MATERIAL AND EQUIPMENT STANDARD

FOR

AXIAL AND CENTRIFUGAL COMPRESSORS AND

EXPANDER-COMPRESSORS

FOR

PETROLEUM, CHEMICAL AND GAS INDUSTRY SERVICES

SECOND REVISION

JUNE 2009

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CHAPTER 1

GENERAL REQUIREMENTS

0. INTRODUCTION

This Standard gives technical specifications and general requirements for the purchase of "Axial and Centrifugal Compressors and Expander-Compressors for Petroleum, Chemical and Gas Industry Services" and is based on API Standard 617, seventh edition July 2002 and shall be read in conjunction with that document.

Since reference Standard is integrated of Axial and Centrifugal Compressors, Expander-Compressors and Integrally Geared Compressors, so this Second(2) edition, which is the "IPS" of the same number but different title of Centrifugal Compressor and has been technically revised, cancels and replaces three Standards of IPS-M-PM-170(1) dated June 2002, IPS-M-PM-190(1) March 2001 and IPS-M-PM-270(0) July 1994.

Guidance for Use of this Standard

The amendments/supplement to API Standard 617 given in this Standard are directly related to the equivalent sections or clauses in API Standard 617. For clarity, the section and paragraph numbering of API Standard 617 has been used as for as possible. Where clauses in API are referenced within this Standard, it shall mean those clauses are amended by this Standard. Clauses in API that are not amended by this Standard shall remain valid as written.

The following annotations, as specified hereunder, have been used at the bottom right hand side of each clause or paragraph to indicate the type of change made to the equivalent clause or paragraph of API.

Sub. (Substitution) : The clause in API shall be deleted and replaced by the new clause in this Standard.

Del. (Deletion) : The clause in API shall be deleted without any replacement.

Add. (Addition) : The new clause with the new number shall be added to the relevant section of API.

Mod. (Modification): Part of the clause or paragraph in API shall be modified and/or the new description and/or statement shall be added to that clause or paragraph as given in this Standard

1. GENERAL

1.1 Scope

Selected equipment shall be in all respect, well within the range of manufacturer's proven experience and shall not involve the use or application of any prototype design or components.

No deviations or exceptions from this Standard shall be permitted, without explicit approval of the company.

Intended deviations shall be separately listed by the vendor, supported by reason thereof and submitted for company's consideration. **(Mod.)**

1.3 Conflicting Requirements

In the case of conflict between documents relating to the inquiry or order, the following priority of documents (whichever is more stringent realized by company) shall govern:

First priority : Purchase order and variations thereto.

Second priority : Data sheets and drawings.

Third priority : This specification.

All conflicting requirements shall be referred to the purchaser in writing.

The purchaser will issue confirmation document if needed for clarification. **(Sub.)**

1.4 DIMENSIONS

SI Unit System, dimension and rating in accordance with IPS-E-GN-100 shall be used, Unless otherwise specified. **(Sub.)**

1.6 Normative References

The editions of the following standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the company and the vendor:

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-E-GN-100 "Engineering Standard for Units"

IPS-G-SF-900 "Engineering Standard for Noise and Vibration Control System"

IPS-E-EL-110 "Engineering Standard for Electrical Area Classification and Extend"

IPS-M-PM-240 "Material and Equipment Standard for General Purpose Steam Turbine"

IPS-M-PM-250 "Material and Equipment Standard for Special Purpose Steam Turbine"

IPS-M-PM-260 "Material and Equipment Standard for Industrial Combustion Gas Turbine for Process Services"

IPS-M-EL-132 "Material and Equipment Standard for Induction Motors"

IPS-M-PM-300 "Material and Equipment Standard for Special Purpose Gear Units for Process Services"

IPS-M-PM-320 "Material and Equipment Standard for Lubrication, Shaft Sealing and Control Oil Special Purpose Application"

IPS-M-PM-110 "Material and Equipment Standard for Special Purpose Couplings" **(Mod.)**

1.8 Unit Responsibility

Unless otherwise specified, compressor manufacturer shall be unit responsible.

The Manufacturer shall be responsible for the design and engineering, the total mechanical/aero-dynamic performance, and the guarantee of the entire compressor unit. This includes the compressor, driver, power transmission equipment and all auxiliary equipment furnished by sub-suppliers when purchased by the Manufacturer. **(Mod.)**

2. BASIC DESIGN

2.1 General

2.1.1 Performance

2.1.1.1 Note: Purchaser shall pay due attention in specifying all the possible process variations such as changes in pressure, temperature, molecular weight,… during the service life specified in (2.1.2). In upstream applications such as gas lift, gas gathering, and gas re-injection the possible variation of the gas molecular weight shall to be consulted with the reservoir specialist. If a variable speed unit is used the speed required to achieve the specified rated operating conditions shall be indicated. (**Mod.)**

2.1.1.4 For reference purpose the physical properties of the process gas (Cp/Cv, Compressibility factor, molecular weight, etc.) may be given on the data/requisition sheets in order to facilitate the compressor calculations. However, the Manufacturer shall base his performance calculations on the gas composition as stated in the data/requisition sheets.

The Manufacturer shall calculate the performance of the proposed compressor using his standard methods for computing the physical properties of the specified gases and shall take full responsibility for any design features affected. The Manufacturer shall affirm the equation of state, mixing rule, interaction coefficients and values of all physical properties of the process gas used in his computations with his proposal. **(Mod.)**

2.1.2 The equipment (including auxiliaries) covered by this standard shall be designed and constructed for a minimum service life of 25 years and at least 5 years of uninterrupted operation.

Note: It is recognized that this is a design criterion. **(Sub.)**

2.1.6 For offshore installations the vendor who has unit responsibility shall notify the Company in his proposal the area required for the maintenance and repair of the entire equipment train to be supplied. **(Mod.)**

2.1.8 Unless otherwise specified, compressors and auxiliaries shall be suitable for outdoor installation in the climatic zone specified. **(Mod.)**

2.1.9 Compressors shall be designed & manufactured to minimize the generation of noise and shall not exceed the noise limits given in the following Table, at any measuring location not less than 1m from the equipment surface.

Sound Pressure Limit in dB re 20 mPa	
Compressor	**87 dB**
Compressor + Driver	**90 dB**

If the equipment produces impulsive noise, the above limits shall be taken 5dB lower, thus 82dB for compressor and 85dB for the compressor + driver.

The above requirements apply in the absence of reverberation and background noise from other sources, and for all operating conditions between minimum flow and rated flow.

Where excessive noise from equipment can not be eliminated by low noise design, corrective measures preferably should take the form of acoustic insulation for pipes, gearbox, etc. where noise hoods are proposed, prior approval of the Purchaser shall be obtained regarding construction, materials and safety requirements.

