

GENERAL SPECIFICATION

ROTATING MACHINERY

GS EP MEC 251

Supply of Axial and Centrifugal Compressors and Expander-compressors for Petroleum, Chemical and Gas Industry Services according to API Standard 617

10	10/2012	Update
09	01/2012	Update
08	01/2011	Update
07	10/2009	Update
00	11/2001	First issue
Rev.	Date	Purpose of the revision

Owning entity: DEV/TEC

Managing entity: DEV/TEC/MTH



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1. Scope

This specification clarifies how to use the recommendations of [API Std 617](#) for the supply to Company of axial compressors, single-shaft and integrally geared process centrifugal compressors and expander-compressor for use in the petroleum, chemical, and gas industries services that handle air or gas.

The purpose of this specification is to clarify the requirements of [API Std 617](#) standard seventh edition, July 2002.

This document modifies or complements some requirements of [API Std 617](#) standard, when deemed necessary considering Company experience.

Technical proposal shall be supported by Data Sheets. Data Sheet format to be used is given in Appendix 1, last page of this document. The paragraph numbering is identified in the same way as in [API Std 617](#) except for additional requirements, which may be presented with new paragraph numbers. The summary sheet at front indicates where to find the information for each paragraph of [API Std 617](#) shown with a bullet.

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the effective date of this document.

Reference	Title
API Std 614	Lubrication, Shaft-sealing and Oil-control Systems and Auxiliaries
API Std 617	Axial and Centrifugal Compressors and Expander-compressors for Petroleum, Chemical and Gas Industry Services
API Std 671	Special-Purpose Couplings for Petroleum, Chemical, and Gas Industry Services
ASME PTC 10-1997	Performance Test Code on Compressors and Exhausters
ASME VIII division 1	Boiler and Pressure Vessel Code
ASTM A 240	Standard Specification for Chromium and Chromium-Nickel Stainless Steel Sheet, and Strip for Pressure Vessel and General Applications
NACE MR0175 / ISO 15156 (All parts)	Petroleum and Natural Gas Industries - Materials for Use in H ₂ S-containing Environments in Oil and Gas Production

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Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published in the applicable yearly collection.

Reference	Title
GS EP COR 170	Materials for Sour Service (Upstream Applications). Specification for design
GS EP INS 120	Control and Choke Valves
GS EP MEC 030	Rotating Machine Package Specification - Turbocompressor
GS EP MEC 031	Rotating Machine Package Specification - Motocompressor
GS EP MEC 101	Driver Power Sizing
GS EP MEC 253	Anti Surge System for Centrifugal and Axial Compressors
GS EP MEC 281	Lubrication, Shaft Sealing, and Oil Control Systems and Auxiliaries according to ISO 10438 / API Standard 614
GS EP MEC 292	Rotating Machines Packages Installation Requirements
GS EP MEC 300	Noise and Vibration of Rotating Machine Packages
GS EP PVV 112	Piping material classes

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3. Comments to **API Std 617**

Chapter 1 - General Requirements

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1. General	
1.5 Definition of terms Terms used in all chapters of this standard are defined in 1.5.1 through 1.5.54. Annexes 2C, 3C and 4C on nomenclature are located in each subsequent chapter of this specification.	The terms and concepts defined in section 1.5 of API Std 617 shall be used, subject to the following amendments:
1.5.14 Inlet volume flow The flow rate expressed in volume flow units at the conditions of pressure, temperature, compressibility, and gas composition, including moisture, at the equipment inlet flange.	This flow shall be expressed in ACMH, Actual Cubic Meter per Hour.
1.5.34 Purchaser The individual or organization that issues the order and specification to the Vendor. Note: The Purchaser may be the Owner of the plant in which the equipment is to be installed or the Owner's appointed agent.	Company refers to TOTAL, its subsidiaries, agents or associates.
1.5.45 Standard volume flow The flow rate expressed in volume flow units at standard conditions as follows: a. ISO Standard (Normal) Conditions Flow: Normal Cubic meters per hour (Nm ³ /h) Pressure: 1.013 bar absolute Temperature: 0°C b. U.S. Customary Standard Conditions Flow: Standard cubic ft per min. (scfm) Million standard cubic ft per day (mmscfd) Pressure: 14.7 PSIA Temperature: 60°F	This flow shall be expressed in Million Standard Cubic Meter per Day, in MMSCMD, (15°C and 101,325 Pa).
1.5.55 (New paragraph)	One single shaft centrifugal compressor casing may consist of several sections, each section including several stages, each stage consisting of one impeller and one diffuser

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	and return channel.
1.6 Normative References	
1.6.4 The editions of the Annex 1A standards, codes, and specifications 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, codes, and specifications that occur after the inquiry shall be mutually agreed upon by the Purchaser and the Vendor.	Replace second paragraph by: The standards, codes and specifications as listed in the Project requisition with their respective revision shall be those applicable.
• 1.6.5 The Purchaser will specify whether equipment supplied to this standard shall comply with the applicable ISO standards or applicable U.S. standards.	Apart from projects based on American codes and standards, ISO standards shall be substituted wherever possible to the documents specified in this section, unless their requirements are not equivalent. Vendor shall submit the list of documents to Company for approval prior to the order.
1.7 Statutory requirements The Purchaser and the Vendor shall mutually determine the measures that must be taken to comply with any governmental codes, regulations, ordinances, or rules that are applicable to the equipment.	Codes and regulations that shall apply are listed in the Project Specification, including ATEX rules requirements.
2. Basic design	
2.1 General	
2.1.1 Performances	
2.1.1.1 The equipment shall be capable of operating at all specified conditions.	If more than one operating point is specified, the specified point leading to the maximum power shall be one of the certified points. 1. Aerodynamic Vendor shall provide with the offer all aerodynamics data respective to each stage, as indicated in the Company data sheet. The left limit of the proposed head versus flow curves shall be a stable point free of any rotating stall indication or flow fluctuation. The corresponding flow shall be indicated in the performance data-sheet and in the exhibit 'D'

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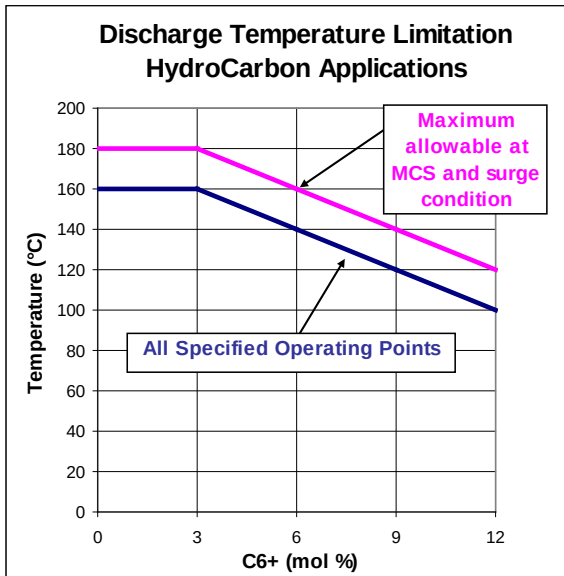
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	as the “surge limit”. The values of Senoo and Nishida/Kobayashi critical angles shall be provided for the above point. At this point the margin between the calculated diffuser inlet flow angle and the critical angle shall be positive or equal to zero. Senoo critical angle, as calculated below: α SENOO PREDICTIVE REVERSE FLOW ANGLE $= 105.91(b_3/r_2)^{1/2} - 117.27(b_3/r_2) - 8.18$ and Nishida critical angle as calculated below: α NISHIDA CRITICAL ANGLE = α SENOO PREDICTIVE REVERSE FLOW ANGLE + $(17.02 - 74.2 b_2/r_2) (1 - b_3/b_2)$ With r_2= impeller outlet diameter b_2= impeller exit width b_3= diffuser width For vaned diffusers, Vendor shall prove that no rotating stall is induced from the impellers. The right limit of the proposed head versus flow curves shall be a stable point and the corresponding flow shall be indicated in the performance data-sheet and in the exhibit 'D' as the “stone-wall limit”. Vendor shall provide with the offer all required data as clearly indicated in Company data sheets for each impeller, including: - The non-dimensional flow and head coefficients, polytropic efficiency and Mach number, at certified point(s), and left and right limits of the proposed curves. - A list of references of each aerodynamic. The references shall be presented using graphs showing the proposed stages versus stages in operation. The references shall at least include the following information: - Diameter and impeller type versus flow coefficient - Tip speed at Maximum Continuous Speed vs. flow coefficient - Impeller tip Mach number also known as Machine Mach number (tip speed

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	divided by average sonic speed at impeller inlet) vs. flow coefficient Impeller inlet relative Mach number (relative speed at impeller eye leading edge divided by impeller eye local sonic speed). In all cases, at certified conditions, the impeller inlet relative Mach number shall not exceed 0.95. 2. CFD analysis When specified in the GS EP MEC 030 or GS EP MEC 031 the CFD analysis shall be performed on the basis of the Annex 1D. 3. Discharge temperature For hydrocarbon applications the discharge temperature shall be limited as per following graph based on C6+ percentage in gas composition. Discharge Temperature Limitation HydroCarbon Applications <table><thead><tr><th>C6+ (mol %)</th><th>Maximum allowable at MCS and surge condition (°C)</th><th>All Specified Operating Points (°C)</th></tr></thead><tbody><tr><td>0</td><td>180</td><td>160</td></tr><tr><td>3</td><td>180</td><td>160</td></tr><tr><td>6</td><td>160</td><td>140</td></tr><tr><td>9</td><td>140</td><td>120</td></tr><tr><td>12</td><td>120</td><td>100</td></tr></tbody></table> For applications such as CO₂, air, nitrogen, or acid gas (CO₂+H₂S without hydrocarbon) compressors, the discharge temperature at any specified operating point shall not exceed 180°C, and the maximum allowable operating discharge temperature shall be limited to 200°C. The same rules apply to particular hydrocarbon applications such as flash gas and boil off gas compressors for LNG plants where no particular polymerization problems	C6+ (mol %)	Maximum allowable at MCS and surge condition (°C)	All Specified Operating Points (°C)	0	180	160	3	180	160	6	160	140	9	140	120	12	120	100
C6+ (mol %)	Maximum allowable at MCS and surge condition (°C)	All Specified Operating Points (°C)																	
0	180	160																	
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12	120	100																	

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	are encountered due to the absence of heavy hydrocarbons. Anti-fouling coating shall be proposed only if Vendor cans demonstrate extensive experience. 4. Interference fit shrinkage For impeller and balance drum shrunk onto the shaft, the Vendor shall provide with the offer the minimum and maximum interference fit values expressed in per thousand related to the shaft diameter. The corresponding values shall be indicated in the Company data sheet. In any case, including zero speed condition, the resulting stresses at bore location shall be lower than either the yield strength of material divided by 1.32 for sweet gas applications (Sweet and Mild Sour Services) or the Stress Corrosion Cracking Resistance (SCCR) for sour gas applications (Intermediate and Severe Sour Services). (see GS EP COR 170 - diagram of sour service pH Vs H₂S partial pressure & ISO 15156) Region 0 - Sweet Service Region 1 - Mild Sour Service Region 2 - Intermediate Sour Service Region 3 - Severe Sour Service The impeller stresses at bore location installed during the over speed test shall cover the stresses due to the maximum interference fit at bore location (see chapter 1 paragraph 4.3.3.1 and Data Sheet). 5. Gas velocity at flange main connections The gas velocity at flange main connections shall be limited to 28 m/s at any specified operating point. 6. Diffuser width The minimum diffuser width shall be greater than 2.8 mm.
2.1.1.2 The Purchaser will specify the conditions for the equipment's normal operating points.	Refer to Project Data Sheets.

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2.1.1.3 The compressor shall be designed to deliver normal head at the normal inlet volumetric flow without negative tolerance. The power at the normal operating point shall not exceed 104% of the predicted value. Note 1: See the optional performance test criteria in each chapter for handling of excess head for constant speed drivers and specified process intermediate pressures. Note 2: The Purchaser may furnish mass flow which will then be converted to volumetric flow by the Supplier.	Refer to paragraphs to 4.3.3.1.2 and 4.3.3.1.4 of chapter 2.
2.1.1.4 Gas properties used shall be mutually agreed upon.	For applications where discharge pressure is exceeding 150 barg, the calculations shall be performed and provided with the two following equations of state: Lee Kessler (modified BWR) and Soave-Redlich-Kwong.
2.1.3 The Vendor shall assume unit responsibility for all equipment and all auxiliary systems included in the scope of the order.	Vendor shall assume full responsibility for the mechanical design of the shaft line even if he does not directly supply all the equipment. Vendor shall be responsible for: • Verification of the shaft line transmission components ratings • Lateral analysis (or verification) of the various shaft line components • Torsional analysis of the shaft line based on component construction data. Calculation reports in respect of the above three items shall be submitted to Company. Vendor shall review and approve the sizing of the upstream scrubber relative to each section.
2.1.6 The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the Purchaser and the Vendor at or before the coordination meeting. Note: The arrangement should consider adequate clearance areas and safe access for operation and maintenance.	The bottom note is applicable.
• 2.1.8 The equipment including all auxiliaries shall be suitable for operation under the environmental conditions specified	Refer to the Project Specification.

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by the Purchaser. These conditions shall include whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), maximum and minimum temperatures, unusual humidity, and dusty or corrosive conditions.	
• 2.1.9 Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the Purchaser and the Vendor having unit responsibility. The equipment furnished by the Vendor shall conform to the maximum allowable sound pressure level specified. The Vendor shall provide expected values for both maximum sound pressure and sound power level per octave band for the equipment.	Control of sound pressure level shall be in accordance to the Project Specification requirement. Vendor proposal shall include curves of sound power levels as a function of frequency for the specified operating conditions. Any noise attenuation device such as cladding or specific enclosure around the compressor casing is not permitted.
• 2.1.10 The Purchaser will advise the Vendor in the inquiry of any specific requirements for liquid injection.	Refer to the Project Specification, if required.
2.1.11 Equipment shall be designed to run without damage to the trip speed and the maximum allowable working pressure.	If the pressure developed by the compressor, and particularly at the trip speed, exceeds the maximum allowable working pressure, Vendor proposal shall clearly indicate this, and provide the information needed to design the compressor protections.
• 2.1.13 Many factors (such as piping loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly at the site) may adversely affect site performance. To minimize the influence of these factors, the Vendor shall, when requested, review and comment on the Purchaser's piping and foundation drawings. When specified, the Vendor's representative shall: a. Observe a check of the piping performed by parting the flanges. b. Check alignment at the operating temperature. c. Be present during the initial alignment check.	This paragraph is applicable. The Vendor shall review and comments Company piping and foundations drawings. Vendor shall observe a check of the piping by parting the flanges and perform the initial alignment.
• 2.1.14 Motors, generators, electrical components, and electrical installations shall	Refer to the Project Specification and to GS EP MEC 030 or GS EP MEC 031 .

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be suitable for the area classification (class, group and division) specified by the Purchaser on the data sheets, and shall meet the requirements of NFPA 70, Articles 500 through 505 or IEC 60079-10 as applicable, as well as local codes specified and furnished by the Purchaser.	
• 2.1.16 When specified, the machine or machines shall be suitable for field run on air. Performance parameters, including any required precautions, shall be mutually agreed upon by the Purchaser and the Vendor.	The compressors shall be capable to run safely with air or nitrogen at high flow, reduced head and speed, during commissioning stage, for process line flushing and cleaning. Vendor shall incorporate any required features to operate compressor safely.
2.2 Materials	
2.2.1 General	
• 2.2.1.3 The Purchaser will specify any corrosive agents (including trace quantities) present in the motive and process fluids in the site environment, including constituents that may cause stress corrosion cracking. Note: Typical agents of concern are hydrogen sulfide, amines, chlorides, cyanide, fluoride, naphthenic acid and polythionic acid.	Refer to the Project Data Sheets.
• 2.2.1.6 Materials exposed to a sour environment (wet H₂S) as defined by NACE MR0175 shall be in accordance with the requirements of that standard. Ferrous materials not covered by NACE MR0175 shall not have a yield strength exceeding 620 N/mm² (90,000 psi), nor a hardness exceeding Rockwell C 22. Components that are fabricated by welding shall be postweld heat treated, if required, so that both the welds and heat-affected zones meet the yield strength and hardness requirements. Note 1: It is the responsibility of the Purchaser to determine the amount of wet H₂S that may be present, considering normal operation, start-up, shutdown, idle standby, upsets, or unusual operating conditions such as catalyst regeneration. Note 2: In many applications, small amounts	Cast irons may be used in compliance with NACE MR0175 / ISO 15156 Part 2. Stainless steels can be used for some parts of equipment. If so, the following requirements and restrictions shall apply: • Martensitic stainless steel shall be heat-treated and have a hardness complying with NACE MR0175 / ISO 15156-3 Table A.22 • Austenitic stainless steels and austeno-ferritic steels shall be in agreement with NACE MR0175 / ISO 15156-3 Table A.6 and A.24 If welding and/or post-weld heat-treatment is required on austenitic stainless steels, these steels shall be low carbon or titanium or niobium-stabilized steels. If welding repairs are required on the bodies

