



Exploration & Production

GENERAL SPECIFICATION

ROTATING MACHINERY

GS MEC 251

Supply of Axial and Centrifugal Compressors and Expanders for Petroleum, Chemical and Gas Service Industries According to API Standard 617

02	10/04	Revision
01	08/03	Change of Group name and logo
00	11/01	First issue
Rev.	Date	Notes



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1. Scope

This specification clarifies how to use the recommendations of [API 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 617](#) standard seventh edition, July 2002.

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

The paragraph numbering is identified in the same way as in [API 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 617](#) shown with a bullet.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
API Standard 617	Axial and Centrifugal Compressors and Expander-Compressors for Petroleum, Chemical and Gas Industry Services
ASTM A240	Standard Specification for Chromium and Chromium-Nickel Stainless Steel Sheet, and Strip for Pressure Vessel and General Applications.
ASME PTC 10-1997	Test Code for Compressors and exhausters.
ISO 5167	Measurement of fluid flow by means of pressure differential devices
ISO 5389	Turbo compressors, Performance Test Code
ISO 8068	Petroleum lubricating oil for turbines.

Professional Documents

Reference	Title
	Refer to document called by API 617

Regulations

Reference	Title
94/9/EC (ATEX 100a ¹ /ATEX 95 ²)	European Directive 94/9/EC (23/03/94) on the approximation of the laws of the Member State concerning equipment and protective systems intended for use in potentially explosive atmosphere
1999/92/EEC (ATEX 118 ¹ /ATEX 137 ²)	European Directive 1999/92/EEC (16/12/99) on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
DS MEC 251	Centrifugal compressor as per API 617, data sheet
GS MEC 101	Power margin
GS MEC 281	Lubrication, shaft sealing and control oil systems for special-purpose applications
GS MEC 290	Rotating Machine Packages
GS PVV 112	Piping material classes
GS INS 101	Instrumentation, engineering, supply and construction general requirements.
GS EXP 101	Precommissioning and commissioning specification

¹ Reference to Articles 100/118 of the Treaty of Rome

² Reference to Articles 95/137 of the Treaty of Amsterdam

3. Comments to API 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 617 shall be used, subject to the following:
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 must 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 must be expressed in Million Standard Cubic Meter per Day, in MMSCMD, (15°C and 101,325 Pa).
1.5.55 One single shaft centrifugal compressor casing may consist of several	

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sections, each section including several stages, each stage consisting of one impeller and one diffuser 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 job 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 Job 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.	VENDOR shall provide with the offer all aerodynamics data respective to each stage, as indicated in the COMPANY data sheet DS MEC 251. At surge conditions, for vaneless diffusers, VENDOR shall ensure a minimum margin of 5° versus Senoo critical angle, calculated as above: α SENOO PREDICTIVE REVERSE FLOW ANGLE

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	$= 105.91(b_2/r_2)^{1/2} - 117.27(b_2/r_2) - 8.18$ and a minimum margin of 7° versus Nishida critical angle calculated as above : $\alpha_{\text{NISHIDA CRITICAL ANGLE}} = \alpha_{\text{SENOO PREDICTIVE REVERSE FLOW ANGLE}} + (17.02 - 74.2 b_2/r_2) (1 - b_3/b_2)$ 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. VENDOR shall provide with the offer all required data as clearly indicated in COMPANY data sheets for each impellers, including: - The non-dimensional flow and head coefficient, polytropic efficiency and Mach number, at rated, best efficiency point, surge and 120% of rated flow. - A list of references of each aerodynamic. The data sheet DS 251 MEC shall be informed with the corresponding data. In all cases, the Mach number shall not exceed 0.85 at any location of the impellers. Mach number is defined as being the ratio between the local gas velocity divided by the local sound velocity.
2.1.1.2 The PURCHASER will specify the conditions for the equipment's normal operating points	Refer to Job Specification Data Sheets
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.

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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. In addition and unless otherwise specified, 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 arrangement shall consider adequate clearance areas and safe access for operation and maintenance.
• 2.1.8 The equipment including all auxiliaries shall be suitable for operation under the environmental conditions specified 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.	Refer to the Job Specification.
• 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	Control of sound pressure level shall be in accordance to the Job Specification requirement. VENDOR proposal shall include curves of sound power levels as a function of frequency for the specified operating

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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.	conditions.
• 2.1.10 The PURCHASER will advise the VENDOR in the inquiry of any specific requirements for liquid injection.	Refer to the Job 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 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.	Refer to the Job Specification, GS MEC 290 and documents called in this GS.
• 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	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

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upon by the PURCHASER and the VENDOR.	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 Job Specification Data Sheets.
2.2.1.6 Materials exposed to a sour environment (wet H₂S) as defined by NACE MR 01-75 shall be in accordance with the requirements of that standard. Ferrous materials not covered by NACE MR 01-75 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 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.	Cast irons are prohibited if they are in contact or liable to be in contact with gas containing H₂S, irrespective of its concentration. Stainless steels can be used for some parts of equipment. If so, the following requirements and restrictions shall apply: 13% Cr stainless steel shall be heat-treated and have a hardness complying with NACE MR 01-75, Section 3.7. - Austenitic stainless steels and austeno-ferritic steels shall be in the annealed condition. 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 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

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	conform to NACE MR 01-75 and shall be subject to H ₂ S-stress corrosion cracking tests (metallurgical requirements, heat-treatments and threshold stress limit with respect to operating stresses).
• 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 Job Specification.
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	Second sentence of this paragraph is not applicable: VENDOR responsibility.