Noise control measures shall cause no hindrance to operations nor any obstruction to routine maintenance activities. **(Sub.)**

2.1.13 d) When specified, be present during initial installation and initial start-up. An outline of initial start-up procedures shall be prepared by the Manufacturer and shall be agreed upon by all parties involved before operations are commenced. **(Mod.)**

2.1.14 All electrical components and installations shall be suitable for the area classification, gas grouping and temperature classes specified by the purchaser on the data sheets, and shall meet the requirements of IPS Standards IPS-M-EL-132 and IPS-E-EL-110. **(Sub.)**

2.1.15 Throughout the service life specified in (2.1.2), spare parts for all components of the unit shall be available for purchase and all manufacturing drawings shall be retained. **(Add)**

2.1.16 Note: For some applications such as offshore, when the specified process gas is not accessible in the platform fabrication yard, compressor may be field run on air for the purpose of pre-commissioning. **(Mod.)**

2.1.17 Compressor ratings shall not exceed the limits of the Vendor's design but shall be well within the manufacturer's actual experience. Only equipment which has proven its reliability is acceptable. **(Add.)**

2.1.18 Unit responsible representative shall be present in HAZOP meeting as requested by the Company. **(Add.)**

2.1.19 A detail statement for supervision of installation, pre-commissioning, startup, and commissioning of the equipment at jobsite, including daily rates, terms and conditions shall indicate in the proposal. **(Add.)**

2.1.20 Vendor shall supply temporary strainers for compressors commissioning. Dimensional drawings of the strainers shall be submitted to the Purchaser **(Add.)**

2.2 Material

2.2.1 General

2.2.1.1 Shaft shall be of forged steel material, and shall be ultrasonically examined prior to machining. **(Mod.)**

2.2.1.2 When vendor's quoted material specification is DIN, JIS or other foreign standards, the proposal shall include the nearest above named American specification equivalent along with exact and specific deviations, (chemical properties, physical properties, tests, type of heat treatment, etc.) if such exist, for purchaser's evaluation of equivalence for service intended. **(Mod.)**

2.2.1.4 Radiographic inspection procedure shall be applied wherever possible. Butt welded joints of pressure casing shall be 100% radiographed. **(Mod.)**

2.2.1.14 Cooper or cooper alloys shall not be used for parts of machines or auxiliaries in contact with process fluid. Nickel-cooper alloy (UNS N04400), bearing babbit, and precipitation hardened stainless steels are excluded from this requirement. **(Sub.)**

2.2.1.15.5 All carbon and low alloy steel pressure-containing components including nozzles, flanges, and weldments shall be impact tested in accordance with the requirements of Section VIII, Division 1, Sections UCS-65 through 68, of the ASME Code standard. High-alloy steels shall be tested in accordance with Section VIII, Division 1, Section UHA-51, of the ASME Code standard. For materials and thicknesses not covered by Section VIII, Division 1 of the ASME Code standards, the purchaser will specify requirements.

Note: Impact testing of a material may not be required depending on the minimum design metal temperature, thermal, mechanical and cyclic loading and the governing thickness. Refer to requirements of Section VIII, Division 1, Section UG-20F of the ASME Code, for example. Governing thickness used to determine impact testing requirements shall be the greater of the following:

a) The nominal thickness of the largest butt-welded joint.

b) The largest nominal section for pressure containment, excluding:

1. Structural support sections such as feet or lugs.

2. Sections with increased thickness required for rigidity to mitigate shaft deflection.

3. Structural sections required for attachment or inclusion of mechanical features such as jackets or seal chambers.

c) One fourth of the nominal flange thickness, including parting flange thickness for axially split casings (in recognition that the predominant flange stress is not a membrane stress).

The results of the impact testing shall meet the minimum impact energy requirements of Section VIII, Division 1, Section UG-84, of the ASME Code standard. **(Sub.)**

2.3 Inter Stage Diaphragms and Inlet Guide Vanes

2.3.1 Pressure-containing casings

2.3.1.1.2 All butt welds on fabricated steel casings shall be 100% X-rayed after post weld heat treatment. Further magnetic particle or dye penetrant examination shall occur after final machining. Purchaser and Vendor shall agree prior to fabrication which welds will be inaccessible upon completion of fabrication for quality control assessment of welds. **(Mod.)**

2.3.1.3 Cast Iron casings are not acceptable. Radial split (barrel) casings and their end covers shall be forged steel if the design pressure exceeds 6900 kPa (69 Bar) or any molecular weight specified is less than 15 **(Sub.)**

2.3.1.11.2 Manufacturer shall provide drawings showing location of all welds inaccessible for NDT, in particular stressed welds on hydrocarbon containing components of the compressors. **(Mod.)**

2.3.1.12 Material Inspection of Pressure-containing Parts

2.3.1.12.4 All pressure welds shall be %100 radio graphic examination. If radiography is not feasible, magnetic particle examination shall be performed. **(Add.)**

2.3.2 Pressure casing connections

2.3.2.1 General

2.3.2.1.8 Casing drains shall be individually valved, and when specified, manifolded, supported and piped up to a single nozzle at the base-plate edge. Blocked valve, shall be easily accessible. Number and locations of drains offered shall indicated in the proposal. **(Add.)**

2.3.2.2 Main process connections

2.3.2.2.2 Main process connections, shall be flange type, unless otherwise specified. **(Mod.)**

2.3.2.3 Auxiliary connections

2.3.2.3.3 Socket welded connections shall not exceed DN50. **(Mod.)**

2.5 Rotating Elements

2.5.1 Shaft ends for coupling fits shall conform to IPS-M-PM-310. **(Sub.)**

2.5.2 Electrical and mechanical run out shall be determined by rolling the rotor in V-block at the journal centrelines, while measuring run out with a noncontacting vibration probe and a dial indicator at the same shaft location. Readings shall be recorded at the probe location and one probe tip width to both sides. Metalizing or plating to reduce electrical run out shall be permitted on precipitation-hardened steel shafts only, and shaft be flame or plasma sprayed aluminium applied by a vendor with proven experience in this process. **(Mod.)**

2.5.3 If the radial combined total electrical and mechanical run out exceeds the 5µm limit of this paragraph, Vendor shall first ensure that mechanical run out at probe locations does not exceed 2.5µm. After achieving this mechanical run out, two attempts shall be made to burnish to meet the 5 µm total run out limit. After these attempts, Purchaser shall be contacted to evaluate this deviation. **(Mod.)**

2.5.4 Impellers shall be designed to limit the maximum stress at maximum continuous speed to a value of 70% of the material yield strength. **(Mod.)**

2.5.8 The design for shaft-impellers and shaft-seal sleeves or shaft-seal labyrinth assembly shall not create distortion of the rotor assembly at rest, or bore growth, deteriorating concentricity and balance at trip speed. Finite element analyses must support the interference fit design for the wheels carrying full torques during the worst case trip speed condition. Keys shall be the cylindrical type when used. **(Mod.)**

2.5.10 Impellers

2.5.10.2 Forged rather than cast impellers are preferred. **(Mod.)**

2.5.10.4 Cast impellers shall be inspected after machine finishing as well. **(Mod.)**

2.5.10.5 Cast iron crack defect repair is not acceptable. **(Mod.)**

2.6 Dynamics

2.6.1 General

2.6.1.1 The effect on rotor stability of high density gas shall be taken in the consideration. **(Mod)**

2.6.1.4 Unless otherwise specified the compressor Vendor shall be unit responsible for Undesirable speed calculations and shall furnish satisfactory verification of Undesirable speed calculations, including all driver train components prior to submittal of certified composite outline drawing.

Both torsional and lateral vibration analysis are the complete responsibility of the compressor Vendor. The Vendor shall furnish a copy of this analysis and related data for review. **(Mod.)**

2.6.2 Lateral Analysis

2.6.2.1 Undesirable speeds (including critical speeds)And their associated AFs shall be determined by means of a damped unbalanced rotor response analysis. **(Mod)**

2.6.2.2 The Location of all Undesirable (including Critical speeds) below the Trip Speed shall be Confirmed on the test stand during the mechanical running test (see2.6.3.1) The accuracy of the analytical model shall be demonstrated (See.2.6.3) **(Mod)**

2.6.2.6 A train lateral analysis, considering the effect of other equipment in the train on the damped unbalance response analysis, shall be quoted as an option by the vendor who is assigned unit responsibility. **(Sub.)**

2.6.2.10 (a.) Every attempt shall be exercised to remove any undesirable speeds with Amplification Factor near to 2.5, from operating speeds ranges. **(Mod)**

2.6.7 Torsional Analysis

2.6.7.1 For motor-driven units and units including gears, units comprising three or more coupled machines (excluding any gears), or the vendor having unit responsibility shall ensure that a torsional vibration analysis of the complete coupled train is carried out and shall be responsible for directing any modifications necessary to meet the requirements of 2.6.7.2 through 2.6.7.6.