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of H₂S are sufficient to require materials resistant to sulphide stress corrosion cracking. When there are trace quantities of wet H₂S known to be present or if there is any uncertainty about the amount of wet H₂S that may be present, the Purchaser should consider requiring materials that are resistant to sulphide stress corrosion cracking. Note 3: Shafts in compressors of between-bearing design may exceed the stated limits of yield strength and hardness because of requirements for higher strength at reduced shaft sections near couplings and because of the low levels of working stress in the portion of the shaft between bearings.	of cast equipment in 304 or 316 stainless steel, the procedure shall be submitted to Company for review and approval. Parts of austenitic stainless steel cold-formed by rolling, bending or stamping shall be quench-annealed a second time if the permanent deformation exceeds 15%. Alloy 400 is prohibited in equipment in which the failure of alloy 400 parts would jeopardize the operation of the equipment in terms of safety (poor mechanical behavior). Alloyed steels and non ferrous materials shall conform to NACE MR0175 / ISO 15156 and shall be subject to H₂S-stress corrosion cracking tests (metallurgical requirements, heat-treatments and threshold stress limit with respect to operating stresses).
2.2.1.13 O-ring materials shall be compatible with all specified services. Special consideration shall be given to the selection of O-rings for high pressure services to ensure that they will not damage upon rapid depressurization (explosive decompression). Note: Susceptibility to explosive decompression depends on the gas to which the O-ring is exposed, the compounding of the elastomer, temperature of exposure, the rate of decompression, and the number of cycles.	All static seals shall be anti-explosive decompression "O" ring type and shall be made of material suitable for gas as specified in the data sheet. In any case, If Methanol injection is specified the suitability of the "O" ring material shall be checked accordingly. Special care for end cover seals for sweet gas application (not sour or acid application): - For initial decompression rate lower than 20 bar/minute, a single "O" ring type shall be selected (Viton material or equivalent). - For initial decompression rate higher than 20 bar/minute a "secured" seal arrangement shall be put in place including 2 static seals in series. The first one shall be elastomer free and spring energized such as PTFE cup seal, the second one shall be a "O" ring type (Viton material or equivalent). The potential leak in between shall be collected to the flare, and provision for a dedicated pressure transducer shall be done. Special care for end cover seals for sour and acid gas applications: - For initial decompression rate lower than

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	20 bar/minute, two “O” rings in serie shall be selected with suitable material (type Kalrez or equivalent). The potential leak in between shall be collected to the flare, and provision for a dedicated pressure transducer shall be done. For initial decompression rate higher than 20 bar/minute a “secured” seal arrangement shall be put in place including 2 seals in series. The first one shall be elastomer free and spring energized such as PTFE cup seal, the second one shall be a “O” ring type with suitable material (type Kalrez or equivalent). The potential leak in between shall be collected to the flare, and provision for a dedicated pressure transducer shall be done.
2.2.1.14 When specified, copper or copper alloys shall not be used for parts of machines or auxiliaries in contact with process fluid. Nickel-copper alloy (UNS N04400) bearing babbitt, and precipitation hardened stainless steels are excluded from this requirement. Note: Certain corrosive fluids in contact with copper alloys have been known to form explosive compounds.	Copper and copper alloys are prohibited except for bearings pads only.
2.2.1.15.2 When specified, 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.	This paragraph is applicable for all other machinery train components.
2.2.1.15.3 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.	Refer to the ambient and process operating conditions as indicated in the Project Specification

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2.2.1.15.4 To avoid brittle failures, materials and construction for low temperature service shall be suitable for the minimum design metal temperature and concurrent pressure in accordance with the codes and other requirements specified. The Purchaser and the Vendor shall agree on any special precautions necessary with regard to conditions that may occur during operation, maintenance, transportation, erection, commissioning and testing. Note: Good design practice should be followed in the selection of fabrication methods, welding procedures, and materials for Vendor furnished steel pressure retaining parts that may be subject to temperatures below the ductile-brittle transition temperature. The published design-allowable stresses for materials in internationally recognized standards such as the ASME Code and ANSI standards are based on minimum tensile properties. Some standards do not differentiate between rimmed, semi-killed, fully killed hot-rolled, and normalized material, nor do they take into account whether materials were produced under fine or course-grain practices. The Vendor should exercise caution in the selection of materials intended for services between -30°C (-20°F) and 40°C (100°F).	Second sentence of this paragraph is not applicable: Vendor responsibility.
2.2.1.16 When specified, mutually acceptable coatings shall be applied to the rotating and/or stationary components in the gas path. When coatings are applied to rotating components, the acceptance balance shall be after coatings have been applied. The sequence of procedures for balancing and coating or rotating components shall be mutually agreed. Note: It is advisable to pre-balance in order to minimize balance corrections and subsequent repair to coating areas for the final acceptance balance. By minimizing the area to be repaired, a final check balance after repair	For sour service (H₂S & CO₂) inlet cold parts shall be overlaid with a first layer of stainless steel 309MO grade followed by a 3 mm minimum thickness layer of 316 L grade. When impeller coating is required: - Impeller pre-balancing (without coating) within final tolerance is required. - Final rotor (with coating) balancing shall be checked after final assembly. Residual balancing correction, if required, shall be achieved by final touch-up.

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may not be required.	
2.2.1.17 (new paragraph)	Material for all internal seals (inter-stage labyrinths, balance drum, process labyrinths, etc.) shall be rub tolerant and selected to avoid "hard-hard" contacts and heat expansion in case of rubbing. Abrasive coating should be proposed only if Vendor can demonstrate extensive experience.
2.3 Casings	
2.3.1 Pressure-containing casings	
2.3.1.10 The Vendor shall be responsible for the review of all repairs and repair welds to ensure that they are properly heat treated and nondestructively examined for soundness and compliance with the applicable qualified procedures (see 2.3.1.8). Repairs shall be nondestructively tested by the same method used to detect the original flaw, however the minimum level of inspection after the repair, shall be by the magnetic particle method in accordance with 4.2.2.4 for magnetic material and by the liquid penetrant method in accordance with 4.2.2.5 for nonmagnetic material. Unless otherwise specified, procedures for major repairs shall be subject to review by the Purchaser prior to any repair.	Pressure-containing cast iron parts shall not be repaired by plugging. In all cases, procedures for major repairs shall be subject to review and approval by Company prior to any repair.
● 2.3.1.11.2 Accessible surfaces of welds shall be inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after post-weld heat treatment. When specified, the quality control of welds that will be inaccessible on completion of the fabrication shall be agreed on by the Purchaser and Vendor prior to fabrication.	For welds inaccessible on completion of fabrication, this paragraph is applicable.
2.3.1.11.5 All pressure-containing welds shall be examined as required by Section VIII, Division 1, of the ASME Code. Requirements for additional examination shall be mutually agreed upon by the Vendor and Purchaser. Note: See 2.3.1.12 for required procedures	In addition, cast steel casing parts and cast impellers shall be inspected by radiographic means according to ASME VIII Division 1 , and Appendix 7.

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and acceptance criteria.	
• 2.3.2.1.7 When specified, individual stage drains, including a drain for the balance piston cavity, shall be provided (see 2.3.2.1.6).	Individual drains shall be provided as a minimum as follows: • Per section • Balance piston cavity • Suction and discharge volutes • Between separation and outboard mechanical seals. Manual drainage is required prior to start the compressor. Each drain shall be provided with isolating valve(s) and shall be piped to a common header up to a customer flange located at skid edge. Valves and flanges shall be in accordance with the applicable piping class specifications. The balance piston cavity shall be equipped with a pressure transmitter to monitor the leakage.
• 2.3.2.2.1 Main process connections shall be flanged or machined and studded and oriented as specified on the data sheets. Note: Main process connections include all process inlets and outlets including those for side loads and intermediate cooling.	Refer to the Project data sheets. Connections design shall be submitted to Company for review prior to fabrication. The drawing shall show weld design, size, materials and pre and post weld heat treatment. Hub connectors flange types are prohibited as main process connections. Vendor shall provide with the offer at least two referenced casings in operation with similar flange size and rating.
• 2.3.2.2.7 When specified, the Vendor shall supply mating flange, studs, and nuts for non standards connections.	This paragraph is applicable. In case of studded flange connections, the Vendor shall provide the interconnecting spool pieces fully assembled. These spool pieces shall be considered as part of the main casing and shall also be used for the hydro test. The material shall be the same as the casing.
2.3.5 (New paragraph)	Horizontally split compressors and integrally gear compressors are prohibited for process gas applications containing more than 10 ppm H₂S. Horizontally split compressors shall be

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	equipped with bottom-bottom nozzles. For offshore applications, integrally gear compressors may be considered only with Company Headquarters prior approval.
2.5 Rotating Elements	
2.5.4 The design of stressed parts shall include proper evaluation of the stress concentration factor (SCF) for the geometry. The design of stressed rotating parts shall include fillets that will limit the SCF. Note: Areas of concern include the impeller vane-to-disk intersections, keyways, and shaft section changes.	The stress of all rotating parts shall be computed in regard of yield strength of the metal, at overspeed and in operation with proper boundary conditions such as those dictated by the interference fit. Those parts include impellers, shaft sleeves, spacers, balance piston, coupling hubs. Vendor shall clearly indicate in the data sheets the maximum calculated stress compared to the maximum allowable stress. For components shrunk onto the shaft (impellers and balance drum), the Vendor shall demonstrate in any case (maximum continuous speed with minimum interference fit) that the interference fit is enough to withstand the aerodynamic load without safety device. Keyways, and/or shear rings are only used to secure the assembly. For discharge pressure over 150 bar, the balance piston shall be axially secured by means of a shear ring, or shall be integrally machined with the shaft. For refrigeration and sour service applications, a FEA (Finite Element Analysis) shall be provided for each impeller. A distinction shall be made between stress and modal analysis. Step 1: A finite element model of each model of impeller shall be built. This model shall cover: a) Static analysis: Calculations of stresses caused by static (with maximum interference fit value) and rotation forces. b) Dynamic analysis: Covering the modal behavior of the impellers under rotation. The excitation frequencies in operation shall be identified: Nozzle passing frequencies, aerodynamic frequencies. An interference

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	diagram shall be issued. Step 2: To confirm the models, one set of impeller shall undergo a modal analysis at rest as follows: a) The rotor shall be mounted on soft suspensions, the purpose being to have the rotor in "free- free" mode. b) Excitation using dynamic exciter shall be applied to each impeller. c) Natural frequencies shall be identified and compared to finite element model analysis results. Upon results, the finite element models shall be adjusted as necessary.
2.5.5 Replaceable thrust collars shall be furnished only when they are required for removal of shaft end seals. When replaceable collars are furnished (for assembly and maintenance purposes), they shall be positively locked to the shaft to prevent fretting. When integral collars larger than 5 in. diameter are furnished, they shall be provided with at least 3 mm (1/8 in) of additional stock to enable refinishing if the collar is damaged. Note: Integral thrust collars are required unless thrust collars must be removed.	Hydraulic assembly of thrust collars is preferred.
2.5.10.1 Impellers may be closed, consisting of a hub, blades, and a cover; or semi-open, consisting of a hub and blades. Impellers shall be of welded, brazed, milled, electro-eroded or cast construction. Other manufacturing methods may be permitted if approved by the Purchaser. Each impeller shall be marked with a unique identification number.	The Vendor shall provide in the offer the procedure applied for welding or brazing impeller parts.

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2.6 Dynamics	
2.6.1 General	
● 2.6.1.4 The Vendor who is specified to have unit responsibility for the complete drive train shall communicate the existence of any undesirable running speeds in the range from zero to trip speed. A list of all undesirable speeds from zero to trip shall be submitted to the Purchaser for his review and included in the instruction manual (see Annex B of the applicable chapter). Note: Examples of undesirable speeds are those caused by the rotor lateral critical speeds, system torsionals, and blading modes.	This paragraph is applicable.
2.6.2 Lateral Analysis	
2.6.2.3 Before carrying out the damped unbalanced response analysis, the vendor shall conduct an undamped analysis to identify the undamped critical speeds and determine their mode shapes located in the range from 0% – 125% of trip speed. Unless otherwise specified, the results of the undamped analysis shall be furnished. The presentation of the results shall include: - Mode shape plots (relative amplitude vs. axial position on the rotor). - Critical speed-support stiffness map (frequency vs. support stiffness). Superimposed on this map shall be the calculated system support stiffness; horizontal (kxx), and vertical (kyy) (see Figure 1.2-2). Note: For machinery with widely varying bearing loads and/or load direction such as overhung style machines, the vendor may propose to substitute mode shape plots for the undamped critical speed map and list the undamped critical speed for each of the identified modes.	The undamped critical speed map shall be provided with the offer. The analysis shall be conducted up to 2 times 125% of trip speed. Horizontal and vertical bearing properties, including minimum and maximum clearances, shall be superimposed on this map, as well as the operating speed range from minimum operating to maximum continuous speed.
2.6.2.4 The damped unbalanced response analysis shall include but shall not be limited	Shall be provided with the offer. Prior to conduct the unbalanced response, the

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to the following: Note: The following is a list of items the analyst is to consider. It does not address the details and product of the analysis which is covered in 2.6.2.7 and 2.6.2.8. - Rotor masses including the mass moment of coupling halves, stiffness, and damping effects (for example, accumulated fit tolerances, fluid stiffening and damping). - Bearing lubricant-film stiffness and damping values including changes due to speed, load, preload, range of oil temperatures, maximum to minimum clearances resulting from accumulated assembly tolerances, and the effect of asymmetrical loading which may be caused by gear forces, side streams, eccentric clearances, etc. - For tilt-pad bearings, the pad pivot stiffness. - Support stiffness, mass, and damping characteristics, including effects of frequency dependent variation. The term "support" includes the foundation or support structure, the base, the machine frame and the bearing housing as appropriate. For machines whose bearing support system stiffness values are less than or equal to 3.5 times the bearing oil film stiffness values, support stiffness values derived from modal testing or calculated frequency dependent support stiffness and damping values (impedances) shall be used. The Vendor shall state the support stiffness values used in the analysis and the basis for these values (for example, modal tests of similar rotor support systems, or calculated support stiffness values). Note 1: The support stiffness should in most cases be no more than 8.75×10^6 N/mm (5×10^6 lb/in). Note 2: Guide lines are used to define whether or not bearing support stiffness should be considered. While modal testing of	natural frequencies with their associated damping and mode shape shall be computed versus operating speed from 0% - 125% of the trip speed. Natural frequencies versus speed shall be identified up to a frequency corresponding to 2 times 0% - 125% of trip speed. The Campbell's diagram (natural frequencies and associated damping) shall be built from 0 to 125% of trip speed, with all identified natural frequencies up to 2 times 125% of trip speed (see also 2.6.2.14)

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the actual bearing support system would be preferred, an analytical analysis (such as FEA) is permitted. e. Rotational speed, including the various starting-speed detents, operating speed and load ranges (including agreed-upon test conditions if different from those specified), trip speed, and coast-down conditions. f. The influence, over the operating range, of the hydrodynamic stiffness and damping generated by the casing shaft end seals. g. The location and orientation of the radial vibration probes which shall be the same in the analysis as in the machine.	
● 2.6.2.6 When specified, the effects of other equipment in the train shall be included in the damped unbalanced response analysis (that is, a train lateral analysis shall be performed). Note: In particular, this analysis should be considered for machinery trains with rigid couplings.	This paragraph is applicable in the case of rigid couplings or quillshaft type couplings, e.g. a train lateral analysis shall be performed.
● 2.6.2.14 When specified, in addition to the other requirements of 2.6.2, the lateral analysis report shall include the following: a. Dimensional data of the bearing design in sufficient detail to enable calculations of stiffness and damping coefficients. b. Shaft geometry with sufficient detail to model the shaft including the location of bearing centerlines and mounted components. c. The weight, polar and transverse moments of inertia and center of gravity of the impellers, balance piston, shaft end seals and coupling(s) with sufficient detail to conduct an independent analysis of the rotor. d. The input model used for the Vendor's analysis. e. The support stiffness used in the analysis and its basis.	This paragraph is applicable. In addition, Vendor shall provide the following with the offer: ● Campbell diagram, showing all the natural frequencies which can be excited by the fundamental frequency and harmonics, as a function of the rotational speed. The logarithmic decrements values when crossing the natural frequencies and across the operating speed range shall be shown, with the corresponding mode shapes. ● Fulton and Kirk Donald Diagrams showing the proposed rotor and other Vendor referenced rotors.

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2.6.5 Level I Stability Analysis	
2.6.5.1 A stability analysis shall be performed on all centrifugal compressors or axial compressors and/or radial flow rotors except those rotors whose maximum continuous speed is below the first critical speed in accordance with 2.6.2.3 as calculated on rigid support. For this analysis, the machine inlet and discharge conditions shall be either the rated condition or another operating point unless the Vendor and Purchaser agree upon another point. Note: Level I analysis was developed to fulfill two purposes: first it provides an initial screening to identify rotors that do not require more detailed study. The approach as developed is conservative and not intended as an indication of an unstable rotor. Second, the level I analysis specifies a standardized procedure applied to all manufactures similar to that found in 2.6.2 (refer to API publication 684, 1.6 for a detailed explanation)	Level I analysis shall also be provided with the offer. The analysis shall be done for the certified point with the highest absorbed power.
2.6.5.10 Level I Screening Criteria a. For centrifugal compressor: If any of the following criteria apply, a level II stability analysis shall be performed: i: $Q_0/Q_A < 2.0$ ii: $\delta_A < 0.1$ iii: $2.0 < Q_0/Q_A < 10$ and CSR is contained in Region B of figure 2.1.5. Otherwise, the stability is acceptable and no further analysis are required. b. For axial flow rotor: If $\delta_A < 0.1$, a level II stability analysis shall be performed. Otherwise, the stability analysis is acceptable and no further analysis is required.	In addition to the figure 1.2.4 and 1.2.5, the Vendor shall provide: The ratio Q_0/Q_A and the stability diagram: stability ratio Q_0/Q_A in ordinate versus the ratio of First Damped Natural Frequency /rotational speed in abscissa. This diagram shall show the other Vendor references. In any case, a log dec lower than 0.1 shall not be accepted for the rotor + bearing system (without aero cross coupled stiffness).
2.6.6 Level II Stability Analysis	Level II shall also be provided with the offer, if required from Level I analysis results. The level II analysis shall also be conducted at the certified point with the highest absorbed power.

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	The Vendor shall clearly indicate how the destabilizing effects are estimated including assumptions and software validation.
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 when specified, 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.	This paragraph is applicable in all cases.
2.6.7.2 Excitation of torsional natural frequencies may come from many sources which may or may not be a function of running speed and should be considered in the analysis. These sources shall include but are not limited to the following: - Gear characteristics such as unbalance, pitch line run-out, and cumulative pitch error. - Cyclic process impulses. - Torsional transients such as start-up of synchronous electric motors and generator phase-to-phase or phase-to-ground faults. - Torsional excitation resulting from electric motors, reciprocating engines, and rotary type positive displacement machines. - Control loop resonance from hydraulic, electronic governors, and variable frequency drives. - One and 2 times line frequency. - Running speed or speeds. - Harmonic frequencies from variable frequency drives.	Vendor shall calculate the response to short-circuit and start-up torques.
2.6.7.3 The torsional natural frequencies of the complete train shall be at least 10% above or 10% below any possible excitation frequency within the specified operating speed range (from minimum to maximum continuous speed).	In addition, a Campbell diagram shall be provided.