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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).	
• 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 may not be required.	All compressor 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.
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 prior to any repair.
• 2.3.1.11.2 Accessible surfaces of welds	For welds inaccessible on completion of

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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.	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 and acceptance criteria.	In addition, cast steel casing parts and cast impellers shall be inspected by radiographic means according to ASME VIII, Division 1, and Appendix 7.
• 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 tertiary and secondary mechanical seals. Automatic drainage, if required, during start sequence shall be indicated in the Job Specification. 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.
• 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 Job Specification 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.
2.3.2.3.5.3 Threaded connections shall not be seal welded.	All threaded connections shall be seal welded.

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• 2.3.2.7 The mating flanges including studs and nuts shall be supplied with the machine and bolted respectively to the compressor casing flanges.	This paragraph is applicable
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. 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 propane and sour service applications, a FEA (Finite Element Analysis) shall be provided for each stage.
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.
2.6 Dynamics	
• 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	This paragraph is applicable.

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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.	
2.6.2.4 The damped unbalanced response analysis shall include but shall not be limited 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).	Shall be provided with the offer.

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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 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 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 (add “torsible” flexible 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 VENDORS analysis. e. The support stiffness used in the analysis	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. • Stability diagram at MCS (Log dec versus Cross coupling stiffness) with calculation of the Wachel number per stage. • Stability diagram showing the stability

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and its basis.	margin versus first critical speed over rotational speed ratio.

2.6.5 Level I Stability Analysis

Level I analysis shall also be provided with the offer.

2.6.6 Level II Stability Analysis

Level II shall also be provided with the offer, if required from Level I analysis results.

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• 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	VENDOR shall calculate the response to short-circuit and start-up torques. The results shall be submitted in the form of Campbell diagrams.

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frequency drives.	
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.
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.
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.
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	Sequential low speed balancing shall be performed and followed by a balance check at operating speed under vacuum. If required,

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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.	corrections shall be made at low speed.
• 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.
2.7 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.
2.8 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	An estimated value of the Settle-Out Pressure, S.O.P., when available, is indicated in the Job Specification Data Sheet.

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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.	
● 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.	Unless otherwise specified, shaft end seals shall be of self-acting dry gas seals type, as per paragraph 2.8.4.
● 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.	Unless otherwise specified, nitrogen buffer gas shall be injected between primary and secondary seals to prevent any process gas leak to atmosphere. When Nitrogen is not available on site, refer to the Job specification, VENDOR shall provide the Nitrogen unit as per GS MEC 281.
● 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 including schematic and bill of material.	This paragraph is applicable.

2.8.2 Clearance Seals

Unless otherwise specified, clearance seals are not applicable.

2.8.3 Oil Seals

Unless otherwise specified, oil seals are not applicable.

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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).	Unless otherwise specified, 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. Bi-directional dry gas seals are mandatory (reverse rotation protection and spares reduction). The design of gas seal support system is detailed in GS MEC 281. The design of the seals housing and compressor casing shall be such to allow the installation of a temperature sensing element without disassembly of the bearings and seals housing in order to measure the temperature of the secondary seals. Separation seals shall consist of carbon rings, either constant clearance or lift off type and shall be fed with nitrogen. Cavity downstream primary seals shall be self-draining. Unless otherwise specified, dry gas seal material selection shall be as follows: • Metallic parts: austenitic or duplex stainless steels or Incolloy. • Seal faces: Tungsten or Silicon carbide. Rotating faces shall be contained in an external retaining sleeve. • Dynamic seals: 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. • "O" rings: Elastomer free designed to withstand explosive decompression without any damage.

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	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 secondary 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. Dry gas seals shall be balanced to grade G 2.5 as a minimum, before installation. Cartridges shall be fully interchangeable between both shaft ends.
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 pressurized bearing housings and reservoirs. These details are covered in	Refer also to GS MEC 281, comments to API 614.

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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 MEC 101 , Design and Power margin.
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.	Unless otherwise specified, the driver shall be capable of starting with the specified settle out pressure without any partial or complete process loop depressurization.
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 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 are accepted by COMPANY.
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.	Coupling guards shall be rigid type, non-sparking and tight shut-off. Refer to GS MEC 290 .
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 Standard 671 shall be supplied as part of the special tools ordered by COMPANY.

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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. Shims shall be made of stainless steel ASTM A240 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 VENDOR .
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 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.	For offshore applications, this paragraph is applicable: All equipment of the shaft line shall be mounted on a common single lift baseplate. For onshore applications, all equipment of the shaft line shall be mounted either on a common single lift baseplate or on separate baseplates. In all cases, baseplate shall be designed according to GS MEC 290 and documents called by this GS.
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	In all cases, the design of the baseplate shall conform to requirements.