2.6.8 Vibration and Balancing

2.6.8.2 Rigid rotors shall have a minimum of three balancing planes. The dynamic balance of the rotor shall be verified after installation of coupling hub. All balance reading shall be recorded. **(Mod.)**

2.6.8.2.1.1 The vendor shall record the balance readings after initial balance for the contract rotor. The rotor shall then be disassembled and reassembled. The rotor shall be check balanced after reassembly to determine the change in balance due to disassembly and reassembly. This change in balance shall not exceed that defined in 2.6.8.2.1c. **(Sub.)**

2.6.8.3 Completely assembled rotating elements shall be subject to operating-speed (at speed) balancing in lieu of a sequential low speed balancing (see 2.6.8.2). When the vendor's standard balance method is by operating-speed balancing in lieu of a sequential low speed balancing and operating speed balancing is not specified, it may be used with the purchaser's approval. The operating-speed balance shall be in accordance with 2.6.8.4. **(Sub.)**

2.6.8.6 A rotor that is to be operating-speed balanced shall, when specified, first receive a sequential low speed balance as specified in 2.6.8.2. **(Sub.)**

2.6.8.11 Any correction action (if needed), such as demagnetization after rotor balancing, shall be performed by Vendor. **(Mod.)**

2.7 Bearings and Bearing Housings

2.7.1 General **(Mod.)**

2.7.1.1 Each radial bearing shall have two thermocouples or RTD embedded in the bottom of most highly loaded shoe. Two thrust bearings pads on each side, 180° a part, shall be furnished with double head thermocouples or RTD suitable for connection to indication and alarm instruments.

2.7.1.2 All sensors shall be permanently cabled up to the local junction box at skid edge.

2.7.1.3 The indicating device shall indicated 2 levels: one for the alarm and one for tripping. They shall be set individually and connected to sensing points.

2.7.4 Bearing Housings

2.7.4.6 The number of connections in cabling, shall be the minimum possible that facilitates assembly and disassembly. **(Mod.)**

2.8 Shaft end Seals

2.8.1 General

2.8.1.1 Unless seal manufactured by main Vendor, manufacturer shall provide full technical details with the proposal, including a reference list with at least two examples of similarly sized seals each having achieved minimum of two years continuous operation in similar services **(Mod.)**

2.8.1.3 Shaft seals in inert gas service shall be of the labyrinth type. Shaft seals in toxic gas services shall be of the liquid film type unless otherwise specified. **(Mod.)**

2.8.1.5 Unless otherwise specified, the seal design shall have provision for buffer gas injection. **(Mod.)**

2.8.1.6 When buffer gas injection is required for compressor, the supplier shall state the gas requirements and limitations, including temperature, dew point in his proposal, and furnish complete system.

The system for continuous buffer gas injection shall include but not limited to dual appropriate mesh size strainer, automatic differential pressure controller, low pressure alarm and buffer gas pressure gage and cooler if required. Piping material for down stream of strainer shall be stainless Steel. **(Mod.)**

2.8.1.9 Various supplemental devices shall be provided to ensure sealing, when the compressor is pressurized but not running and the seal oil system is shutdown. Vendor shall state his means in the proposal. **(Add.)**

2.8.2 Clearance seals

2.8.2.1 The labyrinth seals should be stationary part of the machine. **(Mod.)**

2.8.4 Self-acting dry gas seal

2.8.4.2 The dry gas seal, must be able to withstand seal pressure fluctuations down to under atmospheric. If back ward rotation can occurred, it is required to select a seal which has ability to rotate in both directions. **(Mod.)**

2.10 Lubrication and Sealing Systems

2.10.3 Lubricating Oil and Seal Oil systems shall comply with API Std 614 as amended/supplemented by IPS-M-PM-320. **(Sub.)**

2.11 Nameplates and Rotation Arrows

The text on nameplates shall be in English and, the data shall be in SI Units, unless otherwise specified. The information on nameplates shall include the year of manufactured.

Serial numbers shall be assigned in foundry or engraved on the casing.

The machines shall be labeled before mechanical and performance tests. Changing the serial number after testing is prohibited. All major components (casing, shafts, impellers, etc.) shall have individual identification code numbers and be marked with indices when several identical units are ordered. These code numbers and indices shall be recorded on the test sheets. **(Mod.)**

2.11.3 The text on nameplates shall be in English language and unless otherwise specified the date shall be in SI Units. The information on nameplates shall include the year of manufacture. **(Add.)**

3. ACCESSORIES

3.1 Drivers

3.1.4 Steam turbine drivers shall conform to API Standard 611/ as its supplemented by IPS Std. IPS-M-PM-240, or with API Standard 612/as its supplemented by Std. IPS-M-PM-250 whichever applicable.

Steam turbine drivers shall be sized to deliver continuously not less than 110 percent of the maximum power required by the machine train, when operating at any of the specified operating condition, and specified normal steam conditions. **(Sub.)**

3.1.5 Motor drives shall conform to IPS Standard IPS-E-EI-131 or IPS Standard IPS-E-EL-132, as applicable. Electric motor drivers shall be rated with a 1.0 S.F. The motor rating shall be at least 110 percent of the greatest power required (including gear and coupling losses) for any of the specified operating conditions. Consideration shall be given to the starting conditions of both the driver and driven equipment and the possibility that these conditions may be different from the normal operating conditions. **(Sub.)**

3.1.7 Gas turbine drivers shall conform to API Std. 616 as amended/ its supplemented by IPS Std. IPS-M-PM-260.

There shall be power output margin of at least 7% between the demand of the driven equipment and the power of the gas turbine at site when in new and clean condition. Note that the power extracted by the auxiliaries, directly driven from the gas turbine, is not always included in the vendor's standard information sheets.

Having established the site rating for the gas turbine, the ISO* rating of the gas turbine can be calculated to serve as a guide for comparing the available makes and models of the gas turbine type suitable for the application being considered.

***The ISO rating of a gas turbine is its rating at 15°C ambient temperature, at 1013.25 mbar and 60% relative humidity, with zero inlet and exhaust pressure losses. (Sub.)**

3.1.8 Gears shall be in accordance with API Std. 613 /or as its supplemented by IPS-M-PM-300. **(Mod.)**

3.1.9 Electric motors for auxiliary equipment shall comply with IPS Std. IPS-M-EL-132. **(Add.)**

3.2 Coupling and Guards

3.2.8 All hubs shall be fitted to the finish machined shaft ends before factory testing, and before delivery. **(Add.)**

3.3 Mounting Plates

3.3.1 General

3.3.1.2.6 Unless otherwise specified, anchor bolts and shims plates for alignment, shall be furnished by the Vendor. **(Sub.)**

3.3.2 Base plate

3.3.2.4 Welded non-slip decking plates shall be provided for the top of the base-plate. They shall cover all walk and work areas. The plate s shall be fastened and shall allow access to inside components. **(Mod.)**

3.3.2.6 Supplier shall provide method for leveling to facilitate use of optical, laser or other instruments. **(Mod.)**

3.3.2.12 All auxiliary piping and accessories shall be mounted within the base-plate perimeter. **(Add.)**

3.3.2.13 Unless otherwise specified a common base plate extended as practically as possible to support the driver, other compressors, gears shall be provided. **(Add.)**

3.4 Controls and Instrumentation

3.4.1 General

3.4.1.1 The vendor shall provide sufficient machine performance data (in accordance with Section 5) to enable the purchaser to properly design a control system for start-up operation, for all specified operating conditions, and for surge prevention. The vendor shall review the purchaser's overall machine control system for compatibility with vendor-furnished control equipment.