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2.6.7.4 Torsional natural frequencies at two or more times running speeds shall preferably be avoided or, in systems in which corresponding excitation frequencies occur, shall be shown to have no adverse effect.	Natural frequencies multiple of running speeds, of gearbox speeds, if any, or of the first harmonic frequencies of the electrical power supply system, in the case of an electric motor drive, shall be avoided. Determination of hazardous frequencies shall be the sole responsibility of Vendor having the responsibility of the full shaft line.
2.6.7.5 When torsional resonances are calculated to fall within the margin specified in 2.6.7.3 (and the Purchaser and the Vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted), a stress analysis shall be performed to demonstrate that the resonances have no adverse effect on the complete train. The assumptions made in this analysis regarding the magnitude of excitation and the degree of damping shall be clearly stated. The acceptance criteria for this analysis shall be mutually agreed upon by the Purchaser and the Vendor.	If a torsional resonance frequency lies in the unauthorized range defined in paragraph 2.6.7.3, Vendor shall seek a solution using the adaptation effect of the couplings, the gearbox and the rotor. If no solution can be found, the Vendor shall be able to demonstrate that this natural frequency cannot compromise the integrity of the shaft line. He shall supply the calculations for determining normal and alternating stresses in the various elements of the shaft line, in particular the most sensitive elements. The results of the analysis shall be submitted in the form of modified Goodman diagrams and/or life time element calculations. The excitation assumptions shall be clearly stated as well as damping properties.
2.6.8 Vibration and Balancing	
• 2.6.8.2.1.1 When specified, 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.	For stack rotors requiring disassembly after balancing, Vendor shall record the balance readings after initial balance for the Contract rotor. The rotor shall then be disassembled and reassembled in the diaphragms.

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• 2.6.8.3 When specified, 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.	Sequential low speed balancing shall be performed and followed by and operating speed balancing under vacuum. The Vendor shall demonstrate that the rotor is supported in bearings of the same type and with similar dynamic characteristics as those in which it will be supported in service. The balancing procedure shall be submitted to the Purchaser for approval. In any case, and before making any corrections, the rotor shall be run at trip speed for at least 5 min as per paragraph 2.6.8.4.
• 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.	Refer to paragraph 2.6.8.3 and associated comment.
• 2.6.8.7 For a rotor that has been low speed sequentially balanced (see 2.6.8.2), and when specified for rotors that are high-speed balanced (see 2.6.8.3), a low speed residual unbalance check shall be performed in a low speed balance machine and recorded in accordance with the residual unbalance worksheet (see Annex 1B). Note: This is done to provide a reference of residual unbalance and phase for future use in a low speed balance machine.	This paragraph is applicable.
2.6.8.8 During the mechanical running test of the machine, assembled with the balanced rotor, operating at its maximum continuous speed or at any other speed within the specified operating speed range, the peak-to-peak amplitude of unfiltered vibration in any plane, measured on the shaft adjacent and relative to each radial bearing, shall not exceed the following value or 25 µm (1 mil), whichever is less: In SI units: $A = 25.4 \sqrt{\frac{12000}{N}} \quad (1.2-10a)$ In U.S. Customary units:	These limits apply from 0 to Maximum Continuous Speed. Passing critical speeds these limits can be exceeded only if the Vendor is able to demonstrate that the response amplitude shall not exceed 75% of the minimum design diametral running clearances throughout the machine. In slow roll conditions (at about 500 to 1000 rpm), the total vibration indication of the run-out shall not exceed 10 µm peak-to-peak. It is agreed that this measurement does not reproduce the actual run-out measured on V blocks (see paragraph 2.6.8.9 with a limitation at 6 µm).

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$A = \sqrt{\frac{12000}{N}} \quad (1.2-10b)$ where A = amplitude of unfiltered vibration, in μm (mil) true peak-to-peak, N = maximum continuous speed, in rpm. At any speed greater than the maximum continuous speed, up to and including the trip speed of the driver, the vibration level shall not increase more than $12.7 \mu\text{m}$ (0.5 mil) above the maximum value recorded at the maximum continuous speed. Note: These limits are not to be confused with the limits specified in 2.6.3 for shop verification of unbalanced response.	
2.7 Bearings and Bearing Housings	
2.7.2 Hydrodynamic Radial Bearings Hydrodynamic radial bearings shall be in accordance with the applicable chapters of this specification.	Oil Damper type radial bearings are prohibited.
2.7.4 Bearing Housing	
2.7.4.6 When specified, provisions for locally disconnecting bearing temperature sensors' wiring within the bearing housing shall be provided.	When proposed, this requirement is acceptable.
2.7.4.7 (New paragraph)	The rise in oil temperature through the bearings and housings shall not exceed 28°C at any operating condition including during the mechanical running tests, performance tests, complete unit string tests and site operation.

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2.8 Shaft end seals	
2.8.1 General	
● 2.8.1.1 Shaft seals shall be provided to restrict or prevent process gas leaks to the atmosphere or seal fluid leaks into the process gas stream over the range of specified operating conditions, including start-up and shutdown. Seals shall be suitable for specified variations in seal operating conditions that may prevail during start-up, shutdown, or settling out, and during any other special operation specified. The maximum sealing pressure shall be at least equal to the settling-out pressure. The shaft seals and seal system shall be designed to permit safe machine pressurization with the seal system in operation prior to process start-up. Note: The Purchaser should establish a realistic value for settling-out pressure. This may be the result of the relief valve setting on the suction drum. The value should be shown on the data sheets.	The anticipated Settle Out Pressure (SOP) shall be indicated in the Project Data Sheet. The seals shall be designed for the anticipated SOP plus 10% margin at least. The actual value of the SOP will be available during Detailed Engineering, and the Purchaser shall confirm its value to the Vendor at this stage.
● 2.8.1.3 Shaft seals may be one or a combination of the types described in 2.8.2 through 2.8.4, as specified. The materials for component parts shall be suitable for the service.	Shaft end seals shall be of self-acting dry gas tandem mono-directional type. Bi-directional dry gas seals may be acceptable only if reverse rotation of the compressor is expected and demonstrated by dynamic process simulation carried out by compressor Vendor.
● 2.8.1.5 The Purchaser will specify whether buffer gas injection is to be used and, if so, the composition of that gas. In addition, the Vendor shall state whether buffer gas injection is required for any specified operating conditions. The method of control will be specified by the Purchaser.	Nitrogen buffer gas shall be injected between inboard and outboard seals to prevent any process gas leak to atmosphere.
● 2.8.1.6 When buffer gas is specified by the Purchaser or required by the Vendor, the Vendor shall state the gas requirements, including pressures, flowrates, and filtration.	This paragraph is applicable.
● 2.8.1.7 When specified, the Vendor shall furnish the complete buffer gas control system	This paragraph is applicable.

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including schematic and bill of material.	
2.8.2 Clearance Seals	Clearance seals are not applicable.
2.8.3 Oil Seals	Oil seals are not applicable.
2.8.4 Self-acting dry gas seal	
2.8.4.1 The self-acting dry gas seal may be a single, tandem, triple or double configuration depending on the application. The self-acting dry gas seal requires external seal gas but does not require any liquid for lubrication or cooling. Typical configurations are shown in Figures 1.C-6, 1.C-7, 1.C-8, and 1.C-9 of Annex 1C. Where toxic or flammable seal gases are used, an isolating seal is required to prevent uncontrolled leaks to the atmosphere or to the bearing housing. This isolating seal shall preferably be capable of acting as a backup seal should the primary seal fail during operation. The seal gas shall be filtered and shall be free of any contaminants that form residues. The seal gas source may be taken from the compressor discharge or inter-stage point. An alternate seal gas source may be used, and may be required during start-up or shutdown. The design of the gas seal support system is detailed in API Std 614. Note 1: Caution should be exercised if air is used as a purge or buffer gas to insure that explosive mixtures are not created when air is mixed with the seal outer leakage consisting of process gas. Note 2: Other variations are commonly used depending on the particular application. The seal will leak a small amount of seal gas, and may be unidirectional in operation. For testing considerations at the seal Manufacturer's shop for this type of seal, see Annex 1D. Note 3: If liquids may be formed or are present in the sealing gas, then coalescing filters and condensate traps may be required in the seal support module (see API Std 614, Chapter 4, 2.3.5 and 2.5).	Compressors shall be supplied with tandem self-acting dry gas seals, with intermediate labyrinth and separation seals as per figure 1.C.9.of Annex 1C. Compressor seal housings shall be designed to accommodate, at least, dry gas seal cartridges from two different seal Manufacturers, without any casing or piping rework. The design of gas seal support system is detailed in GS EP MEC 281. Separation seals shall consist of labyrinth type and shall be fed with air as per GS EP MEC 281. The air flow rate shall be such that no explosive mixture can happen in the secondary vent in case of outboard seal leakage or failure. Refer to GS EP MEC 281 for monitoring. Dry gas seal material selection shall be as follows: • Metallic parts: austenitic or duplex stainless steels or Incolloy. • Seal faces: Tungsten or Silicon Carbide or Silicon Nitride. Rotating faces shall be contained in an external retaining sleeve. • Dynamic secondary sealing elements (back of inboard and outboard seats): Elastomer free, spring loaded with anti-extrusion back up rings, designed to withstand explosive decompression without any damage and to prevent any seal face hang-up. • Static secondary sealing elements (cartridge assembly onto the shaft and inside the compressor as well as internal sealing elements): Elastomer free designed to withstand explosive decompression without any damage. For sealing pressure above 50 bar the seal elements shall be

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	also spring energized for both inboard and outboard compartments. Each dry gas seal, including the spare set, shall be tested in the seal Vendor shop as per Annex 1D.
2.8.4.2 Self-acting dry gas seals shall be provided with connections to allow the user to inject filtered gas, and to protect against reversal of differential pressure during sub-atmospheric operation. Note: Some self-acting dry gas seals can be destroyed by reversal of pressure differential. Clean filtered gas is required due to tight clearances of these seals. This may even be required on the inboard side of a double seal to prevent migration of particles through the seal face.	In any case, dry gas seal shall be protected against reversal pressure. Vendor shall ensure that outboard seal cannot undergo reversal pressure.
2.8.4.4 Each dry gas seal assembly, regardless of its arrangement, shall be cartridge mounted and positively located and attached to the compressor shaft. For uni-directional seals, cartridges shall be designed so the incorrect installation of the cartridges is impossible.	Gas seals shall be in the form of a cartridge assembly which can be removed without opening the compressor casing (excepted for expander-compressor). Dry gas seals shall be balanced to grade G 2.5 as a minimum, before installation.
2.10 Lubrication and sealing systems	
2.10.1 If required, a pressurized oil system or systems shall be furnished to supply oil at a suitable pressure or pressures, as applicable, to the following: - The bearings of the driver and of the driven equipment (including any gear). - The continuously lubricated couplings. - The governing and control-oil system. - The shaft seal-oil system. - The Purchaser's control system (if hydraulic).	This paragraph is applicable in all cases.
2.10.3 Unless otherwise specified, pressurized oil systems shall conform to the requirements of API Std 614, Chapters 1 and 2. Note: Expander-compressors utilize	Refer also to GS EP MEC 281, comments to API Std 614.

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pressurized bearing housings and reservoirs. These details are covered in Chapter 4, 2.10.	
3. Accessories	
3.1 Drivers	
3.1.1 The driver shall be of the type specified, sized to meet the maximum specified operating conditions, including external gear or coupling losses, and shall be in accordance with applicable specifications. The driver(s) shall operate under the utility and site conditions specified by the inquiry.	The driver shall be sized according to GS EP MEC 101 , Driver Power Sizing.
3.1.3 The driver shall be capable of starting under the process and utility conditions specified. The starting method and worst case starting torque requirements shall be mutually agreed. The driver's starting-torque capabilities shall exceed the speed-torque requirements of the machine train.	The driver shall be capable of starting with the specified settle out pressure without any partial or complete process loop depressurization.
3.1.4 Steam turbine drivers shall conform to ISO 10437 (API Std 612). Steam turbine drivers shall be sized to deliver continuously not less than 110% of the maximum power required by the machine train, when operating at any of the specified operating conditions, and specified normal steam conditions. Note: The 110% applies to the design phase of the project. After testing, this margin may not be available due to performance tolerances of the driven equipment.	Steam Turbine drivers shall be sized according to GS EP MEC 101 .
3.1.5 Motor drives shall conform to internationally recognized standards such as API Std 541 or API Std 546, as applicable. (Motors that are below the power scope of API Std 541 or API Std 546 shall be in accordance with IEEE 841.) Electric motor drivers shall be rated with a 1.0 S.F. The motor rating shall be at least 110% 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	Electrical Motors drivers shall be sized according to GS EP MEC 101 .

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operating conditions. Note: The 110% applies to the design phase of a project. After testing, this margin might not be available due to performance tolerances of the driven equipment.	
3.1.7 Gas turbine drivers shall conform to API Std 616 and shall be sized as mutually agreed upon by the Purchaser and the Vendor taking account of site conditions, particularly variations in ambient air temperature.	Gas Turbine drivers shall be sized according to GS EP MEC 101 .
3.1.8 Separate gear units shall be in accordance with API Std 613. Epicyclic gears may be used with the Purchaser's approval.	Epicyclic gears shall be subject to Company approval.
3.2 Couplings and guards	
3.2.2 Couplings, coupling to shaft junctures, and coupling guards shall conform to API Std 671. The make, type, and mounting arrangement of the coupling shall be agreed upon by the Purchaser and the Vendor with unit responsibility of the driver and driven equipment.	Lubricated gear couplings are not acceptable. Only diaphragm and disc pack (membranes) couplings are acceptable. Coupling guards shall be rigid type, non-sparking and shall not be subject to any leak. Refer to the GS EP MEC 030 & GS EP MEC 031 .
• 3.2.5 When specified, the machine Vendor shall provide plug and ring gauges in accordance with API Std 671, Appendix D.	Plug and ring gauges in accordance with API Std 671 shall be supplied as part of the special tools ordered by Company.
3.3 Mounting plates	
3.3.1 General	
• 3.3.1.1 The equipment shall be furnished with soleplates or a baseplate, as specified.	In all cases, equipment shall be furnished with a baseplate.
3.3.1.2.2 Alignment shims shall be in accordance with API RP 686, Chapter 7 and shall straddle hold down bolts and vertical jackscrews and shall be at least 5 mm (1/4 in.) larger on all sides than the equipment feet.	Alignment shims shall be machined adjusted, not exceeding 5 mm. Shims shall be made of stainless steel ASTM A 240 type 316 , and shall be provided by Vendor.
3.3.1.2.6 Unless otherwise specified, anchor bolts will be furnished by the Purchaser.	Anchor bolts shall be provided by Contractor.
3.3.2 Baseplates	
• 3.3.2.1 When a baseplate is specified, the Purchaser will indicate the major equipment to be mounted on it. A baseplate shall be a	Separate disconnected baseplates are not allowed. Multiple section base plates are acceptable.

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single fabricated steel unit, unless the Purchaser and the Vendor mutually agree that it may be fabricated in multiple sections. Multiple-section baseplates shall have machined and doweled mating surfaces which shall be bolted together to ensure accurate field reassembly. Note: A baseplate with a nominal length of more than 12 m (40 ft) or a nominal width of more than 4 m (12 ft) may have to be fabricated in multiple sections because of shipping restrictions.	Multiple-section baseplates shall have machined and doweled mating surfaces and shall be bolted together for single lift prior to ex-works delivery. In all cases, baseplate shall be designed according to the GS EP MEC 030 & GS EP MEC 031. Multiple separated driver skid and driven equipment skid shall have machined and doweled mating surfaces. Sections shall be bolted and fitted together with suitable pins to form a single continuous structurally integral skid base for single lift prior to Ex-works delivery. The consideration of a single sub-frame (or soleplate) underneath to support driver/driven skids shall be subject to Company approval. In any case, the complete shaft line skid mounted package shall be shipped in one piece. The responsibility for the overall combined skid design shall be allocated to the Prime Supplier of the Package.
• 3.3.2.4 When specified, nonskid decking or grating covering all walk and work areas shall be provided on the top of the baseplate. Note: If, after grouting, the Purchaser plans to completely fill the baseplate with cement as a finished surface, decking or grating is not required.	This paragraph is applicable.
• 3.3.2.4.1 When specified, horizontal solid decked surfaces shall be sloped to avoid collection of water.	A drip pan shall be provided underneath any equipment mounted on the top of the baseplate and shall be sloped to collect water. Elsewhere, removable grating covering all walking and working areas shall be provided on the top of the baseplate.
• 3.3.2.5 When specified, the baseplate shall be designed for mounting on structural columns and shall be sufficiently rigid without continuous grouting. The Purchaser and the Vendor shall mutually agree on the baseplate design.	In all cases, the design of the baseplate shall conform to the requirements of the GS EP MEC 030 or GS EP MEC 031.
• 3.3.2.6 When specified, the baseplate shall be designed to facilitate the use of optical,	This paragraph is applicable.

