptance Test (SAT)**

8.10.1. Site Acceptance Test (SAT) is an offshore acceptance test to be performed when the motocompressor is able to operate after all commissioning is complete and not pending.

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

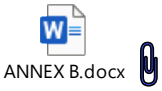
8.10.3. PURCHASER and PACKAGER shall provide all facilities, support and technical assistance for SAT. PURCHASER is responsible for any repairs required during the SAT that are not caused by factors external to the motocompressor system.

8.10.4. The SAT procedure shall be agreed with PETROBRAS.

9. ANNEXES

9.1. Annex A: Rotating Equipment Reliability Test.

9.2. Annex B: Additions and Modifications to API 617.



9.3. Annex C: Inert Gas Centrifugal Compressor Running Test.