The Instrument and Control System Shall Permit Local Start-up Of the equipment and Subsequent Transfer of Control to remote Control room Panel. The equipment shall then normally be operated from the remote Control room Panel.

Instrumentation shall be designed for minimum manning and operator attention. Alarms for equipment and process functions, equipment and process initiated shutdown annunciation and all critical operation information shall be displayed on the remote control room panel and be provided with suitable signals to repeat this information on the local panel. The compressors and drivers shall be suitable for automatic unattended start up. **(Sub.)**

3.4.1.2 The instrumentation and installation shall conform to the requirements of API Std. 614. Chapter 1 / IPS-M-PM-320. **(Sub.)**

3.4.1.3 Compressor and driver monitoring panels shall be mounted in the Control room unless otherwise specified. **(Mod.)**

3.4.2 Control systems

3.4.2.4 An anti-surge device shall be utilized if system requirements indicate that the compressor may operate in surge for intended periods. **(Add.)**

3.4.3 Instrument and Control Panels

Minimum Instrumentation and process controls shall be furnished as specified and listed in Table 1. Any additional instrumentation and controls as deemed necessary. For the smooth and safe operation of the unit under all specified operating conditions shall be provided.

Compatibility of overall compressor control system with the furnished instrumentation and controls, shall be ensured. The nominal supplies and location of each instrument written in the table shall be indicated by the following coded notes:

(LM) Locally Mounted

(LP) Local Panel Mounted

(UCP) Unit Control Panel

TABLE 1- CONTROLS AND INSTRUMENTATION

INSTRUMENTS	SUPPLY & LOCATION
a) Pressure and level gages, pressure controllers, control valves, thermometers, pressure, differential pressure and temperature switches, and relief valves at the compressor for separate lube oil systems.	LM
b) Pressure and level gages, level controllers, pressure controllers, control valves, thermometers; pressure, differential pressure, level and temperature switches, flow meters or indicators, and relief valves, for seal oil system.	LM
c) Start and Stop push button station with pilot lights for lube oil pump motor and seal oil pump motor.	LP
d) Speed indicator for compressor.	LP
e) Pressure gages for compressor suction and discharge.	LP
f) Pressure gage for lube oil pump discharge.	LM
g) Pressure gage for seal oil pump discharge.	LM
h) Pressure gage for Reference Gas Line (if applicable).	LM
i) Pressure gage for Balance Gas Line (if applicable).	LM
j) Pressure gage on air supply for flow regulator to seals.	LP
k) Pressure gage for lube oil to compressor bearings.	LP
l) Sight glasses on Seal & Lube oil out-let lines.	LM
m) Differential pressure gage for seal oil.	LM
n) Gage glass for seal oil overhead tank.	LM
o) High seal oil return temperature.	LP
p) Sight glass for Lube oil reservoir	LM
q) Temperature indicator for discharge gas	LP

A free standing local control panel shall be supplied by the Vendor, completely enclosed and sealed and suitable for pressurizing to keep out dust.

The panel shall include all the applicable items listed, together with alarm lights suitably screened to be easily visible in bright sunlight and other process instruments as required.

Access for easy maintenance to this panel shall be provided, and location of the panel shall be so as to facilitate easy control of the equipment.

Consideration may also be given to the installation of a separate ground mounted panel to cover auxiliary equipment mounted on the console if easier operation would be achieved. **(Mod.)**

3.4.4 Instrumentation

Alarms and interlock/ shutdown Circuits shall be generally "fail safe" i.e.. normally energized, contacts Closed in the healthy state. **(Mod.)**

3.4.5 Alarms and Shutdown

Refer to API std 614 for details on instrument and control panels as amended /supplemented by IPS-M-PM-320.

As a minimum, following mentioned items (Table-2) shall be furnished. Local indication lights shall indicate green for normal operation, yellow for warning-Alarm, and red, for shutdown. Alarm system shall be independent of shutdown devices.

TABLE 2 - ALARMS AND SHUTDOWNS

SERVICE	ALARM LIGHTS	ALARM SWITCHES	SHUTDOWN DEVICE
a) Low lube oil pressure	LP, UCP	LM	UCP
b) Low seal oil differential pressure	LP	LM	None
c) High seal oil differential pressure	LP	LM	UCP
d) High lube oil temperature (after oil cooler)	LP, UCP	LM	UCP
e) High compressor discharge temperature	LP	LM	UCP
f) Low level in lube oil reservoir	LP	LM	None
g) Low level in seal oil reservoir	LP	LM	None
h) Axial movement of compressor shaft	LP	LM	None
i) High vibration of compressor	LP	LM	UCP
j) Main seal oil pump failure	LP, UCP	LM	UCP
k) Main lube oil pump failure	LP, UCP	LM	None
l) Start standby lube oil pump	LP, UCP	LM	None
m) Start standby seal oil pump	LP	LM	None
n) High temperature in Lube oil reservoir (if applicable)	LP	LM	None
o) High temperature in Seal oil reservoir (if applicable)	LP	LM	None

The alarm and shutdown systems involving equipment, environmental and/or personnel safety shall be so designed as they cannot be bypassed during operation the alarm units shall However 20% spare lines. **(Mod.)**

3.4.7 Vibration, position and bearing temperature detectors

3.4.7.1 a) Unless otherwise specified, vibration and axial displacement measurement probes shall be installed in removable, externally mounted probe holders. Each holder shall be shouldered so that probe location is maintained when the probe is removed and reinstalled. Both the probes and the holders shall be securely locked in place. Mountings shall permit removal and installation during compressor operation with a minimum spillage of oil.

b) The shaft, in the region of the radial probes, shall present an un-plated, ground surface, having a total run-out not exceeding 25% of the specified test level or 6 microns, which ever is greater. The shaft shall be de-magnetized prior to the installation of the probes.

c) Readout equipment provided for continuous monitoring of the vibration/axial displacement shall match the characteristics of the detector-probe system and shall not require field calibration.

d) Standardized cable lengths shall be used to interconnect the detector probe and readout equipment. Radial vibration readout equipment shall be suitable for combining the two signals from H/V probes in the right phase and shall indicate the real value of the maximum peak to peak displacement. Readout equipment shall be mounted on the local panel. Each monitor shall be provided with jack connectors, one per probe to permit connection of portable analysis equipment (oscilloscope, etc.).

e) The supplier shall indicate the settings for the alarm and shutdown in case of excessive radial vibration and axial displacement. Alarm and shutdown signals shall be individually connected to the alarm and shutdown alarm annunciation system of the compressor unit. **(Mod.)**

3.4.8 As a minimum and unless otherwise specified, the following instrumentation shall be provided.

1. All thrust bearing temperatures (50% of pads on active side and 2 pads on inactive side) shall be monitored as follows:

a) Each thermocouple point high temperature alarm.

b) If specified, a temperature recorder shall be provided for thermocouple points.

2. Permissive start facility shall be provided for lube oil seal oil and control oil. so that the driver cannot be started unless the oil system is functioning correctly.