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laser or other instruments for field leveling during installation. Design details are described in 3.3.2.6.1 to 3.3.2.6.3. The Purchaser and the Vendor shall mutually agree the final design.	
• 3.3.2.9 When specified, the bottom of the baseplate shall have machined mounting pads. These pads shall be machined in a single plane after the baseplate is fabricated. Note: These machined mounting pads are necessary when the baseplate is mounted on sub-soleplates or structural steel members to facilitate field leveling.	In all cases, this paragraph is applicable.
• 3.3.2.10 When specified, sub-sole plates shall be provided by the Vendor.	This paragraph is applicable.
3.3.3 Soleplates and subsoleplates	
• 3.3.3.1 When soleplates are specified, they shall meet the requirements of 3.3.3.1.1 through 3.3.3.1.4.	This paragraph is applicable.
• 3.3.3.1.2 Soleplates shall be large enough to extend beyond the feet of the equipment in all directions and shall be designed such that the anchor bolts are not covered by machine feet. When specified, anchor bolt holes shall be counterbored so that the hold-down nuts do not extend beyond the upper surface of the soleplate.	This paragraph is applicable.
• 3.3.3.1.3 When specified, sub-sole plates shall be provided by the Vendor.	Sub sole plates shall be provided by Vendor.
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. When specified, the Vendor shall review the Purchaser's overall machine control system for compatibility with Vendor-furnished control equipment.	In all cases, the machine control system shall be designed and provided by Vendor.

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3.4.2 Control systems	
3.4.2.1 The Purchaser will specify the method of control, the source of the control signal, its sensitivity and range, and the equipment to be furnished by the Vendor. When specified, the Vendor shall review the Purchaser's control system. Note: Compressor control may be accomplished by suction throttling, variable inlet guide vanes, variable stator vanes, and speed variation, a cooled bypass from discharge to suction, discharge blow off or discharge throttling.	In all cases, the machine control system shall be designed and provided by Vendor. The extent of process control by the machine control system, if required, shall be indicated in the Project Specification.
3.4.2.2 When specified, an anti-surge system shall be provided. Note: Anti-surge systems are generally required to prevent operating in unstable regions which may cause damage to the compressor. The scope of supply for these systems is process dependent and should be mutually determined.	Refer to GS EP MEC 253 requirements.
3.4.3 Instruments and Control Panels Refer to API Std 614 for details on instrument and control panels.	Refer to GS EP MEC 281.
3.4.4 Instrumentation Refer to API Std 614 for details on instrumentation, and API Std 670 for details on installation	Refer to GS EP MEC 281.
3.4.5 Alarms and Shutdowns Refer to Chapters 1 and 2 of API Std 614.	Refer to GS EP MEC 281.
3.4.6 Electrical systems Refer to Chapters 1 and 2 of API Std 614.	Refer to GS EP MEC 281.
3.5 Piping and appurtenances	
3.5.4 (New paragraph) Temporary Suction strainer	This paragraph is applicable to chapters 2, 3 and 4. The compressor suction strainers shall be designed and provided with associated spool piece by the compressor Vendor and installed by Contractor. According to the piping rating and flange type (RF or RJ) the compressor

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	Vendor shall also provide additional RJ or RF mating rings to be used with the same spool piece when the temporary strainer is removed. As per GS EP MEC 292, these temporary strainers shall be located in a horizontal part of compressor suction piping as close as possible to the compressor suction nozzle but upstream the PT and TT anti-surge instrumentation. The spool piece shall be straight type. The compressor Vendor shall have the full responsibility on the mechanical design of these suction strainers, in terms of sizing, maximum allowable delta P resistance, holes sizing, etc. These temporary suction strainers shall consist of: • Spool piece made of steel, built and designed as per Project piping specifications. • The type of the inlet and outlet connections, flange or bevel for construction yard welding, shall be dictated by pipe diameter and/or the result of the piping stress analysis. • Fabricated internal basket made of stainless steel 316L drilled plate holding a 316 stainless steel wire mesh provided with three guides at 120° in accordance with the American Welding Society requirements. Free through flow area size of strainers, wire mesh and plate drilled holes, shall be as per Vendor recommended standards to be provided to Company. • The basket shall be supported by a ring to be installed between spool piece and main process piping flanges. This ring shall be made of stainless steel 316L and welded to the basket. The spool piece shall be provided with: • Brackets designed to support spring boxes (if required), • Tapping points upstream and downstream

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	the basket. These temporary strainers shall be monitored by means of a differential pressure gauge to be provided by Vendor.
4. Inspection, testing and preparation for shipment	
4.1 General	
4.1.1 After advance notification of the Vendor by the Purchaser (see 4.1.4), the Purchaser's representative shall have entry to all Vendor and Sub-Vendor plants where manufacturing, testing, or inspections of the equipment is in progress.	Company will witness the test as described in paragraph 4.3. Testing extend of inspection shall be jointly defined during a pre-inspection meeting, and listed in a quality manual, provided by Vendor for approval and review.
4.1.4 The Purchaser will specify the extent of his participation in the inspection and testing.	This paragraph is applicable.
4.1.6 When specified, the Purchaser's representative, the Vendor's representative or both shall indicate compliance in accordance with the Inspector checklist (annex D of the applicable chapter) by initialing, dating, and submitting the completed form before shipment.	This paragraph is applicable.
4.2 Inspection	
4.2.1 General	
4.2.1.5 When specified, the hardness or parts, welds, and heat-affected zones shall be verified as being within the allowable values by testing of the parts, welds, or heat-affected zones. The method, extent, documentation, and witnessing of the testing shall be mutually agreed upon by the Purchaser and the Vendor.	All components in contact with the process gas (rotor and diaphragms) shall be checked for hardness and fully documented.
4.3 Testing	
4.3.3 Overspeed test	
4.3.3.1 Each impeller shall be subjected to an overspeed test at not less than 115% of maximum continuous speed for a minimum of duration of 1 min. Impeller dimensions identified by the Manufacturer as critical (such as bore, eye seal, and outside diameter) shall	The test speed shall be sufficient to reach at any location of impeller bore the same equivalent stress level induced at any location of impeller bore by any operating conditions including the stresses induced by the maximum interference fit.

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be measured before and after each over-speed test. All such measurements and the test speed shall be recorded and submitted for the Purchaser's review following the test. Any permanent deformation of the bore or other critical dimension outside drawing tolerances might be cause for rejection.	This test speed shall be clearly indicated in the data-sheet. Any permanent deformation of the bore diameter over 0.01 mm shall be cause for rejection. Any permanent deformation of other critical dimension shall be cause for rejection. Repair procedures such as Chromium coating, Kanigen plating or Plasma deposit are prohibited to recover the original bore diameter in case of permanent deformation.
4.3.6 Mechanical Running Test	
4.3.6.1 During the mechanical running test, the requirements of 4.3.6.1.1 through 4.3.6.1.5 shall be met.	The mechanical running test shall be conducted under inert gas or vacuum environment and the temperature inside the aerodynamic parts shall be representative of the site conditions. The temperature shall be controlled within $\pm 10^{\circ}\text{C}$ of the maximum discharge temperature of any certified point (see Project data sheets). At the end of the 4-hour mechanical run test, the compressor shall be completely stopped during 30 minutes, and a hot re-start shall be performed up to the maximum continuous speed for 15 minutes duration, and the same vibration criteria shall be respected.
• 4.3.6.1.2 Synchronous vibration amplitude and phase angle versus speed for deceleration shall be plotted before and after the 4-hour run. Both the synchronous (one per revolution) and overall vibration levels shall be plotted. When specified, these data shall also be furnished in polar form. The speed range covered by these plots shall be from trip speed to 400 rpm.	Data in polar form are also requested.
• 4.3.6.1.3 When specified, tape recordings shall be made of all real-time vibration data as mutually agreed upon by the Purchaser and the Vendor.	During mechanical running test all vibration data shall be recorded using a dedicated system such as ADRE or equivalent.
• 4.3.6.1.5 When specified, lube-oil and seal-oil inlet pressures and temperatures shall be varied through the range permitted in the compressor operating manual. This shall be	This paragraph is applicable.

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done during the 4-hour test. This option, when specified, does not constitute a waiver of the other specified test requirements.	
● 4.3.6.2.2 When specified, shaft end seals shall be removed for inspection following a successful running test. Note: Removal and inspection of some seal types (such as cartridges) may require that the seal be returned to the seal Manufacturer's facility.	This paragraph is applicable. The inspection of bearings and shaft end seals shall take place after the successful mechanical and/or performance test.
4.3.8 Optional tests	
● 4.3.8.1 Performance test Performance testing requirements for specific equipment types are covered in the subsequent chapters of this standard.	When several fully identical machines including the spare rotors or bundles are ordered, only one machine with one rotor and one bundle shall undergo a performance test. This paragraph is applicable to chapters 2, 3 and 4.
● 4.3.8.2 Helium test The compressor casing shall be tested for gas leakage with helium at the maximum allowable working pressure. The test shall be conducted with the casing submerged in water. The maximum allowable working pressure shall be maintained for a minimum of 30 min, with no bubbles permitted. As an alternative, a nonsubmerged soap-bubble test may be performed if approved by the Purchaser. Note: This test is done immediately after hydrotest.	Compressor casings are not requested to be helium tested.
● 4.3.8.3 Sound-level test The sound-level test shall be performed in accordance with Purchaser requirements.	Compressor casings are not requested to be sound-level tested.
● 4.3.8.4 Auxiliary equipment test Auxiliary equipment such as oil systems and control systems shall be tested in the Vendor's shop. Details of the auxiliary-equipment tests shall be developed jointly by the Purchaser and the Vendor.	This paragraph is applicable.
● 4.3.8.5 Post-test inspection of	

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Compressor internals The compressor shall be dismantled, inspected, and reassembled after satisfactory completion of the mechanical running tests. The Purchaser will specify whether the gas test shall be performed before or after the post-test inspection. 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.	Upon satisfactory completion of the last test, each compressor bundle shall be removed. The compressor bundle with or without the seals and bearings assembly (depending on compressor Vendor design) shall be shipped separately from the casing in a dedicated nitrogen pressurized container equipped with a pressure indicator. The casing shall be properly isolated with flanges blinds and taps and preserved to sustain a period of at least 18 months. Preservation method shall be submitted to Company for approval.
● 4.3.8.6 Full-pressure/Full-load/Full-speed Test The details of the full-pressure/full-load/full-speed test shall be developed jointly by the Purchaser and the Vendor. This test may be substituted for the mechanical running test.	For the requirement of this test, refer to the Project Specification.
● 4.3.8.7 Post-test inspection of the Hydraulic Coupling Fit After the running tests, the shrink fit of hydraulically mounted couplings shall be inspected by comparing hub/shaft match marks to ensure that the coupling hub has not moved on the shaft during the tests.	This paragraph is applicable.
● 4.3.8.8 Spare-parts test Spare parts such as rotors, gears, diaphragms, bearings and seals shall be tested as specified.	Any rotating component (rotor, gears) shall undergo a mechanical running test. Spare dry gas seals cartridges shall be tested at full speed and full pressure at the seals Vendor shop. Any complete bundle, including seal cartridges and bearing assemblies shall undergo a mechanical running test.
4.4 Preparation for shipment	
4.4.1 Equipment shall be suitably prepared for the type of shipment specified, including blocking of the rotor when necessary. Blocked rotors shall be identified by means of corrosion resistant tags attached with stainless steel wire. The preparation shall	In addition, all spare rotors and/or bundles shall be provided with N2 pressurized container suitable for several years of storage. The container shall be equipped with a pressure indicator. This paragraph is applicable to chapters 2, 3 and 4.

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make the equipment suitable for 6 months outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals. If storage for a longer period is contemplated, the Purchaser will consult with the Vendor regarding the recommended procedures to be followed.	
• 4.4.3.11 When specified, the fit-up and assembly of machine mounted piping and intercoolers shall be completed in the Vendor's shop prior to shipment.	This paragraph is applicable for module type compression trains. This paragraph is applicable for all machine auxiliary components (lube oil, dry gas seals, instrument, hydraulic, etc. systems).
5. Vendor's data	
5.1 General	
5.1.1 The information to be furnished by the Vendor is specified in 5.2 and 5.3.	The detailed list of Vendor documents shall cover all Company requirements as listed in the Project Specification.
5.1.3 A coordination meeting shall be held, preferably at the Vendor's plant, within a mutually agreed time after the purchase commitment. Unless otherwise specified, the Vendor will prepare and distribute an agenda prior to this meeting, which, as a minimum, shall include review of the following items: - The purchase order, scope of supply, unit responsibility, Sub-Vendor items, and lines of communication. - The data sheets. - Applicable specifications and previously agreed upon exceptions. - Schedules for transmittal of data, production, and testing. - The quality assurance program and procedures. - Inspection, related acceptance criteria, and testing. - Expediting. - Schematics and bills of material for auxiliary systems. - The general arrangement of equipment,	A coordination meeting shall be held at the Vendor's plant within 4 weeks after order commitment.

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piping and auxiliary systems. Operating and maintenance access areas shall be reviewed. Access for any parts required for maintenance shall be detailed. j. Coupling selections and rating. k. Thrust- and journal-bearing sizing, estimated loading and specific configurations. l. The rotor dynamics analysis (lateral, torsional, and transient torsional, as required). m. Machine performance for normal and other specified conditions and other operating conditions, such as start-up, shutdown, and any operating limitations. n. Instrumentation and controls. o. Items for design reviews. p. Other technical items. q. Seal operation and controls.	
• 5.1.4 When specified, a design audit/review meeting shall be held at the Vendors plant within 16 weeks after order commitment. The Purchaser/Owner shall prepare and distribute the agenda prior to the meeting.	Several meetings at regular intervals for design audit, review and coordination purposes shall be held at the Vendor's plant during the life of the order.
5.2 Proposals	
5.2.4 Curves	
5.2.4.1 Curves for variable-speed compressors shall include the following: discharge pressure; power; polytropic head; and polytropic efficiency versus inlet capacity (from predicted surge point to 115% rated capacity) at minimum operating speed and 80%, 90%, 100% and 105% speed, and indicating the effect of specified inlet pressures, temperatures, and molecular weights. Any specified operating points shall be noted within the envelope of the performance curve predicted.	Non dimensional performance curves: polytropic head coefficient versus flow coefficient and polytropic efficiency versus flow coefficient at various Mach numbers or iso speeds shall be furnished by Vendor for each compressor section. In addition to the plots, all curves shall be provided under spread sheets and polynomial forms. Head versus flow curves shall include the capacity limitations due to the drivers.

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5.3 Contract data	
5.3.1 General	
5.3.1.1 Contract data shall be furnished by the Vendor in accordance with the agreed VDDR form (Annex B of each chapter).	Refer to the Contract.
5.3.1.3 The Purchaser will promptly review the Vendor's data upon receipt; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon writing. After the data been reviewed and accepted, the Vendor shall furnish certified copies in the quantities specified.	Refer to the Contract.
5.3.2 Drawings and Technical data	
5.3.2.1.1 The Vendor shall provide complete performance curves to encompass the map of operations, with any limitations indicated. The curves shall comply with the requirements of 5.3.2.1.2 through 5.3.2.1.6.	All expected curves shall be updated after performance shop tests as per test results. This requirement also applies to Data-Sheets.
5.3.2.1.3 If a performance test is specified, the Vendor shall provide test data and curves when the test has been completed. The surge points shall be shown on the performance curves.	The as tested performance curves during FAT shall also clearly indicate the anticipated position of the Surge Control Line.
5.3.2.2 Data Sheets The Vendor shall provide full information to enable completion of the data sheets for the train and auxiliary equipment, first for "as-purchased", and then for "as-built". This should be done by the Vendor correcting and filling out the data sheets and submitting copies to the Purchaser. Datasheets are available in Annex A of each chapter.	The data sheet for centrifugal compressors is given in appendix XXX. For integrally geared compressor and for expander compressors the data sheets are respectively those of API Std 617 chapters 3 & 4 - Annex A.
• 5.3.2.1.5 When specified, the Vendor shall supply curves of balance piston line differential pressure versus thrust load.	This paragraph is applicable.
5.3.3 Progress Reports	
• 5.3.3.2 When specified, one week prior to the start of assembly the Vendor shall issue a "Tail End Schedule", bi-weekly. The schedule	Refer to the Contract.

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shall include major assemblies, sub-assemblies, test setup, testing, paint, pack and shipment preparation. Included in the columns shall be start (Schedule/Actual), Finish (Schedule/Actual), Status (Sym./Date), Comments.	
5.3.5 Installation, Operation, Maintenance, and Technical Data Manuals	
● 5.3.5.1.2 When specified, a draft manual(s) shall be issued to Purchaser 8 weeks prior to testing for review and comment.	This paragraph is applicable.
● 5.3.5.4 Technical Data Manual When specified, the Vendor shall provide the Purchaser with a technical data manual within 30 days of completion of shop testing. See description in Annex B of each of the listed chapters for minimum requirements of this manual: a. Chapter 2, line 53 b. Chapter 3, line 57 c. Chapter 4, line 54	This paragraph is applicable.

General Specification		GS EP MEC 251
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Annex 1D (Additional)

Computational Flow Dynamic Analysis

1-The purposes of the CFD Analysis are:

- When the compressor includes one or several side streams: to analyze pressure, velocity and temperature distributions in the mixing areas
- For the compressor arrangement (straight through, back to back, in line etc.) to analyze the whole compressor aerodynamic behavior.

2-The Vendor shall indicate:

- The CFD codes
- The references in the application of the codes
- The calculations and corresponding experimental measurements or measurements in similar applications.

3-The CFD shall be performed:

- At the guarantee point
- At one operating point corresponding to surge protection line: The analysis shall prove that the compressor is free of any stall, either generated at inlet, or in the impeller, or at exit of the impeller.

4-The CFD analysis shall be supported by a project specification and a calculation note, part of the supply. The specification shall give the assumptions taken to handle the computation: area covered, meshing, boundary layer, initial conditions.

5-Company reserves the right to perform a verification of the CFD Analysis through an Independent Third Party Consultant.

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Chapter 2 - Centrifugal and Axial Compressors

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2. Basic design	
(new paragraph)	The centrifugal compressor shall be variable speed driven. In case of Electrical Motor driver the variable speed can be achieved either with EM variable speed + VFD (Variable Frequency Drive) or with EM constant speed + Hydraulic coupling.
2.3 Casings	
2.3.1 Pressure containing casing	
2.3.1.1 The Purchaser will specify the relief valve setting. The maximum allowable working pressure of the casing shall be at least equal to the specified relief valve setting.	The relief valve setting is specified in the Project data sheets.
2.3.2 Pressure casing connections	
2.3.2.4 When specified, connections for boroscopic examination shall be supplied in mutually agreeable locations.	Connections for boroscopic examination are not requested. Casings with several inlet process connections (typically refrigeration compressors) shall be equipped with permanent taping points for temperature measurement located downstream each diffuser which is installed upstream a side stream. This measurement allows to compute the efficiency of the compression section upstream the side stream and the inlet temperature for the section downstream the side stream.
2.3.4 External Forces and Moments	
2.3.4.1 The compressor shall be designed to withstand external forces and moments on each nozzles calculated per modified Equations of Annex 2E.	Refer to revised Annex 2E of this document. While API limit corresponds to 1.85 times NEMA, the current specification extends the limit to 5 times NEMA. This requirement applies to normal conditions including normal operation, start-up, nitrogen run, shut-down, string test, external support movement, etc. However, this requirement does not apply to exceptional events such as earthquakes, tsunami, etc in which case dedicated studies shall be carried out.

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2.4 Guides vanes, stators and stationary internals	
• 2.4.1 When specified or required to meet specified operating conditions, Adjustable Inlet Guide Vanes (AIGVs) on centrifugal compressors or variable stators on axial compressors shall be supplied. All or some of the stator blade rows may be adjustable.	Except for refrigeration compressors or axial compressors, adjustable inlet guide vanes or variable stators are not permitted.
• 2.4.2 When specified, the guide vane housing shall incorporate an external shell capable of providing an external purge of filtered air or inert gas.	This paragraph is applicable.
• 2.4.3 When specified, a vane control system consisting of a valve positioner with local position indicator and other component as specified shall be provided.	This paragraph is applicable with in addition, a valve position transmitter and close position adjustable limiting device.
• 2.4.5 Interstage diaphragms shall be suitable for all specified operating conditions, including start-up, shutdown, trip-out, settling-out, and momentary surge. When intermediate main process connections are used, the Purchaser will specify the maximum and minimum pressure at each connection. The Vendor shall confirm that the diaphragms furnished are suitable for the maximum differential pressure.	Refer to the data sheets and P&IDs. Vendor shall clearly indicate if the proposed machine includes shunt holes either at division wall labyrinth or at the balance piston. In the case of two sections within a single compressor casing, the back to back arrangement is preferred.
2.4.7 Seals shall be provided at all internal close clearance points to minimize internal recirculation. Seal components shall be renewable or replaceable in order to restore design clearances.	Vendor shall clearly indicate the type of labyrinths: interstage, division wall, balance piston... (teeth, honeycomb, hole pattern, stepped, with or without swirl brakes). All seals, except those installed inside dry gas seals, shall be stationary and easily replaceable at site.
2.5 Rotating elements	
2.5.4 Thrust balancing	
2.5.4.1 A balance piston, balance line, and porting shall be provided if required to reduce axial loads on the thrust bearings. A separate pressure-tap connection or connections shall be provided to indicate the pressure in the balancing chamber, not in the balance line.	Pressure in the balancing chamber shall be made available at unit control panel.
2.5.4.2 The balance line, if required, shall be	In any case the balance line shall be required.

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flanged and sized to handle balance piston gas leakage at twice the initial design seal clearance without exceeding the load rating of the thrust bearings (see 2.7.3.3). If the balance line involves a connection to Purchaser's piping, then the connection size and locations shall be indicated on the data sheets.	Cooling of the balance line flow and connection of the balance line to the process piping are not permitted.
• 2.5.4.3 When specified, a pressure tap connection shall be supplied in the downstream end of the balance line to allow measurement of differential pressure in the balance line. Note: This connection may not be in the compressor supply, it might be in the process piping.	This connection is not required.
2.7 Bearings and bearing housings	
2.7.1 General	
• 2.7.1.1.2 When specified, active magnetic bearings shall be provided. Note: Annex 4F gives application considerations for use of active magnetic bearings. These bearings are not specifically being recommended for equipment included in this chapter of this standard, although some users may decide to incorporate this technology into their units.	Refer to the Project Specification.
2.7.2 Hydrodynamic radial bearings	
• 2.7.2.2 When specified, tilting pad bearings shoes shall be cooper-alloy backed.	Vendor standard shall apply.
• 2.7.2.3 When specified, cooper-alloy bearings shall have hardened steel inserts for supports.	Vendor standard shall apply.
2.7.3 Hydrodynamic thrust bearings	
• 2.7.3.6 When specified, or as approved by Purchaser, directed lube may be used in lieu of flooded lube. Note: Directed lube has advantages in power requirements, but has small passages with greater potential to plug.	Vendor standard shall apply.

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• 2.7.3.7 When specified, thrust bearings pads shall be cooper-alloy backed and shall have hardened steel inserts for supports.	Vendor standard shall apply.
2.8 Shaft end seals	
• 2.8.2 Purchaser will specify the type of shaft end seal to be provided and all operating conditions including start-up, shutdown and settle out conditions. Note: Axial compressors in process air service will generally be supplied with labyrinth shaft end seals. Process compressors may have any type of shaft end seal specified.	Shaft end seals shall be as per here above paragraph 2.8.4 of chapter 1. Sealing design pressures shall be indicated in the data sheets and as follows: • Operating pressure not lower than the maximum operating suction pressure. • Static pressure not lower than the settle out pressure. The dry gas seals shall be able to be started with the settle out pressure without any partial venting.
• 2.8.3 Shaft end seals and, when specified, shaft sleeves shall be accessible for inspection and for replacement without removing the top half of the casing for an axially split compressor of the heads of a radially split unit. Note: This requirement may not be feasible for overhung designs.	This paragraph is applicable to axially and radially split compressors.
2.10 Lubrication and sealing systems	
• 2.10.1 The Purchaser will specify whether the seal-oil and lube-oil systems are to be separate or combined. If separate systems are specified, the means of preventing interchange of oil between the two systems shall be described in the Vendor's proposal.	When liquid film shaft end seals are specified, lube and seal oil systems shall be separated.
• 2.10.2 Purchaser will specify type and properties of oil to be used. Unless otherwise specified, the lubricant shall be hydrocarbon oil, of viscosity Grade 32, in accordance with ISO 8068.	Lubricant used shall be specified by the compressor Vendor and selected whenever possible among the brand names of lubricants produced by the Company.
2.11 Nameplates and rotation arrows	
• 2.11.2 The following data shall be clearly stamped or engraved on the nameplate: • Vendor's name.	SI units shall be shown on the nameplate. The year of fabrication shall also be stamped or engraved on the nameplate.

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• Serial number. • Size, type and model. • Rated capacity. • Rated power. • Lateral critical speeds up to and including the next lateral above maximum allowable speed (see 2.11.2.1). • Purchaser item number or other reference. • Maximum allowable working pressure. • Minimum and maximum allowable working temperature. • Minimum operating speed • Maximum continuous speed • Trip speed • Hydrostatic test pressure The Purchaser will specify whether SI or U.S. Customary units are to be shown.	
3. Accessories	
3.4 Controls and instrumentation	
• 3.4.2.2 For constant-speed centrifugal compressors, the control signal shall actuate either a Purchaser-furnished control valve in the compressor inlet piping or the adjustable inlet guide vanes furnished by the Vendor as an integral part of the compressor, as specified. In the latter case, the Vendor shall also furnish a guide-vane positioner compatible with the type of control signal specified by the Purchaser. A direct-driven vane position indicator shall be provided that will be visible during operation of the machine.	If a suction control valve is required, this valve shall be provided by Contractor and controlled by the plant Integrated Control and Safety System (ICSS). This valve must then conform to GS EP PVV 112 and GS EP INS 120. The extent of process control by the machine control system, if required, shall be indicated in Project Specification.
• 3.4.2.3 For constant-speed axial compressors, the control signal shall the adjustable inlet guide vanes or and/or adjustable stator vanes furnished by the Vendor as an integral part of the compressor, as specified. The Vendor shall also furnish a vane positioner compatible with the type of control signal specified by the Purchaser. A direct-driven vane position indicator shall be	Refer to Project Specification.

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provided that will be visible during operation of the machine.	
3.4.7 Vibration, position and bearings temperature detectors	
• 3.4.7.2 When specified, radial shaft vibration and axial-position monitors shall be supplied and calibrated in accordance with API Std 670.	This paragraph is applicable. The axial position detection shall be equipped with alarm and trip levels which shall be set outside the normal operation gap of the thrust bearing. In addition, a key phasor shall be provided with the associated monitoring system based on non contact vibration probes.
• 3.4.7.3 Purchaser will specify type of temperature detector required per API Std 670.	This paragraph is applicable. Each journal bearing shall be provided with two temperature detectors and associated monitoring system. The two RTDs shall be fitted within two successive pads, one being the most loaded. Both RTDs shall be wired up to a skid battery limit junction box.
• 3.4.7.4 When specified, a bearing temperature monitor shall be supplied and calibrated according to API Std 670.	This paragraph is applicable. Both outboard and inboard thrust bearings shall be provided with two temperature detectors and monitoring system. On each side, the two RTDs shall be fitted within two separate pads and wired up to a skid battery limit junction box.
• 3.4.7.5 When specified, casing vibration transducers shall be supplied, installed, and calibrated in accordance with API Std 670.	Casing vibration transducers are not required.
• 3.4.7.6 When specified, casing vibration monitors shall be supplied, installed and calibrated in accordance with API Std 670.	Casing vibration monitors are not required but monitor racks shall include provision for installation of as many monitors as compressor casings provided.
3.5 Piping and appurtenances	
3.5.1 General	
• 3.5.1.2 When specified, a liquid injection manifold shall be supplied. It shall include a throttle valve, an armored flow meter, a check valve, a pressure indicator, and a block valve for each injection point.	Refer to Project Specification.

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4. Inspection, testing and preparation for shipment	
4.3 Testing In addition to the requirements of Chapter 1, 4.3, the compressor(s) shall be tested in accordance with 4.3.1 and 4.3.2 of this chapter. Other tests that may be specified are described in 4.3.3. Immediately upon completion of each witnessed mechanical or performance test, copies of the log data recorded during the test shall be given to the witnesses.	Before commencing any test, Vendor shall make available the calibration certificates of all the instruments for the test and prove that data acquisition system is fully operating. Print out of all the input data shall be made available. Company reserves the right to check at random several complete instrument loops by injecting a calibrated signal at the transducer and printing the data from the data acquisition system.
4.3.1 Mechanical Running Test	
4.3.1.1.9 Shop test facilities shall include the capability of continuously monitoring, displaying, recording and printing vibration displacement and phase, vibration spectra, Bode plots, and shaft orbits.	Shop test facilities as per paragraph 4.3.1.1.9 of API Std 617 chapter 2 shall be made available and implemented for any vibration probe.
4.3.1.1.10 When specified, the user may furnish his own vibration equipment to record baseline readings.	Company reserves the right to use his own vibration equipment during the test.
4.3.1.3.4 Shop verification of the unbalanced response analysis shall be performed in accordance with Chapter 1, 2.6.2.	This verification, as part of the mechanical running test, is not required.
4.3.2 Assembled Compressor Gas Leakage Test	
4.3.2.3 When specified, the assembled compressor (with or without end seals installed) shall be pressurized with an inert gas to the maximum specified discharge pressure, held at this pressure for a minimum of 30 min., and subjected to a soap-bubble test, or alternate method, to check for gas leaks. The test shall be considered satisfactory when no casing or casing joint leaks are observed. Note: The requirements of 4.3.2.2 and 4.3.2.3 may necessitate two separate tests.	The leakage test of the compressor shall be carried out with the dry gas seals installed. The test shall be conducted at the settle out pressure.
4.3.3 Optional tests The Purchaser will specify whether any of the following shop tests shall be performed. Test	Refer to the Project Specification.

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details shall be mutually agreed upon by the Purchaser and the Vendor prior to the test.	
4.3.3.1 Performance Test	
4.3.3.1.1 The compressor shall be performance tested in accordance with ASME PTC 10-1997, ISO 5389 or other approved national standard. A minimum of five points, including surge and overload, shall be taken at normal speed. For variable-speed machines, additional points may be specified. Note: Refer to the applicable test code for general instructions. ASME PTC 10-1997 may not apply to some low pressure ratio compressors. Refer to the scope, 1.2.2, of ASME PTC 10-1997 for the selection of the appropriate test code to be used.	Performance test shall be a type 2 as per ASME PTC 10-1997. Only the first unit of identical design (including spare bundle) shall be aerodynamically tested according to ASME PTC 10-1997 type 2. For constant speed compressor, a minimum of five points, evenly spaced, from stonewall to surge at the normal speed, is required. For variable speed compressor, a minimum of six points, evenly spaced, from stone wall to surge at speed corresponding to the certified point(s), is required. In addition, the surge flow of the compressor shall be clearly measured during the Type 2 test at speed(s) corresponding to the certified point(s), and at maximum continuous speed and minimum operating speed. For computation of the performance, Reynolds number correction is not permitted. When multi-section compressors are tested, inlet flow at each section shall be measured. When compressors with several side streams are tested, flow at each section shall be measured as well as the final discharge flow. Temporary shop instrumentation shall be installed for measuring the efficiency of each section. Balancing line flow shall be measured during the ASME PTC 10-1997 type 2 test and compared to design values.
4.3.3.1.2 For variable speed machines, head and capacity shall have zero negative tolerance at the normal operating point (or other point as specified), and the power at this point shall not exceed 104% of the Vendor predicted shaft power value. This tolerance shall be inclusive of all test tolerances. Surge shall comply with provisions of 2.1.1.1. Note: Both of the performance test codes referred to have provisions for calculating	<i>At the guaranteed (or certified) points(s):</i> <i>For each compressor section:</i> • Speed: +/-2% allowable adjustment but not to exceed 100% (rated) speed. • Absorbed gas power: expected +4% • Polytropic head: expected +/-0% after speed adjustment. • Inlet volume flow: expected +/-0% In addition, and after the speed adjustment,

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inaccuracy based on instrumentation and procedures. These test inaccuracies are already included in the above tolerance and, therefore not to be further additive	the following tolerances shall be also verified: • Inlet volume flow at surge: expected +0% • Polytropic head at surge: expected -2% • Inlet volume flow at stone wall: expected -0% • Polytropic head at stone wall: expected -3% Complete compressor shaft line: • The complete shaft line speed shall be determined so as to reach the overall polytropic head value with zero tolerance. • Inlet mass flow: expected +/-0% • Compressor shaft end power: expected +4% At any other specified points as indicated in the data sheets: • Each individual compressor section inlet mass flow values: expected +/-0% • Overall polytropic head value: expected +/- 0% • Speed shall not exceed 100% (rated) speed. • The driver shall be capable to deliver the power required.
4.3.3.1.3 For variable speed compressors, a speed other than normal speed may be used, if necessary, to achieve the specified performance and performance tolerances, provided that this adjusted speed meets the criteria specified in chapter 1.2.6.	Refer to comment to paragraph 4.3.3.1.2.
4.3.3.1.4 For constant speed compressors, the capacity shall be as defined in 4.3.3.1.2. The head shall be within the range of 100-105% of the normal head. The horsepower, based on measured head at normal capacity, shall not exceed 107% of the value at specified normal operating point. If the power required at this point exceeds 107%, excess head may be removed by trimming impellers at the Purchaser's option.	At the guaranteed (or certified) points(s): For each compressor section: • Absorbed gas power: expected +7% • Polytropic head: expected -0% / +3% (X is the difference between the actual polytropic head test value and the expected polytropic head value at guarantee point. X is expressed in kJ/kg. See below for the shape of the curve from stone wall to surge). • Inlet volume flow: expected +/-0% In addition, the following tolerances shall be

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	also verified: - Inlet volume flow at surge: expected +0% - Polytropic head at surge: (expected + X) -2% - Inlet volume flow at stone wall: expected -0% - Polytropic head at stone wall: (expected + X) -3% Complete compressor shaft line: - Inlet mass flow: expected +/-0% - Compressor shaft end power: expected +7% At any other specified points as indicated in the data sheets: - Each individual compressor section inlet mass flow values: expected +/-0% The driver shall be capable to deliver the power required.
4.3.3.1.5 The performance test shall be conducted using only one Contract rotor, unless otherwise specified.	Refer to paragraph 4.3.8.1 of Chapter 2.
4.3.3.1.6 Compressors with intermediate specified process pressures shall have individual sectional head (pressure) tolerances as mutually agreed.	Refer to comments to paragraphs 4.3.3.1.2 and 4.3.3.1.4 of Chapter 2.
4.3.3.2 Complete Unit Test Such components as compressors, gears, drivers, and auxiliaries that make up a complete unit shall be tested together during the mechanical running test. A separate auxiliary test may be performed with the Purchaser's approval. The complete unit test may be performed in place of, or in addition to, separate tests of individual components as specified by the Purchaser. When specified, torsional vibration measurements shall be made to verify the Vendor's analysis.	Refer to the Project Specification and to GS EP MEC 300 .
5. Vendor's data	
Vendor's data shall be in accordance with Section 5 of Chapter 1 of this document.	Refer to comment to section 5 of Chapter 1.

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Annex 2E Forces and Moments

E.1 General

E.1.1 For the calculations of nozzle forces and moments, reference to NEMA documents shall be done with the constants in the equations be multiplied by 5. Therefore, the equations have been adapted to the compressors by identifying the new constants.