3. Compressor discharge high gas temperature alarm shall be provided (shutdown shall be provided if there is a possibly of compressor discharge temperature exceeding maximum case design temperature)

4. Diaphragm cooling water system, Low water Pressure alarm and Stand-by water pump cut-in alarm (when a applicable). **(Add.)**

3.5 Piping and Appurtenances

3.5.1 General

3.5.1.5 All interconnecting piping between the twin units, the lube and seal oil console(s) and the various equipment groupings shall also be provided. **(Add.)**

3.5.1.6 All piping for utilities (cooling water, steam, instrument air, purge gas, buffer gas etc.) shall be provided and arranged in a way that will permit single inlet/outlet connections. **(Add.)**

3.5.1.7 When a buffer gas manifold is specified, the required components such as valves, flow meter, check valves, pressure indicators, throttle valves, differential pressure indicators, controllers, and control valves shall be furnished by the vendor **(Add.)**

3.5.3 Process Piping

Process piping, if furnished, shall be in accordance with 2.4 of Chapter 1 of API Std. 614 / IPS Standard M-PM-320. **(Mod.)**

3.6 Special Tools

3.6.1 For radially split units, vendor shall furnish a cradle or similar device for ease of removal of the compressor rotor and diaphragm. **(Mod.)**

4. INSPECTION, TESTING AND PREPARATION FOR SHIPMENT

4.1 General

4.1.2 Auxiliary equipment such as drivers, gears, and oil systems shall be inspected and tested in accordance with the specified IPS and/or API standards for the equipment as well as the requirements (including specified optional test) of this standard. **(Mod.)**

4.1.8 The purchaser's representative shall have the right to reject any parts of the equipment which do not conform to purchase order. **(Add.)**

4.2 Inspection

4.2.1.3 Any portion of the oil system furnished shall meet the cleanliness requirements of the IPS-M-PM-320. **(Mod.)**

4.2.1.4 Final inspection for cleanliness of the compressor piping and auxiliary equipment shall be performed. **(Mod.)**

4.2.1.6 Purchaser shall be informed by Vendor of any defects noticed during manufacturing. Supplier shall also informed the Purchaser and obtain his permission before proceeding with any repairs which may affect equipment operation, integrity of interchangeability. Repair procedure shall be approved by the Purchaser before rectification. **(Add.)**

4.3 Testing

4.3.1 General

Acceptance of shop test does not constitute a waiver of equipment to field performance under specified operating conditions nor does inspection relieve the vendor of his responsibilities. **(Mod.)**

4.3.1.3 The vendor shall notify the purchaser not less than 15 days before the date that equipment will be ready for test. **(Mod.)**

4.3.3 Overspeed Test

4.3.3.1 Impeller Overspeed Test

Each impeller shall be subjected to an over speed test at not less than 115 percent of maximum continuous speed for a minimum duration of 3 minutes. **(Mod.)**

4.3.6 Mechanical running test

4.3.6.1.3 Vendor shall make tapes recordings of all real-time vibration data starting with initial shop run and given to Purchaser, even if not witnessed or observed. **(Sub.)**

4.3.6.1.4 a) Seal leakage rates per seal, shall not exceed the guaranteed maximum rates stated in vendor's proposal. **(Mod.)**

4.3.6.1.5 During the mechanical running test the lubricating oil and seal oil temperatures shall be held for a minimum period of 30 minutes at the temperature corresponding to the minimum allowable viscosity and per 30 minutes at the temperature corresponding to the maximum allowable viscosity. **(Mod.)**

4.3.6.1.6 If the compressor is designed with variable stator geometry, the linkage, servo-motor and stator blade seal shall be checked during mechanical test. **(Add.)**

4.3.7 Assembled Machine Gas Leakage Test

During the leak test the rotor shall be turned manually to check seal adjustment. Gas leakage test of assembled unit with seals installed shall be performed on the maximum discharge pressure. Leak test shall be the last tests to be performed before dispatch. If a casing joint has to be remade after this test, the test shall be performed again. **(Mod.)**

4.3.8 Optional test

4.3.8.5 Post-test Inspection of Compressor Internals

The compressor shall be dismantled, inspected, and reassembled after satisfactory completion of the mechanical running test. The purchaser will specify whether the gas test shall be performed before or after the post-test inspection. However for toxic gas compressors, leak shall be conducted after assembly, as per Para 4.3.7 **(Sub.)**

Note: The merits of post-test inspection of compressor internals should be evaluated against the benefits of shipping a unit with proven mechanical assembly and casing joint integrity.

4.3.6.8 Full-pressure/Full-load/Full-speedTest

Following the mechanical run test, the compressor shall be opened for internal inspection. Leak test per para. 4.3.5 shall be conducted after assembly. **(Mod.)**

4.3.8 Optional Tests

4.3.8.1 Performance Test

If a performance test is specified, it shall be conducted in accordance with ASME PTC-10, and the following information shall be furnished prior to the test :

a) Identification of the class of test (I,II or III) required to meet objectives and selection of operating conditions to satisfy the limitations outlined in Table 1,2,3 and 4 of ASME PTC-10.

b) The nature of the test gas, if the design or specified gas can not be used and the means for establishing its physical and thermodynamic properties.

c) Procedures to be employed for adjusting test results to specify operating conditions with respect to test classifications I,II and III. **(Mod.)**

4.3.8.8 Spare-parts Test

When spare rotors are supplied, they shall be dynamically balanced to the same tolerances as the main rotor. **(Mod.)**

4.4 Preparation for Shipment

4.4.1 The preparation shall make the equipment suitable for 12 months of outdoors storage from the time of shipment. **(Mod.)**

4.4.3.1 The paint for all exterior surfaces shall be suitable for the environment specified. **(Mod.)**

4.4.3.2 Unless otherwise specified, the rust preventive applied to unpainted exterior machined surfaces shall be of a type: (1) to provide protection during outdoor storage for a period of twelve months exposed to a normal industrial environment, and (2) to be removable with mineral spirits or any standard solvent. **(Sub.)**

4.4.3.6 The height of shanks shall be at least 35mm. **(Mod.)**

4.4.3.9 Unless otherwise specified, separate shipment of the material is not permitted**.** **(Mod.)**

4.4.3.11 Unless otherwise stated in the purchase order, all on package pipe work shall be fully fitted and assembled prior to dispatch. pipe work between main packages and off package auxiliaries shall not be fully fitted, but shall have sufficient spare lengths for field welding, any loose items should be packed separately. **(Mod.)**

4.4.3.12 Exposed shaft end should be protected against physical damage. **(Mod.)**

5. VENDOR'S DATA

5.1 General

5.1.3 Details of the thrust and radial bearing rated and actual Loads with respect to volume flow over the full speed range including start up. **(Add.)**

5.1.5 All data and information provided during the proposal and clarification stages shall also be reconfirmed for the contract and as-built stages of the contract. **(Add.)**

5.2 PROPOSALS

5.2.3 Technical Data

5.2.3 (b) A statement of guaranteed noise emission data shall be provided. **(Mod.)**

5.2.3 (f) A list of spare parts for two years of continuous operation, including price list shall be submitted. Vendor's proposal for spare parts (other than spare rotor) shall include proposed method of protection from corrosion during shipment and subsequent storage. **(Mod.)**

5.2.3 (i) The Vendor shall state in the operating manual the required amount, specifications, supply temperature and pressure ranges of the lubricating and sealing oil. (**Mod.)**

5.2.3 (w) Type of rust preventive to be applied to the compressor interior and bearing surfaces. **(Add.)**

5.2.3 (x) Performance curves for each specified operating case at the corresponding operating speed shall be supplied. **(Add.)**

5.2.4 Curves

The supplier shall use his own method for verifying the gas molecular weights and characteristics indicated in the data sheet. Any divergence shall be clearly stated in the proposal.