E.2 Equations

- a. The total resultant force and total resultant moment imposed on the compressor at any connection should not exceed the values shown in Equations 2.E-1a or 2.E-1b

In SI units $F_r + 1.09 M_r \leq 146.2 D_e$ (2.E-1a)

In U.S. Customary units $3 F_r + M_r \leq 2505 D_e$ (2.E-1b)

- b. The combined resultants forces and moments of the inlet, side stream and discharge connections resolved at the centerlines of the largest connection should not exceed the following:

1. The resultants shall not exceed:

In SI units $F_c + 1.64 M_c \leq 109.2 D_c$ (2.E-5a)

In U.S. Customary units $2 F_c + M_c \leq 1249 D_c$ (2.E-5b)

2. The individual components of these resultants should not exceed:

In SI units:

$$F_x = 43.5 D_c \quad M_x = 66.5 D_c$$

$$F_y = 109.5 D_c \quad M_y = 33.2 D_c$$

$$F_z = 87.6 D_c \quad M_z = 33.2 D_c$$

In U.S. Customary units:

$$F_x = 248.6 D_c \quad M_x = 1248.6 D_c$$

$$F_y = 624.3 D_c \quad M_y = 624.3 D_c$$

$$F_z = 500 D_c \quad M_z = 624.3 D_c$$

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Chapter 3 - Integrally Geared Compressors

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2. Basic design	
2.3 Casings	
2.3.1 Pressure-containing casings	
2.3.1.1 The maximum allowable working pressure of each pressure casing shall be at least equal to the specified relief valve setting for that casing. The Purchaser will specify the relief valve setting(s) for final discharge pressure and intermediate casing pressures if applicable. Note: If only one relief valve pressure is specified, its set points may be not apply to the intermediate pressure	Refer to the Project data sheets.
2.3.1.2 When a relief valve setting is not specified, each pressure casing shall be rated for the settle out pressure, or at least 1.25 times the maximum discharge pressure (gauge) of that pressure casing as determined by the Vendor.	This paragraph is applicable.
2.3.4 External forces and moments	
2.3.4.1 The Vendor shall furnish the allowable forces and moments for each nozzle in tabular form in the proposal. Note: forces and moments allowed on integrally geared compressors are generally less than allowed on chapter 2 compressors.	Vendor's recommendations shall apply.
2.3.5 (New paragraph)	Integrally geared compressors are prohibited for process gas applications containing more than 10 ppm of H ₂ S.
2.4 Guides vanes, stators, and stationary internals	
2.4.1 Adjustable guide vanes shall be provided when specified or required by the Vendor to meet specified operating conditions.	Vendor's responsibility.
2.4.3 When specified, the actuation shaft seal shall be buffered using a barrier gas.	In case of toxic gas, this paragraph is applicable.

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2.7 Bearing and bearing housing	
2.7.2 Hydrodynamic bearing	
2.7.2.2 When specified, tilting pad bearings shall be copper alloy backed and shall have hardened steel inserts for supports	Vendor's standard shall apply.
2.7.3 Hydrodynamic thrust bearings	
2.7.3.2 When specified, bearings shall be tilting pad on one or both sides	Vendor's standard shall apply.
2.11 Nameplates and rotation arrows	
2.11.2 The following data shall be clearly stamped or engraved on the nameplate(s): - Vendor's name - Serial number - Size, type and model - Rated capacity - Rated power - Number of teeth of each pinion - Number of teeth of the gear wheel - Gear ratio - Rated input speed - Rated output speed of each pinion - Lateral critical speed up to and including the next lateral above maximum allowable speed (see 2.11.2.1 of chapter 2 of this standard) - Purchase item number - Maximum allowable working pressure of each pressure-casing - Maximum and minimum allowable working temperature of each pressure-containing casing - Minimum and maximum allowable speed(s) for each rotor - Hydrostatic pressure for each pressure-containing casing - Gear service factor. The Purchaser will specify whether SI or US	This paragraph is applicable. The year of fabrication shall also be stamped or engraved on the nameplate.

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customary units are to be shown. Note: normally, multiples nameplates are provided.	
3. Accessories	
3.4 Controls and instrumentation	
3.4.2 Control systems	
3.4.2.1 For constant-speed centrifugal compressors, the control signal shall actuate either a Purchaser-furnished control valve in the compressor inlet piping or the adjustable inlet guide vanes furnished by the Vendor as an integral part of the compressor, as specified. In the latter case, the Vendor shall also furnish a guide-vane positioner compatible with the type of control signal specified by the Purchaser. When specified, the guide vane positioner shall include a local manual override. A direct driven vane position indicator shall be provided that will be visible during operation of the machine.	This paragraph is applicable. If a suction control valve is required, this valve shall be provided by Contractor and controlled by the plant Integrated Control and Safety System (ICSS). This valve must then conform to GS EP PVV 112 and GS EP INS 120. This pressure control valve shall be provided with instrument air operated actuator and fitted as a minimum with the following accessories: • Electro-pneumatic positioner • Position recopy transmitter • Fully open and close position limit switches • Boosters • Quick exhausts, solenoid valves, instrument air pressure regulators.
3.4.7 Vibration, position, and bearing temperature detectors	
3.4.7.2 When specified, radial shaft vibration and axial position monitors shall be supplied and calibrated in accordance with API Std 670.	This paragraph is applicable. The axial position detection shall be equipped with alarm and trip levels which shall be set outside the normal operation gap of the thrust bearing In addition, a key-phasor shall be provided with the associated monitoring system based on non contact vibration probes.
3.4.7.3 When specified, a bearing temperature monitor shall be supplied and calibrated in accordance with API Std 670.	This paragraph is applicable. Each journal bearing shall be provided with two temperature detectors and associated monitoring system. The two RTDs shall be fitted within two successive pads, one being the most loaded. Both RTDs shall be wired up to a skid battery limit junction box.

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	Both outboard and inboard thrust bearings shall be provided with two temperature detectors and monitoring system. On each side, the two RTDs shall be fitted within two separate pads and wired up to a skid battery limit junction box.
• 3.4.7.5 When specified, gearbox vibration monitors shall be supplied, installed and calibrated in accordance with API Std 670.	This paragraph is applicable.
• 3.4.7.7 When specified, accelerometer(s) shall be mounted on the gearbox near the pinion bearing(s) to measure the gearmesh vibration. Monitors, when supplied, shall be suitable for measuring gearmesh frequencies.	This paragraph is applicable and accelerometers range shall cover up to 20 kHz.
3.5 Piping and appurtenances	
3.5.1 General	
• 3.5.1.2 When soleplates are specified, the Purchaser shall define the extent of the piping system supplied by the Vendor.	Refer to the Project Specification.
• 3.5.1.3 When specified, a liquid injection manifold shall be supplied. It shall include a throttle valve, an armored flow meter, a pressure indicator, and a block valve for each injection point.	Refer to the Project Specification.
3.5.2 Process piping	
• 3.5.2.2 When specified, the Purchaser shall provide specification for process heat exchanger and interconnecting piping to be provided by the Vendor with API Std 614 chapters 1.5.5.	This paragraph is applicable. Refer to the Project Specification.
4. Inspection, Testing, and Preparation for Shipment	
4.3 Testing	
4.3.1 Mechanical running test	
• 4.3.1.1.2 Compressors covered in this chapter generally do not use oil-injected seals or seal-oil systems. When these are specified, testing shall be mutually agreed upon between user and Vendor.	When oil seals are specified, the Vendor's standard procedure shall apply.
• 4.3.1.3.6 When specified, all real-time	This paragraph is applicable.

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vibration data as mutually agreed by the Purchaser and the Vendor shall be recorded and a copy provided to the Purchaser.	
4.3.1.3.7 When specified, the user may bring in the user's own vibration equipment to record base line readings.	This paragraph is applicable.
4.3.2 Assembled compressor gas leakage test	
4.3.2.3 When specified, the assembled compressor (with or without seals installed) shall be pressurized with an inert gas to the maximum specified discharge pressure, held at this pressure for a minimum of 30 min., and subject ed to a soap-bubble test, or alternate method, to check for gas leaks. The test shall be considered satisfactory when no casing or casing joint leaks are observed. Note: The requirements of 4.3.2.2 and 4.3.2.3 may necessitate two separate tests.	This paragraph is applicable.
4.3.3 Optional tests The Purchaser will specify whether any of the following shop tests shall be performed. The Purchaser and the Vendor shall mutually agree upon test details prior to the test.	Refer to the Project Specification.
4.3.3.1 Performances tests	
4.3.3.1.1 The compressor shall be performance tested in accordance with ASME PTC 10-1997 or ISO 5389 as specified. A minimum of five points, including surge and overload, shall be taken at normal speed and vane setting. For variable-speed machines, or variable vane machines, additional points may be specified. Note: Refer to the applicable test code for general instructions. ASME PTC 10-1997 may not apply to some low pressure ratio compressors. Refer to the scope, 1.2.2, of ASME PTC 10-1997 for the selection of the appropriate test code to be used.	Performance test shall be a type 2 as per ASME PTC 10-1997. For constant speed compressor, a minimum of six points, evenly spaced, from stonewall to surge at the normal speed, is required. For variable speed compressor, a minimum of six points, evenly spaced, from stonewall to surge at speed corresponding to the certified point(s), is required. In addition, the surge flow of the compressor shall be clearly measured during the Type 2 test from minimum to maximum continuous speed by taking 3 or 4 points. For computation of the performance, Reynolds number correction is not permitted. When multi--section compressors are tested, inlet flow at each section shall be measured.

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4.3.3.1.2 For variable speed machines or variable vane machines, head and capacity shall have zero negative tolerance at the normal operating point (or other point as specified), and the power at this point shall not exceed 104% of the Vendor predicted shaft power value. This tolerance shall be inclusive of all test tolerances. Surge shall comply with provisions of 2.1.1.1. Note: Both of the performance test codes referred to have provisions for calculating inaccuracy based on instrumentation and procedures. These test inaccuracies are already included in the above tolerance and, therefore not to be further additive.	At the guaranteed (or certified) points(s): For each compressor section: • Speed: +/-2% allowable adjustment but not to exceed 100% (rated) speed. • Absorbed gas power: expected +4% • Polytropic head: expected +/-0% after speed adjustment. • Inlet volume flow: expected +/-0% In addition, and after the speed adjustment, the following tolerances shall be also verified: • Inlet volume flow at surge: expected +0% • Polytropic head at surge: expected -2% • Inlet volume flow at stone wall: expected -0% • Polytropic head at stone wall: expected -3% Complete compressor shaft line: • The complete shaft line speed shall be determined so as to reach the overall polytropic head value with zero tolerance. • Inlet mass flow: expected +/-0% • Compressor shaft end power: expected +4% At any other specified points as indicated in the data sheets: • Each individual compressor section inlet mass flow values: expected +/-0% • Overall polytropic head value: expected +/-0% • Speed shall not exceed 100% (rated) speed. • The driver shall be capable to deliver the power required.
4.3.3.1.3 For constant speed compressors, the capacity shall be as defined in 4.3.3.1.2. The head shall be within the range of 100-105% of the normal head. The horsepower, based on measured head at normal capacity, shall not exceed 107% of the value at specified normal operating point. If the power required at this point exceeds 107%, excess head may be removed by trimming impellers	At the guaranteed (or certified) points(s): For each compressor section: • Absorbed gas power: expected +7% • Polytropic head: expected -0% / +3% (X is the difference between the actual polytropic head test value and the expected polytropic head value at guarantee point. X is expressed in kJ/kg. See below for the shape of the curve from stone wall to

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at the Purchaser's option.	surge). • Inlet volume flow: expected +/-0% In addition, the following tolerances shall be also verified: • Inlet volume flow at surge: expected +0% • Polytropic head at surge: (expected + X) -2% • Inlet volume flow at stone wall: expected -0% • Polytropic head at stone wall: (expected + X) -3% Complete compressor shaft line: • Inlet mass flow: expected +/-0% • Compressor shaft end power: expected +7% At any other specified points as indicated in the data sheets: • Each individual compressor section inlet mass flow values: expected +/-0% • The driver shall be capable to deliver the power required.
4.3.3.2 Complete unit test Such components as compressors, gears, drivers, and auxiliaries that make up a complete unit shall be tested together during the mechanical running test. A separate auxiliary test may be performed with the Purchaser's approval. The complete unit test may be performed in place of, or in addition to, separate tests of individual components as specified by the Purchaser. When specified, torsional vibration measurements shall be made to verify the Vendor's analysis.	Refer to the Project Specification.

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Chapter 4 - Expander-Compressors

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2. Basic design	
2.3 Casings	
2.3.1.1 The Purchaser will specify the system relief valve settings. The maximum allowable working pressure of the casing(s) shall be at least equal to the specified relief valve set pressure(s).	The system relief valve setting shall be indicated in the Project data sheets.
2.5 Rotating Elements	
2.5.4 Impellers For impellers requirements see 2.5.10 of Chapter 1	Expander wheels shall be made of titanium. For maximum allowable stresses, refer to paragraph 2.5.4 of Chapter 1.
2.6 Dynamics	
2.6.1 Vibration balancing	
2.6.1.6 When specified, rotors shall be assembled and the balance verified. The residual unbalance for the randomly assembled components shall not exceed the greatest value determined by the following expressions: In SI units: $U = 25,400 (W/N), \text{ or}$ $U = 12.7 (W) \quad (4.2.2a)$ In U.S. Customary units: $U = 40 (W/N), \text{ or}$ $U = 0.008 (W) \quad (4.2.2b)$ Where: U = residual unbalance, in g-mm (oz,-in) W = weight of the rotor, in kg (lb.), apportioned to the balance planes so that the sum of the weight apportionment for both planes equals the total weight of the rotor. N = maximum continuous operating speed, in rpm Assembled rotors that fail to meet these criteria shall be balance corrected by	This paragraph is applicable.

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repeating the component balance, not by trim balancing the assembly.	
2.6.1.7 Residual Unbalance Procedure When specified, a residual unbalance check shall be performed on assembled rotors. The residual unbalance check shall be performed after assembly balancing or assembly check-balancing is complete and before the assembled rotor is removed from the balancing machine. Note: Refer to Annex 1B for a description of the procedure for residual unbalance verification.	This paragraph is applicable.
2.7 Bearings and bearing housings	
2.7.1 General	
2.7.1.2 When specified, magnetic bearings shall be supplied in accordance with Annex 4F.	Active magnetic bearings shall be provided.
2.8 Expander-compressor shaft seals	
2.8.1 General	
2.8.1.1 Shaft seals shall be provided to restrict the leakage of process gas into the bearing housing over the range of specified operating conditions, including start-up and shutdown. Seals shall be suitable for specified variations in seal operating conditions that may prevail during start-up, shutdown, or settling-out, and during any special operation specified.	In case of H ₂ S in the gas, sweet gas shall be injected to protect the active magnetic bearings.
3. Accessories	
3.4 Controls and instrumentation	
3.4.2 Vibration, position and bearing temperature detectors	
3.4.2.2 When specified, axial position probes shall be provided in accordance with API Std 670. Note: Expander-compressors normally use pressure from active thrust compensation system rather than axial position probes for alarm/shutdown functions.	This paragraph is applicable.

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• 3.4.2.3 When specified, vibration monitors shall be supplied and calibrated in accordance with API Std 670.	This paragraph is applicable. In addition, a key phasor shall be provided with the associated monitoring system based on non contact vibration probes.
3.4.2.4 Unless otherwise specified, hydrodynamic radial bearings shall be fitted with bearing-metal temperature sensors installed in accordance with API Std 670. The Purchaser will specify the type of detector.	This paragraph is not applicable. Expander-compressors are equipped with active magnetic bearings.
• 3.4.2.5 When specified, hydrodynamic thrust bearings shall be fitted with bearing-metal temperature sensors installed in accordance with API Std 670. The Purchaser will specify the type of detector required.	This paragraph is not applicable. Expander-compressors are equipped with active magnetic bearings. Each journal bearing shall be provided with dual temperature detection and associated monitoring system consisting of two RTD embedded in the most loaded pad (one main and one spare), both being wired up to a skid battery limit junction box or up to the UCP terminal when the latter is integrated in the skid.
• 3.4.2.7 When specified, a bearing temperature monitor shall be supplied and calibrated in accordance with API Std 670.	This paragraph is not applicable. Expander-compressors are equipped with active magnetic bearings.
3.4.3 Overspeed shutdown system	
3.4.3.1 General	
3.4.3.1.2 When specified, an overspeed shutdown system based on two-out-of three voting logic shall be furnished.	This paragraph is applicable.
3.4.3.4 Permanent strainer	
3.4.3.4.1 When specified, a permanent strainer for installation in a removable spool piece, with an effective free flow area at least twice the cross-sectional area of the expander inlet trip valves shall be furnished by the Vendor. Note: The spool piece is normally provided by the user. Differential pressure indication with a high pressure alarm switch should be provided for the strainer. The strainer should be located upstream of the trip valve.	A permanent suction strainer shall be provided as defined in paragraph 3.5.4 of Chapter 1. These compressor suction strainers shall be designed, fabricated and installed by EPSC Contractor. Nevertheless, Vendor shall approve and endorse the design of each compressor section suction strainer as defined in GS EP MEC 292.

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• 3.4.3.4.2 When specified, the spool piece and differential pressure instrumentation for the permanent strainer shall be provided.	This paragraph is applicable. Refer to paragraph 3.5.4 of Chapter 1 for the design of the spool piece. Note: In addition the spool piece shall be fitted with taping points for methanol injection.
• 3.4.3.5 The Vendor's design shall include a provisions for local manual trip mechanism located near the expander inlet trip valve. Actuation of the manual trip mechanism shall close the trip valve and the variable inlet nozzles. When specified, the Vendor shall furnish the local manual trip mechanism.	This paragraph is applicable.
4. Inspection, testing and preparation for shipment	
4.3 Testing	
4.3.3 Mechanical running test	
• 4.3.3.3.5 When specified, all real-time vibration data as agreed by the Purchaser and Vendor shall be recorded and a copy provided to the Purchaser.	This paragraph is applicable.
• 4.3.3.4.2 When specified, shaft seals shall be removed for inspection following a successful running test. Note: Removal and inspection of some seal types (such as cartridges) may require that the seal be returned to the seal Manufacturer's facility.	This paragraph is not applicable.
• 4.3.5.1 Performance Test	Performance test is required.
4.3.5.1.2 The expander shall be performance tested at the normal U/C ratio, where: U = expander wheel tip speed C = velocity equivalent to the enthalpy drop across the machine. Sufficient points shall be taken to either side of the peak to establish the expander efficiency parabolic curve. The measured efficiency shall be at least 98% of the predicted value. Note 1: The expander U/C ratio is the single most important parameter affecting the machine performance. The typical expander is	Performance test shall be a type 2 as per ASME PTC 10-1997. A minimum of six points, evenly spaced, from stonewall to surge at speed corresponding to the certified point(s), is required. Furthermore, each operating point as specified in the data sheets shall be taken. In addition, the surge line has to be identified from minimum to maximum continuous speed by taking 3 or 4 points. For computation of the performance, Reynolds number correction is not permitted.

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designed to peak at U/C ratio (a dimensionless number) of 0.7. Note 2: It may be necessary to perform corrections to the data such as when the expander U/C ratio and the Q//N ratio cannot be simultaneously met. (Q is the expander outlet volumetric flow rate and N is the normal speed of the machine)	
● 4.3.5.2 Post-test Inspection of Machine Internals The machine shall be dismantled, inspected, and reassembled after satisfactory completion of the mechanical running test. The Purchaser will specify whether the gas test required by 4.3.4 shall be performed before or after the post-test inspection. Note: The merits of post-test inspection of expander-compressor internals should be evaluated against the benefits of shipping a unit with proven mechanical assembly and casing joint integrity.	Gas test shall be performed after the post-test inspection.
● 4.3.5.3 Spare-parts Test Spare parts such as spare center sections, bearings and seal shall be tested, as specified. Note: A mechanical test of the spare center section is mandated in 4.3.3.3.6.	Any spare complete mechanical center section including seals and bearings shall be given a mechanical test as per paragraph 4.3.3.
4.4 Preparation for shipment Preparation for shipment shall be in accordance with 4.4 of Chapter 1 and the following.	Refer to comments to paragraph 4.4 of chapter 1.
5. Vendor's data	
Vendor data shall be provided in accordance with Section 5 of Chapter 1 of this standard and the following.	Refer to comments to Section 5 of Chapter 1.



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Appendix 1

Appendix 1 Data Sheets

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		Titre Principal du Projet				
		Titre Secondaire			Page 1 of 14	
Issuing Dpt	Rev. / Date	1/	2/	3/	4/	5/
Written by :						
CENTRIFUGAL COMPRESSOR AS PER API STD 617					DS EP MEC 252	
1	Specification applicable to :				Site/Unit :	
2	Manufacturer :				Engineering identifier :	
3	Tender reference :				Service frequency :	
4	Compressor model :				Number of machines :	
5	Driver type (3.1.1) :				Driver supplied by :	
6					Compressor manufacturer	
OPERATING CONDITIONS AND PERFORMANCE FOR EACH MACHINE						
7	DUTY REQUIREMENTS					
8						
9	Flowrate, MMSCMD (1.01325 bar abs/15.56°C)					
10	Weight flow, kg/h					
11						
12	<u>Inlet conditions</u>					
13	Pressure at compressor inlet flange, bar abs					
14	Average Temperature, °C					
15	Cp/Cv					
16	Compressibility, Za					
17	Relative humidity, %					
18	<u>Discharge conditions</u>					
19	Pressure at compressor outlet flange, bar abs					
20						
21						
22	<u>Gas handled</u>					
23	Gas analysis, mol %					
24		Molar Weight				
25	C1	16.04				
26	C2	30.07				
27	C3	44.09				
28	IC4	58.12				
29	NC4	58.12				
30	IC5	72.14				
31	NC5	72.14				
32	C6	86.17				
33	C7+	100.19				
34	C8	114.22				
35	C9	128.25				
36	C10	142.27				
37	C11	170.22				
38	H2O	18.02				
39	CO2	44.01				
40	N2	28.02				
41	H2S	34.08				
42						
43						
44						
45						
46						
47						
48						
49						
50						
51						
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57						
58						
59						
COMPANY REFERENCES			SUPPLIER REFERENCES			
			Company :			
			JOB N° :			

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CENTRIFUGAL COMPRESSOR AS PER API STD 617		DS EP MEC 252					
1	DUTY REQUIREMENTS (See page 1)						
2	NUMBER OF RUNNING UNITS						
3	Casing type						
4	Required Flowrate (from page 1), MMSCMD						
5	Required Weight Flow (from page 1), kg/h						
6	Recycle Flowrate (if any), kg/h						
7	Compressor Flowrate, kg/h						
8	<u>Inlet conditions</u>						
9	Pressure at compressor inlet flange, bar abs						
10	Temperature, °C						
11	Relative humidity, %						
12	Molar weight, g/mole						
13	Cp/Cv						
14	Compressibility, Za						
15	Inlet volume flow, m3/h						
16	<u>Discharge conditions</u>						
17	Pressure at compressor outlet flange, bar abs						
18	Temperature, °C						
19	Cp/Cv						
20	Compressibility, Zr						
21	Outlet volume flow, m3/h						
22	<u>Performance</u>						
23	Balance line leakage rate, kg/min						
24	Absorbed gas power per section, kW						
25	Power absorbed at end of compressor shaft, kW						
26	Total absorbed power at end of driver shaft, kW						
27	Speed, rpm						
28	Polytropic head, kJ/kg						
29	Polytropic efficiency, %						
30	Flow at stone wall, m3/h (at speed above)						
31	Flow at surge, m3/h (at speed above)						
32	Guarantee (certified) point						
33							
34	DUTY REQUIREMENTS (See page 1)						
35	NUMBER OF RUNNING UNITS						
36	Casing type						
37	Required Flowrate (from page 1), MMSCMD						
38	Required Weight Flow (from page 1), kg/h						
39	Recycle Flowrate (if any), kg/h						
40	Compressor Flowrate, kg/h						
41	<u>Inlet conditions</u>						
42	Pressure at compressor inlet flange, bar abs						
43	Temperature, °C						
44	Relative humidity, %						
45	Molar weight, g/mole						
46	Cp/Cv						
47	Compressibility, Za						
48	Inlet volume flow, m3/h						
49	<u>Discharge conditions</u>						
50	Pressure at compressor outlet flange, bar abs						
51	Temperature, °C						
52	Cp/Cv						
53	Compressibility, Zr						
54	Outlet volume flow, m3/h						
55	<u>Performance</u>						
56	Balance line leakage rate, kg/min						
57	Absorbed gas power per section, kW						
58	Power absorbed at end of compressor shaft, kW						
59	Total absorbed power at end of driver shaft, kW						
60	Speed, rpm						
61	Polytropic head, kJ/kg						
62	Polytropic efficiency, %						
63	Flow at stone wall, m3/h (at speed above)						
64	Flow at surge, m3/h (at speed above)						
65	Guarantee (certified) point						
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1	MACHINE LOCATION				
2	Indoor :	☐	Heated :	☐	Unheated :
3	Outdoor :	☐	Without roof :	☐	Under roof :
4	Grade :	☐	Concrete base :	☐	Platform :
5			Winterisation :	☐	Tropicalisation :
6	SITE DATA				
7	Elevation :		Atmospheric Pressure :		
8	Normal temperature :		Minimum temperature :		Minimum temperature :
9					
10	NOISE SPECIFICATION				
11	Required noise level :		Proposed :		Acoustic housing required :
12	Specif n° :		Applicable to machine :		Applicable to neighbourhood :
13	PAINT				
14	According to Attachment E :		Supplier's standard (1) :		Other :
15					
16	SHIPMENT				
17	Domestic :	☐	Export :	☐	Export boxing required :
18	Outdoor storage for more than 6 months :				
19	one spare rotor :		Packaged for horizontal storage :		Vertical storage :
20					
21	ELECTRICAL AREA CLASSIFICATION				
22	Zone :		Group :		Temperature :
23	VALVES				
24	- Inlet :	☐	Paddle blank :	☐	Shut-off valve :
25	- Discharge :	☐	ESDV :	☐	Shut-off valve :
26			Blowdown valve :	☐	Paddle blank :
27					
28	SAFETY RELIEF VALVE				
29		supplied by :			
30	Stage N°				
31	Identification				
32	Manufacturer				
33	Model				
34	Rated pressure				
35	Connections: Inlet				
36	Exhaust				
37					
38	CASING				
39	Section				
40	Inlet/Discharge				
41	Connections				
42	Diameter				
43	Rating				
44	Facing				
45	Position				
46	Gas velocity at certified point m/s (2)				
47	Piping class				
48	Allow. forces/moments(3)				
49	Axial : Force, N				
50	Moment, Nm				
51	Vertical: Force, N				
52	Moment, Nm				
53	Others connections				
54	Individual stage drains required :		Valved and blinded:		
55	Valved and blinded and manifold:				
56					
57					
58	(1):	Refer to the Project Specification			
59	(2):	In case of several certified points, gas velocity to the maximum flow shall be indicated.			
60	(3):	The maximum allowable forces and moments on inlet and discharge flanges shall not be less than five times the values calculated according to NEMA-SM23 (refer to GS EP MEC 251 paragraph 2.3.4.1)			
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CENTRIFUGAL COMPRESSOR AS PER API STD 617				DS EP MEC 252	
1	PROCESS CONTROL				
2	Required flow variation :				
3	Method :	Suction throttling:	from to bar abs	Vanes :	
4	Speed variation :		from to %	Discharge blowoff :	
5	Recirculation :		from to Rated flow;	Piping supplied by :	
6	Recirculation valve supplied by :		Valve type :		Make :
7	Parameter to be monitored				
8	Type de signal	Electronic :	pneumatic :	Other :	
9	Signal type :				
10	Anti-surge device : Type		Anti-surge per casing :		per section :
11	Piping supplied by :		Valve supplied by :		
12	Valve type :		Make :		
13	CONSTRUCTION FEATURE				
14	ROTORDYNAMICS				
15	Train lateral analysis required (2.6.2, 2.6.2.6 & 2.6.2.14): ☐				
16	Undamped stiffness map required (2.6.2.4): ☐				
17	Train torsional analysis required (2.6.7.1): ☐				
18		1st Casing	2nd casing	3rd casing	
19	Driver rated speed (100%), rpm				
20	Driver maximum continuous speed (MCS), rpm				
21	Compressor minimum operating speed (MOS), rpm				
22	Compressor rated speed (100%), rpm				
23	Compressor maximum continuous speed, rpm				
24	Gear ratio				
25	Impeller maximum diameter, mm				
26	Maximum tip speed, m/s at 100% speed				
27	Maximum tip speed, m/s at maximum continuous speed				
28	Rotor weight, kg				
29	FULTON & KIRK DONALD DIAGRAMS				
30	NC1, rpm				
31	MCS/NC1				
32	Gas mean density, kg/m ³				
33	P x Delta P, bar ²				
34	CAMPBELL DIAGRAM				
35	1st critical speed, RPM				
36	Log. Decrement				
37	Amplification factor, AF				
38	Required separation margin, RSM				
39	Actual separation margin, ASM				
40	2nd critical speed, RPM				
41	Log. Decrement				
42	Amplification factor, AF				
43	Required separation margin, RSM				
44	Actual separation margin, ASM				
45	3rd critical speed, RPM				
46	Log. Decrement				
47	Amplification factor, AF				
48	Required separation margin, RSM				
49	Actual separation margin, ASM				
50	1st and 2nd natural frequencies at 100% speed				
51	1st natural frequency at 100% speed, cpm				
52	Log. Decrement				
53	2nd natural frequency at 100% speed, cpm				
54	Log. Decrement				
55	Stability diagram (Stability analysis API617 - Level 1)				
56	Aerodynamic cross coupled stiffness (Q _A), 10 ⁻⁶ N/m				
57	Corresponding (including Q _A) Log. Decrement				
58	Corresponding (including Q _A) frequency, cpm				
59	Stability margin (Q ₀ /Q _A)				
60					
61					

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		CENTRIFUGAL COMPRESSOR AS PER API STD 617		DS EP MEC 252
1	COMPRESSOR CASING			
2	Model			
3	Casing split (horizontally versus vertically)			
4	Casing arrangement (in line versus back to back for 2 sections)			
5	Material			
6	Maximum allowable working pressure, bar abs			
7	Test pressure: hydro, bar abs			
8	Design temperature, °C			
9	Maximum number of impellers			
10	Maximum flow at inlet, m ³ /h			
11	Maximum depressurization rate, bars/min			
12	Number of O-rings			
13	Maximum allowable O-ring temperature			
14	Number of stage drains			
15	Suction and discharge volute drains			
16	DIAPHRAGMS			
17	Material			
18	Maximum differential pressure at MCS and surge point, bar			
19	SHAFT			
20	Type of shaft (cylindrical, scalloped, ...)			
21	Shaft length, mm			
22	Shaft bearing diameter, mm			
23	Shaft diameter under impellers, mm			
24	Shaft diameter at coupling, mm			
25	Shaft bearing span, mm			
26	Material			
27	Shaft end (tapered/cylindrical)			
28	Minimum yield strength, MPa			
29	Hardness (HB, HR)			
30	Torque stress at coupling at certified point, MPa			
31	Maximum transmissible power at MCS, kW			
32	Direction of rotation, viewed from driven end			
33	BALANCE PISTON			
34	Material			
35	Fixation method			
36	Maximum differential pressure at MCS and surge point, bar			
37	Shunt Holes / Swirl Brakes provided: Yes/No			
38	Leakage at certified point, kg/min			
39	Cavity drain			
40	Pressure connections for delta P			
41	Flange orifice in balance line			
42	CENTRAL BALANCE PISTON (if any)			
43	Material			
44	Maximum differential pressure at MCS and surge point, bar			
45	Shunt Holes / Swirl Brakes provided: Yes/No			
46	Leakage at certified point, kg/min			
47				
48				
49				
50				
51				
52				
53				
54				
55				
56				
57				
58				
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		CENTRIFUGAL COMPRESSOR			DS EP MEC 252
		AS PER API STD 617			
1	IMPELLERS		1st casing	2nd casing	3rd casing
2	Configuration: in-line, back-to-back				
3	Number of impellers				
4	SHAFT SLEEVES				
5	Interstage - material				
6	At seals - material				
7	LABYRINTHS				
8	Interstage: type				
9	Interstage: material				
10	Balance piston seal: type				
11	Balance piston seal: material				
12	RADIAL BEARINGS				
13	Type				
14	Manufacturer				
15	Normal (Damped not allowed)				
16	Maximum allowable load, daN/cm ²				
17	Effective load, daN/cm ²				
18	Number of pads				
19	Lubrication type (Flooded / Directed)				
20	L/D ratio				
21	Bearing clearance (min/max), %				
22	Geometrical preload (min/max)				
23	Pivot Offset (50% centered), %				
24	2 RTDs in each radial bearing				
25	THRUST BEARING				
26	Type				
27	Manufacturer				
28	Maximum residual axial load according to API 617 chapter 2, section 2.7.3.3, N/cm ²				
29	Thrust Bearing Maximum allowable load, N/cm ²				
30	Number of pads				
31	Thrust collar: integral/replaceable				
32	Method of fixing onto shaft				
33	Diameter, mm				
34	Location, outside/between bearings				
35	4 RTDs, 2 in active, 2 in inactive pads				
36					
37	Materials inspection requirements : Refer to Project Specification				
38	Impact strength tests :		Radiography required for : (Note:7)		
39	Magnetic particle inspection required for : (Note:7)		Liquid penetrant required for : (Note:7)		
40					
41	Gearbox :	Manufacturer :	Type :	Gear ratio :	
42		Maximum power, kw :	According to API 613 : X	Service factor :	
43					
44	NOTES				
45					
46	Magnetic bearings	Account taken of corresponding job specification sections :			
47		Proposal and corresponding calculations in tender N° dated			
48		Section n° :			
49					
50					
51					
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		CENTRIFUGAL COMPRESSOR AS PER API 617				DS EP MEC 252				
1	IMPELLER	Position :	1	2	3	4	5	6	7	8
2	Type (2D, 3D, "Wedge")									
3	Name									
4	Diameter D ₂ , mm									
5	Impeller exit width, b ₂ , mm									
6	Diffuser width at start of // edges, b ₃ , mm									
7	b ₃ /b ₂									
8	Following data at certified point (3)									
9	Tip speed at maximum continuous speed, m/s									
10	Impeller tip Mach Number (machine Mach Number) (1)									
11	Impeller inlet relative Mach number (2) - Criteria 0.95									
12	Inlet density, kg/m ³									
13	Discharge density, kg/m ³									
14	Pressure rise per stage, bar									
15	Power, kW									
16	Flowrate coefficient (4):	at certified point (3):								
17		at curve left (surge) limit:								
18		at curve right (stone-wall) limit:								
19	Head coefficient (5):	at certified point (3):								
20		at curve left (surge) limit:								
21		at curve right (stone-wall) limit:								
22	Polytropic Efficiency:	at certified point (3):								
23		at curve left (surge) limit:								
24		at curve right (stone wall) limit:								
25	Critical angle according to Senoo (6)		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
26	Critical angle according to Kobayashi - Nishida (7)		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
27	Diffuser type, vanes, vaneless, LSV									
28	Critical angle at certified point:									
29	Impeller exit flow angle versus tangential									
30	Diffuser inlet flow angle versus tangential									
31	Margin / Senoo critical angle (for information)		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
32	Margin / Kobayashi-Nishida critical angle (criteria) (8)		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
33	Critical angle at surge conditions (left limit):									
34	Impeller exit flow angle versus tangential									
35	Diffuser inlet flow angle versus tangential									
36	Margin / Senoo critical angle (for information)		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
37	Margin / Kobayashi-Nishida critical angle (criteria) (8)		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
38	Material									
39	Rockwell C hardness									
40	Construction method									
41	Minimum Yield strength, MPa									
42	Maximum stress at max. continuous speed, MPa									
43	Maximum stress at impeller bore, MPa									
44	Fixing method onto shaft									
45	Minimum interference fit, o/oo									
46	Maximum interference fit, o/oo									
47	Impeller overspeed, rpm (9)									
48	Maxi stress at impeller bore during impeller OS, MPa									
49	(1) Tip speed divided by average sonic speed at impeller inlet									
50	(2) Relative speed at impeller eye leading edge divided by impeller eye sonic speed. In any case this Mach number at inlet conditions shall not exceed 0.95									
51	(3) In case of several certified points, the most centered inside the compressor operating field map shall be considered.									
52	(4) Flowrate coefficient = $4 \cdot Q_0 / (\pi \cdot D_2^2 \cdot U_2)$ (m ³ /s)/(m ²)·(m/s)									
53	(5) Head coefficient = H_p / U_2^2 (m/s)									
54	(6) Senoo angle = $105,91 \cdot \sqrt{2 \cdot b_3 / D_2} - 117,27 \cdot (2 \cdot b_3 / D_2) - 8,18$. Refer to GS EP MEC 251 Chapter 1, paragraph 2.1.1.1)									
55	(7) Nishida angle = Senoo angle + $(17,02 - 148,4 \cdot b_3 / D_2) \cdot (1 - b_3 / b_2)$. Refer to GS EP MEC 251 Chapter 1, paragraph 2.1.1.1)									
56	(8) The flow angle shall be greater or equal to Nishida critical angle. Refer to GS EP MEC 251 Chapter 1, paragraph 2.1.1.1)									
57	(9) The overspeed shall be at least equal to MCSx1.15 and shall cover the impeller bore stresses due to maximum interference fit refer to GS EP 251 (Refer Chapter 1, para. 4.3.3.1)									