(Mod.)

5.3 Contract Data

5.3.2 Drawings and Technical Data

5.3.2.3 Drawings **(Add.)**

The vendor shall provide complete following drawings:

5.3.2.3.1 Coupling drawings giving all dimensions necessary for the detailed design on the connections between shafts including space requirements for assembly and dismantling.

5.3.2.3.2 Dimensional thrust bearing, journal bearing, seal, and coupling assembly drawings.

5.3.2.3.3 Dimensional cross-sectional drawing showing all radial and axial clearance**.**

5.3.2.3.4 Illustrated part list.

5.3.5.1.2 A draft manual(s) shall be issued to purchaser 8 weeks prior to testing for review and comment. **(Sub.)**

5.3.5 Installation, Operation, Maintenance, and Technical Data Manuals

5.3.5.3 Operating and Maintenance Manual

Clearances measured during factory inspections shall be included. **(Mod.)**

5.3.5.4 Technical Data Manual

The Technical data manual shall be provided. Format and content shall comply with the requirements of the purchase order. **(Mod.)**

6. GUARANTEE AND WARRANTY (Add.)

6.1 Mechanical

Unless exception is recorded by the vendor in his proposal, it shall be understood that vendor agrees to the following guarantees and warranties:

1) All equipment and component parts shall be guarantee by the vendor against defective materials, design, and workmanship for 1 year after being placed in service or 18 months after date of shipment.

2) If any malfunction or defects occur during the guarantee and warranty period, the vendor shall make all necessary alterations, repairs, and replacements free of charge, free on board (f.o.b.) factory. Field labor charges, if any, shall be subject to negotiation between vendor and purchaser. **(Add.)**

6.2 Performance

Each compressor casing shall be guaranteed for head with no negative tolerance, capacity and behavior satisfying all points mentioned on the data sheet. Power consumption shall also be guaranteed. If several compressor sections/casings are on the same shaft line, the power guarantees shall cover the total power.

The rotation speed, the guaranteed head and flow rate shall not vary from the indicated theoretical-value by more than ±3%.

If the compressor consists of several casings, or several sections in a casing handling different flow rates, each section shall satisfy its individual guaranteed performance.

Intermediate, outlet and inlet pressures shall not differ from the guaranteed values by more than ±2% with the compressor operating under the following conditions:

- Flow rates, pressures, temperature and nature of gas at inlet, corresponding to guarantee.
- Outlet pressure corresponding to guarantee.

CHAPTER 2

CENTRIFUGAL AND AXIAL COMPRESSORS

SECTION 1 – GENERAL

1.1 Scope

This chapter, in conjunction with Chapter 1 of this Standard, covers minimum requirements for Centrifugal and Axial compressors for use in refinery services, gas, chemical and petrochemical plant and where applicable in production and new ventures.

Compliance by the Vendor with the provisions of this Standard specification does not relieve him of responsibility of furnishing properly designed equipment, mechanically and electrically suited to meet operating conditions.

The Compressors shall be the product of a manufacturer regularly engaged in manufacture of the machine at least for three years.

Unless specific exception accompanied by a description of the proposed substitute that is recorded under the heading "exception" in manufacturer's proposal, it shall be mutually understood that proposal complies strictly with the requirement of this Standard. **(Mod.)**

SECTION 2 – BASIC DESIGN

2.3 Casings

2.3.2 Pressure Casing Connections

2.3.2.4 Supplier shall advise in his proposal all possible locations for borescope inspection points and the advantages any such inspection points would have. **(Mod.)**

2.4 Guide Vanes, Stators, and Stationary Internals

2.4.2 Supplier shall advise in his proposal whether such a feature is required or of benefit. **(Mod.)**

2.4.3 Where AIGVs are supplied, supplier shall also provide a valve positioner with local position indicator, unless otherwise specified. **(Mod.)**

2.4.11 AIGVs shall only be supplied of a type where the identical design has been demonstrated to operate in a validly similar duty, for a period of 3 years without any operational problems. In particular, no blade linkage or bearing wear or failure has been observed due to high frequency or resonant vibration. **(Add.)**

2.4.12 Design of diaphragms shall be such that they can be removed without disassembly of the rotating element, unless otherwise specified. **(Add.)**

2.5 Rotating Elements

2.5.4 Thrust Balancing

2.5.4.3 Unless otherwise stated, the pressure tapping shall be provided. **(Mod.)**

2.5.7 Centrifugal compressor impeller construction. **(Add.)**

2.5.7.1 The impellers preferably should be the closed type.

2.5.7.2 Riveted type impellers are not acceptable.

2.5.7.3 Brazed impellers would be acceptable providing that references are submitted for similar impeller and services.

2.5.7.4 Impellers components preferably should be forged.

2.7.2 Hydrodynamic Radial Bearings

2.7.2.1 The use of non-split design is forbidden unless approved by purchaser. **(Mod.)**

2.7.4 Bearing Housings

2.7.4.1 If separate lube-oil and seal oil systems or labyrinth seals are used, bearing ends shall be separated from the seals by a distance of at least 20 mm. The possibility of installing a buffer gas feed (air or inert gas) between the bearings and the seals must be demonstrated. **(Mod.)**

2.7.4.3 If the process gas is liable to cause deterioration of the lube oil, the bearings shall be isolated from the shaft seal by a ventilated space and labyrinths or other seals to prevent contamination or interchange of the seal oil, process gas and lube oil. The space shall have provision for external or inert gas purge. **(Add.)**

2.8 Shaft End Seals

2.8.2 Shaft seals in inert gas service shall be of the labyrinth type. Shaft seals in toxic gas services shall be of the liquid film type unless otherwise specified. **(Mod.)**

2.8.3 Shaft end seals and unless other specified, shaft sleeves shall be accessible for nspection and for replacement without removing the top half of the casing for an axially split compressor or the heads of a radially split unit.

Note: This requirement may not be feasible for overhung designs. **(Mod.)**

2.8.3.2 The guaranteed figure for total waste seal oil leakage for both seals (per case) shall not exceed 50 lit/day. No waste oil shall be returned to the oil system unless all contaminating components are removed. **(Mod.)**

2.10 Lubrication and Sealing Systems

2.10.2 Unless otherwise specified, supplier shall propose the type and properties of oil to be used. **(Mod.)**

3.1.1 For compressors driven by electric motor or steam turbine, the compressor Supplier shall have the overall responsibility for the entire unit, comprising compressor, driver, power transmission, controls, instrumentation and all associated auxiliary equipment. Unless otherwise specified, for compressors driven by gas turbines, the turbine vendor shall have the overall responsibility. **(Add.)**

3.1.2 The supplier having the overall responsibility, shall co-ordinate and resolves any engineering or contractual problems for the complete unit. **(Add.)**

3.1.3 When compressor flushing is specified its effect on power requirements shall be considered in sizing the driver. **(Add.)**

3.1.4 For air compressors, the effect of minimum design ambient temperature on compressor power requirements shall be considered in sizing the driver. **(Add.)**

3.4.2 Control Systems

3.4.2.2 Unless otherwise specified, Supplier shall state in his proposal his standard type of control signal, witch will be mutually agreed between purchaser and vendor prior to order placement. **(Mod.)**

3.4.7 Vibration, Position, and Bearing Temperature Detectors

3.4.7.2 Unless otherwise specified, vendor shall supply the monitors. **(Mod.)**

3.4.7.4 Unless otherwise stated, temperature monitors shall be supplied by the supplier. **(Mod.)**

3.4.7.5 Unless otherwise specified, supplier shall propose his standard arrangement for casing vibration transducers. **(Mod.)**

3.4.7.6 Unless otherwise specified, vender shall supply the monitors, piping and appurtenances. **(Mod.)**

3.5 Piping and Appurtenances

3.5.3 Inlet system for process air compressors

3.5.3.1 If specified, the vendor shall supply the inlet system for process air compressors per the applicable portions of API 616. In addition the following requirements apply:

a) The free area of the inlet screen shall be at least 2½ times the cross-sectional area of the air compressor inlet flange. Inlet screen shall be 5 × 5 mesh, 3.5 mm. avg. opening, 1.6 mm wire type 304 stainless steel. The free area of this screen arrangement is 47% of total actual area; therefore, the actual area of inlet screen shall be at least 2.5/0. 47 or 5.3 times the compressor inlet area.

b) Louvers, if used, shall have a free area at least equal to the free area of the screen.

c) Provide a flanged opening DN 150 (6 in. NPS) minimum diameter on the inlet ducting to permit future onstream cleaning of compressor blading.