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		CENTRIFUGAL COMPRESSOR		DS EP MEC 252	
		AS PER API STD 617			
1	SHAFT SEALS	Required	1st casing	2nd casing	3rd casing
2	Seal type	Self active gas seal			
3	Settling out pressure, bar abs				
4	Self Active Dry Gas Seals				
5	Type	Tandem			
6	Manufacturer				
7	Model				
8	Unidirectionnal / Bidirectionnal	Unidirectional			
9	Max allowable pressure, bar abs				
10	Tip speed at MCS, m/s				
11	Tip speed at 100% speed, m/s				
12	Operating temperature/max allowable temp., °C				
13	Materials: Stationary seal seat				
14	Rotating seat				
15	O-rings, material				
16	Maximum initial depressurization rate, bar/min				
17	Inboard Seal				
18	Seal gas	Process gas			
19	Take-off connection				
20	Feed pressure, bar a				
21	Sealing gas flow, kg/h				
22	Filtration level, µm	Yes			
23	Double gas filter type	Yes, Coalescer			
24	Switchable in operation	Yes			
25	Scrubber, cyclone separator type	Yes			
26	Automatic purge valve	Yes			
27	Piping, duplex filter, scrubber material	AISI 316L			
28	Heater				
29	Dual type pressure amplifier (Booster)				
30	Gas leakage guarantee at rated conditions:				
31	Flow per seal, Nm3/h				
32	Max. allowable primary vent back pressure, barg				
33	Outboard Seal				
34	Seal Gas	Nitrogen			
35	Min/Max available pressure, bar abs				
36	Temperature, °C				
37	Buffer gas flow per seal : Normal, Nm3/h				
38	Max, Nm3/h				
39	Supply Pressure (Normal/Design), barg				
40	Separation Seal				
41	Type	Labyrinth			
42	Separation Gas	Air			
43	Flow per seal: Normal, Nm3/h				
44	Max, Nm3/h				
45	Supply Pressure (Normal/Design), barg				
46	Filtration, µm				
47	Automatic trap mechanism				
48	Drain with sight glass				
49	Max. allowable secondary vent back pressure, bar				
50	Piping, duplex filter material	AISI 316L			
51					
52					
53					
54					
55	NOTES				
56	VENDOR to assess hydrate formation in the gas supply lines and provide appropriate devices to prevent them. Refer to GS EP MEC 281.				
57					

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CENTRIFUGAL COMPRESSOR				DS EP MEC 252		
AS PER API STD 617						
1	OIL SYSTEM (Refer Oil System D/S also)					
2	LUBRICATION :	API 614 diagram n° :				
3	Flowrate :		Working pressure :		Power to evacuate :	
4	Lubrication common to :	Compressor(s) :	X	Gearbox :	X	Driver :
5	Oil tank :	API 614 diagram n° :				
6		Separate :		Integral with frame :	X	
7		conforming with API 614 :		Manufacturer's standard :	X	
8		Material :		Oil type :		Capacity :
9		Oil consumption(at 8000h/year) :				liters
10	Removable strainer on filling hole :					
11	Plugged drain out of skid :	X				
12	Level gauge :	X				
13	Temperature gauge :	X				
14	Temperature limit switch :	X				
15						
16	Oil tank vent with :	Mist eliminator :	X			
17		Flame arrestor :	X			
18		Screen :	X			
19		Rain guard :	X			
20	Oil heating	Electrical with thermostat :	X	Explosion proof :	X	Steam :
21	Oil pump(s) :	API 614 diagram n° :				
22		Design flowrate :		Design pressure :		bar
23	- Main pump	Driven by electric motor :		Gas-Turbine driven :		
24	Driver manufacturer :		Type :		Speed :	rpm
25	Pump manufacturer :		Type :		Speed :	rpm; Flow :
26	- Standby pump	Driven by electric motor :	X	Steam turbine :		
27	Driver manufacturer :		Type :		Speed :	rpm
28	Pump manufacturer :		Type :		Speed :	rpm; Flow :
29	- Emergency pump	Driven by electric motor :	X	Steam turbine :		
30	Driver manufacturer :		Type :		Speed :	rpm
31	Pump manufacturer :		Type :		Speed :	rpm; Flow :
32	Relief valves :					
33		Manufacturer :		Type :	Relief press., bar g	
34	Accumulator :	API 614 diagram n° :				
35		Manufacturer :		Type :		Volume :
36		Material :		Design pressure :		bar g; Constr. code :
37	Oil filter(s) :	API 614 diagram n° :				
38		Manufacturer :		Type :	Filtration :	µm
39		Single :		Double :	X	Switchable in operation :
40		Construction code :		Design pressure :		bar g; Max allow. diff. pressure :
41	Material :			Filter casing :		
42	Oil cooler :	API 614 diagram n° :				
43	- Air cooler	Electric motor :	X	Hydraulic transmission :		
44		Common with gas cooling :		On compressor skid :		On separate frame :
45					X	
46	Materials :	Headers :	AISI 316L	Tubes :	AISI 316L	Fins (1) :
47						
48	(1) If Offshore or coastal Installation, fins made with Aluminium shall use Marine Aluminium grade 5000 or 6000 as per ASTM					
49						
50						
51						
52	Transfer valves	- filters and coolers :	Manufacturer :		Type :	
53			Material :			
54	Feeder tank	- for oil tank auto feed :		Supplied by Manufacturer :		
55		Capacity :		Material :		
56	Rundown tank :	API 614 diagram n° :				
57		Supplied by Manufacturer :		capacity :		liters
58	Oil circuit :	Piping material upstream filters :	AISI 316L	Downstream filters :	AISI 316L	
59		Return :				
60		Prefabricated link pipes :	X	Manufacturer's responsibility :	X	
61						

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CENTRIFUGAL COMPRESSOR				DS EP MEC 252	
AS PER API STD 617					
1 VIBRATION DETECTORS					
- Non contacting probe : ☒ Type : PROX. Model : Manufacturer :					
Location : Compressor : ☒ Gearbox : ☒ Driver : ☒					
N° per bearing : Total : Proximitor supplied by : VENDOR					
Monitor supplied by : VENDOR					
Location : TCP Degree of protection :					
Alarm at : µm SD at : µm Time delay : s					
- Accelerometer : Type : Model :					
Manufacturer : Number : Location :					
Monitor supplied by : VENDOR Location : TCP Degree of protection :					
Model :					
Alarm at : mg Shut Down at : mg Time delay : s					
Keyphasor : ☒					
15 AXIAL POSITION DETECTOR					
Type : PROX. Model : Manufacturer : Number :					
Location : CONTROL PANEL					
Proximitor supplied by : VENDOR					
Monitor supplied by Vendor : ☒ Location : TCP Degree of protection :					
Model :					
Alarm at : mm Shut Down at : mm					
23 BEARING TEMPERATURE DEVICES					
Thermocouples :					
Resistance temp. probe : ☒ Type : Resistance material : Platinum Resistance : Ohm					
Location, radial bearings number per bearing :					
Location, thrust bearing Active side, number :					
Inactive side, number :					
Other locations : Electric motor bearings :					
Gearbox thrust bearing : Active side :					
Inactive side :					
Monitor supplied by Vendor : ☒ Location : TCP Degree of protection :					
Manufacturer : Model :					
Alarm at : °C Shut-Down at : °C					
38 COUPLINGS AND GUARDS (Refer the Coupling Data sheets as enclosed)					
Coupling between					
Compliant with API 671 ☒					
Coupling supplied by					
Manufacturer					
Type/model					
Coupling guard: material					
Hub weight, daN					
Spacer length, mm					
Spacer weight, daN					
Max allowable torque, kW/rpm					
Manufacturer mount half coupling : ☒					
Coupling idling adapter :					
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AS PER API STD 617					
1 SHOP INSPECTION AND TESTS		MOUNTING PLATES			
		Required	Witnessed	Proposed	
2					Baseplate supplied Comp. Manuf.: ☒
3					Baseplate under compressor: ☒
4	Shop inspection	☒			Under driver: ☒
5	Cleanliness	☒			Under gear: ☒
6	QA plan review	☒			Common (compressor - driver): ☐
7	Hydrostatic test (4.3.2)	☒	☒		Other: ☐
8	Rotor balance (1)	☒	☒		Bolted: ☒ 3 points: ☐
9	Impeller overspeed test (4.3.3)	☒	☒		Drip stone: ☐ Ref pads: ☒
10	Mechanical test (Chap. 1 - 4.3.6 & Chap. 2 - 4.3.1)	☒	☒		Shims: ☒
11	Contract coupling (Chapter 2 - 4.3.1.1.7)	☒			Stainless steel shims (mm): ☒
12	Contract vibration sensors (Chapter 2 - 4.3.1.1.8)	☒			Primer: ☐
13	Vary seal and lube oil T° & Pr. (Chap. 1 - 4.3.6.1.5)	☒			(If epoxy resin coated) type ☐
14	Polar form vibration data (Chap. 1 - 4.3.6.1.2)	☒			Sole plates: Not allowable
15	Tape record vibration data (Chap. 1 - 4.3.6.1.3)	☒			WEIGHT (daN)
16	Vibration behaviour (Chapter 2 - 4.3.1.3)	☒	☒		Compressor(s): ☐
17	Seals and bearings inspection (Chap. 1 - 4.3.6.2)	☒	☒		Gear: ☐ Driver: ☐
18	Gas leakage test (Chapter 2 - 4.3.2)	☒	☒		Base: ☐ Complete unit: ☐
19	Performance tests (Chapter 2 - 4.3.3.1)	☒	☒		Rotors: Compressor: ☐
20	Full pressure/Full load/Full Speed Test (Chap. 1-4.3.8.6)	☒ (2)	☒		Driver: ☐ Gear: ☐
21	PTC 10 Type I string test (Chapter 2 - 4.3.3.1)	☒	☒		Compressor upper casing: ☐
22	Dry seal test	☒	☒		Sour seal oil tank: ☐
23	Torsional & Lateral vibration (Chap. 2 - 4.3.1.3)				Seal oil console: ☐
24	Tandem test (Chapter 2 - 4.3.3.3)				Lube oil console: ☐
25	Gear test (Chapter 2 - 4.3.3.4)	☒	☒		Overhead seal oil tank: ☐
26	Helium sealing test (Chapter 1 - 4.3.8.2)				Heaviest service part: ☐
27	Sound level test (Chapter 1 - 4.3.8.3)	☒	☒		Heaviest assembly part: ☐
28	Assembling couplings inspection	☒	☒		Total shipping weight: ☐
29	Certified copies of test data	☒			DIMENSIONS (m)
30	Parachute test (if A.M.B. "m")				
31	*** Active Magnetic Bearings				
32	High density test per PTC 10 Type II				
33					
34					
35					
36	OTHERS				
37	Recommended straight run of pipe before suction (m): ☐				Provision for liquid injection: ☐
38	Purchaser's piping and foundation: ☐				Compressor field start-up on air: ☐
39	Supply of control system: ☒				Extent of process piping supplied: ☐
40	Welding hardness tests: ☒				Auxiliary motors explosion proof: ☐
41	All piping within skid limit: ☒				Special tools: ☒ Jack screws: ☒
42	First oil fill supplied: ☐				Spare parts: emergency & startup: ☒ 1 year: ☐ 2 years: ☒
43	Responsibility for complete shaft line taken by Manufacturer of: Compressor				
44	Temporary filter at compressor inlet: ☒				
45	Lifting accessories: ☒				
46	Handling devices for maintenance: ☒				
47	NOTES:				
48					
49	(1): As per API 617 Annex 1B - Rotor balance shall be performed at low speed and checked only at high speed.				
50					
51	(2): As per GE EP MEC 030 and GS EP MEC 031				
52					
53					
54					
55					
56					
57					
58					
59					
60					
61					

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		CENTRIFUGAL COMPRESSOR							
		AS PER API STD 617							
1	Minimum instrumentation required :								
2									
3									
4									
5									
6	<u>Oil system</u>								
7									
8	Oil tank level	yes				AL+SD		AL+SD	
9	Oil tank temperature	yes				AL+SD		AL+SD	
10	Oil pump discharge pressure	yes				AL		AL	
11	Temperature upstream of cooler	yes							
12	Temperature downstream of cooler	yes				AL+SD		AL+SD	
13	Oil filter differential pressure	yes				AL		AL	
14	Accumulator pressure	yes				AL		AL	
15	Bearing inlet pressure	yes				I+AL+SD		I+AL+SD	
16	Bearing inlet temperature	yes							
17	Bearing outlet flow	yes							
18	Bearing outlet temperature	yes							
19	Rundown tank level	yes							
20									
21									
22									
23	<u>Seal system</u>								
24	- Oil								
25	Oil tank level								
26	Tank oil temperature								
27	Pump discharge oil pressure								
28	Temperature upstream of cooler								
29	Temperature downstream of cooler								
30	Filter differential pressure								
31	Overhead tank level								
32	Overhand tank pressure								
33	Trap levels								
34	Clean oil outlet flow								
35	Sour oil outlet flow								
36									
37									
38	- Gas (see appended schematic)								
39									
40	Feed gas filter differential pressure	yes				AL		AL	
41	Leak pressure, first seal	yes				AL+SD		AL+SD	
42	Buffer gas flowrate	yes							
43	Buffer gas filter differential pressure	yes							
44	Buffer gas differential pressure	yes							
45	Vent gas detection					AL+SD		AL+SD	
46	Feed air filter differential pressure	yes				AL		AL	
47	Separation air differential pressure	yes				AL+SD		AL+SD	
48									
49									
50									
51									
52									
53									
54									
55									
56									
57	AL = ALARM								
58	SD = SHUTDOWN								
59	MC = MAINTENANCE COMPUTER								
60	I = INDICATION								
61	DCS = DIGITAL CONTROL SYSTEM								
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		CENTRIFUGAL COMPRESSOR AS PER API STD 617							
1	INSTRUMENTATION								
2		LOCAL ON MACHINE		LOCAL PANEL		CONTROL CABINET		TRANSFERRED TO DCS	
3		Required	Proposed	Required	Proposed	Required	Proposed	Required	Proposed
4									
5	Compressor					I+AL+SD		I+AL+SD	
6	Bearing temperatures					I+AL+SD		I+AL+SD	
7	Thrust bearing temperatures, active side					I+AL+SD		I+AL+SD	
8	Thrust bearing temperatures, non active side					I+AL+SD		I+AL+SD	
9	Vibrations (x,y)					I+AL+SD		I+AL+SD	
10	Axial displacements					I+AL+SD		I+AL+SD	
11	Keyphasor					I		I	
12									
13									
14	Driver and gear								
15	Bearing temperatures					I+AL+SD		I+AL+SD	
16	Thrust bearing temperatures, active side					I+AL+SD		I+AL+SD	
17	Thrust bearing temperatures, non active side					I+AL+SD		I+AL+SD	
18	Vibrations (x,y)					I+AL+SD		I+AL+SD	
19	Axial displacements					I+AL+SD		I+AL+SD	
20									
21									
22									
23									
24	Cooling water								
25	Water temperature upstream of cooler								
26	Water temperature downstream of cooler								
27	Expansion vessel level								
28	Pump discharge pressure								
29									
30									
31									
32									
33	Gas								
34	Inlet pressure	yes				I+AL+SD		I+AL+SD	
35	Inlet pressure/section	yes				I+AL+SD		I+AL+SD	
36	Inlet temperature/section	yes				I		I	
37	Discharge pressure/section	yes				I		I	
38	Discharge temperature/section	yes				I+AL+SD		I+AL+SD	
39	Discharge pressure	yes				I		I	
40	Separator level	yes							
41									
42									
43									
44									
45									
46									
47									
48									
49									
50									
51									
52									
53									
54									
55									
56	AL = ALARM								
57	SD = SHUTDOWN								
58	MC = MAINTENANCE COMPUTER								
59	I = INDICATION								
60	DCS = DIGITAL CONTROL SYSTEM								
61									

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CENTRIFUGAL COMPRESSOR AS PER API STD 617				DS EP MEC 252	
1	<u>UTILITY CONSUMPTION</u>				
2	<u>Electric motors</u>				
3	Motor description	Voltage	Installed power, kw	Absorbed power, kw	
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23	TOTAL				
24	<u>Heating (electric)</u>				
25	Heater description	Voltage	Installed power, kw	Absorbed power, kw	
26					
27					
28					
29					
30					
31	TOTAL				
32	<u>Steam</u>				
33	Consumer description	Consumption, kg/h	Pressure, bar g	Temperature, °C	
34					
35					
36					
37					
38					
39	TOTAL				
40	<u>Cooling water</u>				
41	Consumer description	Flow, m³/h	Inlet Temp., °C	Outlet Temp., °C	Inlet press., bar g
42					
43					
44					
45					
46					
47					
48	TOTAL				
49	<u>Air</u>				
50	Consumption :		Nm³/h;	Required pressure : bar g	
51	<u>Nitrogen</u>				
52	Consumption :		Nm³/h;	Required pressure : bar g	
53					
54	NOTES :				
55					
56					
57					
58					
59					
60					
61					

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