The vendor furnishing the discharge blowoff silencers for air compressors (Downstream side of blowoff valves) shall submit cross-sectional drawings and at least one example of prior satisfactory experience to purchaser for approval. The experience case(s) submitted shall be for the same diameter and flow rate range as the proposed silencer. **(Add.)**

3.5.3.2 The vendor furnishing the discharge blowoff silencers for air compressors (Downstream side of blowoff valves) shall submit cross-sectional drawings and at least one example of prior satisfactory experience to purchaser for approval. The experience case(s) submitted shall be for the same diameter and flow rate range as the proposed silencer. **(Add.)**

4. INSPECTION, TESTING, AND PREPARATION FOR SHIPMENT

4.3 Testing

4.3.1 Mechanical Running Test

4.3.1.1.3. Oil system components downstream of the filters shall meet the cleanliness requirements of IPS Standard M-PM-320 before any test is started. **(Sub.)**

4.3.2 Assembled Compressor Gas Leakage Test

4.3.2.3 Casings for compressors handling gas containing 30 mol-percent or higher of hydrogen, shall be subject to a helium leakage test, at not less than the casing maximum allowable working pressure. **(Mod.)**

4.3.3 Optional Tests

4.3.3.1 Performance Test

4.3.3.1.1 Air shall not be used for closed loop testing. For all other gases, open loop air performance tests shall be performed, providing the ASME Power Test Code 10 permissible tolerances are complied with; otherwise a closed loop performance test shall be performed. Machine Reynolds number correction to performance test data allowed by ASME Power Test Code 10 shall not be used. **(Mod.)**

4.3.3.1.2 Any guarantees shall be based on the purchaser's stated guarantee point, which may not be the normal operating point. **(Mod.)**

4.3.3.1.6 The required guarantees for the complete compressor shall not be affected by those for the intermediate pressures. **(Mod.)**

5. VENDOR'S DATA

5.1 General

5.1.2 Technical data

Following addition data shall be identified on transmittal (cover) letters and in title blocks or title pages. **(Add.)**

a) Expected variation in bearing clearances and oil viscosity.

b) Input data required for an axial compressor performance check:

1) Number of stages.

2) Presence of inlet guide vanes (IGV) and exit guide vanes (EGV).

3) Number of blades in each blade row (rotor, stator, IGV, EGV).

4) Inlet and outlet blade angles as a function of blade height for rotor, stator, IGV, EGV.

5) Stator blade angles for alternate operating setting if machine has variable stator geometry.

6) Design incidence angle and loss coefficients at mean radius for each rotor and stator blade row.

7) Rotor blade area ratio (tip profile area/base profile area).

8) Hub and tip radii for inlet and exit to each blade row (rotor, stator, IGV, EGV).

9) For each rotor and stator blade row the chord length as a function of blade height and the solidity (chord/pitch ratio) at the mean radius.

10) Type of airfoil (subsonic or transonic).

11) Statement if free-vortex flow is assumed.

12) Tangential velocity of gas at rotor blade tip.

13) Rotor and stator blade thickness as a function of chord length.

14) Young's modulus, density and material for rotor blades.

15) Any additional mass (i.e. shrouds, lacing, wire, etc.) and radius of application.

16) Total temperature rise per stage.

17) Polytrophic efficiency for each stage (rotor & stator, IGV + rotor + stator and rotor + stator + EGV).

18) Minimum flow at design speed and alternate speed conditions.

CHAPTER 3

INTEGRALLY GEARED COMPRESSORS

SECTION 1 – GENERAL

1.1 Scope

This chapter, in conjunction with Chapter 1 of this Standard, covers minimum requirements for Integrally Geared Compressors for use in refinery services, gas, chemical and petrochemical plant and where applicable in production and new ventures.

Compliance by the Vendor with the provisions of this Standard specification does not relieve him of responsibility of furnishing properly designed equipment, mechanically and electrically suited to meet operating conditions.

The compressors shall be the product of a manufacturer regularly engaged in manufacture of the machine at least for three years.

Unless specific exception accompanied by a description of the proposed substitute that is recorded under the heading "exception" in manufacturer's proposal, it shall be mutually understood that proposal complies strictly with the requirement of this Standard. **(Mod.)**

1.1.2 Equipment offered by the Supplier shall satisfy the following minimum service and manufacturing experience requirements:

1- Compressors shall be identical or validity similar in power rating, speed discharge pressure, suction capacity, mechanical design, materials or rotor dynamics, as compared with at least one unit produced by the Supplier at the proposed manufacturing plant. The compressor must have at least one year's satisfactory operation.

2- Corresponding requirements of Items 1 shall also apply to the driver, gear and auxiliary equipment. **(Add.)**

2.6 Dynamics

2.6.1 The torsional resonances of the package shall be at least 10% above trip or 10% below any operating speed for any possible excitation frequency. **(Add.)**

2.7 Bearings and Bearing Housings

2.7.4 Bearing Housings

2.7.4.1 If separate lube-oil and seal oil systems or labyrinth seals are used, bearing ends shall be separated from the seals by a distance of at least 20 mm. The possibility of installing a buffer gas feed (air or inert gas) between the bearings and the seals must be demonstrated. **(Mod.)**

2.7.4.5 If the process gas is liable to cause deterioration of the lube oil, the bearings shall be isolated from the shaft seal by a ventilated space and labyrinths or other seals to prevent contamination or interchange of the seal oil, process gas and lube oil. The space shall have provision for external or inert gas purge. **(Add.)**

2.9 Gears

2.9.1 Gearboxes

2.9.1.10 Gears shall have at least 80% tooth contact at full load. **(Add.)**

SECTION 3 – ACCESSORIES

3.4 Controls and Instrumentation

3.4.7 Vibration, Position, and Bearing Temperature

3.4.7.6 Vibration monitoring shall be provided for all shafts with hydrodynamic bearings, including the driver. **(Mod.)**

3.5 Piping and Appurtenances

3.5.1 General

3.5.1.4 All oil piping (supply and return) shall be stainless steel. **(Add.)**

3.5.3.1 If specified, the vendor shall supply the inlet system for process air compressors per the applicable portions of API 616. In addition the following requirements apply:

3.5.2 Process Piping and Accessories

a) The free area of the inlet screen shall be at least 2½ times the cross-sectional area of the air compressor inlet flange. Inlet screen shall be 5 × 5 mesh, 3.5 mm. avg. opening, 1.6 mm wire type 304 stainless steel. The free area of this screen arrangement is 47% of total actual area; therefore, the actual area of inlet screen shall be at least 2.5/0. 47 or 5.3 times the compressor inlet area.

b) Louvers, if used, shall have a free area at least equal to the free area of the screen.

c) Provide a flanged opening DN 150 (6 in. NPS) minimum diameter on the inlet ducting to permit future onstream cleaning of compressor blading.

The vendor furnishing the discharge blowoff silencers for air compressors (Downstream side of blowoff valves) shall submit cross-sectional drawings and at least one example of prior satisfactory experience to purchaser for approval. The experience case(s) submitted shall be for the same diameter and flow rate range as the proposed silencer.

3.5.2.3 Inlet system for process air compressors **(Add.)**

If specified, the vendor shall supply the inlet system for process air compressors, the following requirements apply:

SECTION 4 - INSPECTION, TESTING, AND PREPARATION FOR SHIPMENT

4.3 Testing

4.3.1 Mechanical Running Test

4.3.1.1.2 Unless otherwise specified, a seal oil system shall be subjected to a separate package functional test and shall in addition be fully functionally tested as part of the complete unit test if this test is required. **(Mod.)**

4.3.1.3.7 Unless otherwise specified, Supplier shall provide all necessary vibration monitoring equipment for test, where contract equipment is not utilized. **(Mod.)**

4.3.1.4.1 The gear contact pattern shall not be less than 80% of the effective width of the gear mesh. **(Mod.)**

4.3.1.4.3 All bearings shall be removed, inspected and re-assembled after completion of the running test. **(Add.)**

4.3.3 Optional Tests

4.3.3.1 Performance Test

4.3.3.1.1 The requirements of Chapter 1 Part 4.3 shall apply. **(Mod.)**

CHAPTER 4

EXPANDER-COMPRESSORS

SECTION 1 – GENERAL

1.1 Scope

This chapter, in conjunction with Chapter 1 of this Standard, covers minimum requirements for expander-compressor for use in refinery services, gas, chemical and petrochemical plant and where applicable in production and new ventures.

Compliance by the Vendor with the provisions of this Standard specification does not relieve him of responsibility of furnishing properly designed equipment, mechanically and electrically suited to meet operating conditions.

The expander-compressors shall be the product of a manufacturer regularly engaged in manufacture of the machine at least for three years.

Unless specific exception accompanied by a description of the proposed substitute that is recorded under the heading "exception" in manufacturer's proposal, it shall be mutually understood that proposal complies strictly with the requirement of this Standard. **(Mod.)**

SECTION 2 – BASIC DESIGN

2.1 General

2.1.1 Performance

2.1.1.2 Normal point of operation shall be the guarantee point and be as close as possible to optimum efficiency unless otherwise specified. (Refer to paragraph 2.1.1.1 for tolerances.). When other operating points are specified at higher flow, higher head or both, Vendor shall achieve a power balance by adjusting the unit's speed and shall state any negative tolerance on head at these other flows and shall obtain company approval. **(Mod.)**

2.1.1.3 Expanders and compressors shall be designed for 110% of the largest flow that can be expected during continuous operation and startup. **(Add.)**

2.1.1.4 Expanders and compressors shall be capable of operating at 50% of the normal flow rate without using recycle on the compressors. **(Add.)**

2.2 Materials

2.2.1 All parts shall be suitable for the lowest expected temperature. **(Add.)**

2.2.2 Other components of the machinery train should also be evaluated for the prevention of brittle fracture due to materials exhibiting change from ductile to brittle fracture as temperatures are reduced. **(Add.)**

2.2.3 The purchaser will specify the minimum design metal temperature and concurrent pressure used to establish impact test and other material requirements.

Note: Normally, this will be the lower of the minimum surrounding ambient temperature or minimum fluid pumping temperature, however, the purchaser may specify a minimum design metal temperature based on properties of the pumped fluid, such as auto-refrigeration at reduced pressures. (Add.)

2.3 Casings

2.3.1 Pressure-containing Casings

2.3.1.1 Purchaser shall provide system protection for pressure that may develop by compressors when operating, at trip speed. Vendor shall indicate the maximum allowable working pressure for each casing. **(Mod.)**

2.4 Inlet Guide Vanes, Variable Nozzles, and Heat Shields

2.4.2 Inlet guide vanes shall be capable of handling at least 125% of the design mass flow rate at normal pressures and temperatures, or at least 110% of the maximum specified mass flow at minimum specified inlet pressure and maximum specified inlet temperature, whichever gives the highest actual flow.

2.4.3 Actuating devices shall be pneumatic, with integral positioners and guide vanes incorporating a pressure balanced design to limit the nozzle forces and provide smooth, accurate and reliable operation **(Mod.)**

2.4.5 Inlet guide vanes shall incorporate pressure actuated sealing rings to minimize side leakage and prevent galling. Nozzle design shall allow for:

a) Rotational movement about nozzle pins only.

b) Minimum travel of nozzle segments.

c) Floating pins in nozzle segments to allow lapping to provide equal sealing of segments. **(Mod.)**

2.5 Rotating Elements

2.5.3 Shafts

2.5.3.3 Vendor shall provide specific details for coating or overlays on journals of precipitation hardened stainless steel shafts. The use of lube oil additives to mitigate bearing wire wooling shall be subject to Purchaser approval. **(Mod.)**

2.5.4 Impellers

Proposed impellers shall have proven performance on identifiably similar units, preferably supported by manufacturer's performance tests on expanders and compressors. **(Mod.)**

2.5.5 Thrust Balancing

2.5.5.3 Trust equalizing valves shall incorporate built in bias to prevent hunting. **(Mod.)**

2.6 Dynamics

2.6.1 Vibration Balancing

2.6.1.4 Rotors shall be a stiff-shaft design with no undesirable running speeds between zero and trip speed as proven by Manufacturer's experience. **(Mod.)**

2.6.1.6 Rotors shall assembled and the balance verified. Rotors failing to meet the criteria of equations 4.2-2a or 4.2-2b, shall be balance corrected by repeating the component balance and not by trim balancing the assembly. **(Mod.)**

2.6.1.7 A residual unbalance check shall be performed on the assembled rotor directly following the balance verification of Paragraph 2.6.1.6 and before the assembled rotor is removed from the balancing machine. **(Mod.)**

2.6.1.8 A damped unbalanced rotor response analysis shall verify that the first bending critical speed is at least 125% above the trip speed. For new rotor designs, a complete lateral analysis shall be performed. The undamped analysis shall identify the first three system natural frequencies. **(Add.)**

2.6.1.9 A torsional analysis shall be performed if not already available for a similar torsional model or when specified by Purchaser. **(Add.)**

2.6.1.10 The first torsional mode shall be at least 125% above trip speed. **(Add.)**

2.7 Bearings and Bearing Housings

2.7.2 Hydrodynamic Radial Bearings

2.7.2.2 Bearing design shall feature high stiffness to suppress oil whirl (half speed gyration) or oil film resonance over the operating speed range. **(Mod.)**

2.7.3 Hydrodynamic Thrust Bearings

2.7.3.1 Each half of the hydrodynamic thrust bearing preferably be combined with a journal bearing housing to limit the overall length of the assembly. **(Mod.)**

2.8 Expander-Compressor Shaft Seals

2.8.1 General

2.8.1.1 For application (using pressurized Oil reservoir) that use buffer gas as sealing media, provision shall be provided by vendor to prevent the build up of condensate and contamination of the Oil system. **(Mod.)**

2.10 Lubrication and Sealing Systems

2.10.2 When approved by the Purchaser, a pressurized integral oil system may be provided for closed loop. In this case a continuous indicator of actual lubricant viscosity at the bearing inlet shall be required. **(Add.)**