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continuous grouting. The PURCHASER and the VENDOR shall mutually agree on the baseplate design.	
• 3.3.2.6 When specified, the baseplate shall be designed to facilitate the use of optical, 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.	This paragraph is applicable.
• 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	In all cases, the machine control system shall be designed and provided by VENDOR.

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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.	
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 Job 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.	In case of side stream, such as for refrigeration compressors, each compressor section shall have its own anti-surge protection valve. In case of a multistage compressor with intermediate gas refrigeration, compressor may have one anti surge valve only operated by each section anti surge protection loop through a low level selector. In all cases, the anti-surge control algorithm shall be integrated in the PLC of the unit control panel. Any external anti-surge controller separately provided is not permitted. The anti-surge system shall consist as a minimum of: • Compressor suction flow measuring device with associated taps, flanges and bolts, nuts and gaskets. • Compressor suction flow transmitter. • Compressor suction and pressure transmitters. • Compressor suction and temperature transmitters if required for flow compensation. • Anti-surge valve and associated

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	accessories (refer below). • Low signal selector and bias. Flow measuring devices shall be based on orifice plates with flange taps designed according to ISO 5167. Anti-surge valves shall be designed for critical and severe service in accordance with the COMPANY General Specifications PVV 112 and INS 101. Anti-surge valves 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. Opening time from full close to full open positions shall not be greater than 1 second. Anti-surge valve shall be sized for 100% of the rated flow. VENDOR shall verify that there is no hydrate formation downstream the anti-surge valve and provide all information to COMPANY regarding insulation or heat tracing to prevent hydrates. The compressor discharge volume between the compressor discharge flange and the check valve downstream the gas cooler tie-in point shall be minimized. The anti-surge valve shall not be located at a low location point. Metallurgy of the anti-surge valve shall be in accordance with applicable COMPANY piping class specifications (PVV 112). Anti-surge valve shall be designed fail open by lack of instrument air and power. Anti-surge system transmitters and valve accessories shall be powered from the unit

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	control panel. In automatic mode, it shall not be possible to manually open or close the anti-surge valve. The anti-surge controller shall be designed to accept remote manual control signal. Unless otherwise specified, the anti-surge protection system algorithm shall be based as a minimum on three lines: • The theoretical surge line • The surge protection line • The surge control line. The theoretical surge line as defined on the expected performance curves shall be checked during the shop tests and during the field tests as part of the commissioning acceptance tests. Compressor VENDOR and COMPANY shall jointly define the field test procedures. The surge protection line shall be parallel to the theoretical surge line and set with a margin of 5%. When the compressor operates on this line, the anti-surge valve shall be fully open. The surge control line shall be parallel to the theoretical surge line and set with a margin of 10%. When the compressor starts to operate on this line, the anti-surge valve shall start to open and be on control. Unless otherwise specified, VENDOR shall handle a dynamic simulation, based on actual process volumes. Dynamic simulation study shall cover all operating cases as defined in the job specification, including start-up, shutdown, emergency shutdown. Scenario shall be based on steady state conditions on which perturbations are applied. Those perturbations are typically: closing of discharge and/or suction valves, fast driver speed changes, flow variations caused resulting from upstream or downstream process changes. VENDOR and COMPANY shall mutually agree on the list and content of scenarios to

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	be analyzed. The process design loop shall be such that hot by-pass valve is avoided. This shall be confirmed by the dynamic simulation study. If compressor operation requires that recycle be used, recycling can be performed using the surge valve. If there is a risk of hydrate formation downstream surge valve, VENDOR shall provide all information to COMPANY regarding insulation or heat tracing to prevent hydrates upstream and downstream anti-surge valve.
3.4.3 Instruments and Control Panels Refer to API Std 614 for details on instrument and control panels.	
3.4.4 Instrumentation Refer to API Std 614 for details on instrumentation, and API Std 670 for details on installation	
3.4.5 Alarms and Shutdowns Refer to Chapters 1 and 2 of API Std 614 .	
3.4.6 Electrical systems Refer to Chapters 1 and 2 of API Std 614 .	
3.4.7 Vibrations, position, and bearing temperature detectors Vibration, position and bearing temperature detectors will be covered in 3.4.7 of each subsequent chapter.	
3.5 Piping and appurtenances	
3.5.4 Permanent suction strainer (new paragraph)	Refer to annex 1F. This paragraph is applicable to chapters 2, 3 and 4.
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),	Unless otherwise specified, COMPANY will witness the test as described in paragraph

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the PURCHASER's representative shall have entry to all VENDOR and SUBVENDOR plants where manufacturing, testing, or inspections of the equipment is in progress.	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 extend 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 be measured before and after each over-speed test.all such measurements and the test speed s 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.	Any permanent deformation of the bore or other critical dimensions outside the drawing tolerances shall be cause for rejection.

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4.3.6 Mechanical Running Test	
• 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.	This paragraph is applicable.
• 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 done during the 4-hour test. This option, when specified, does not constitute a waiver of the other specified test requirements.	This paragraph is •
• 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	Unless otherwise specified, compressor casings are not requested to be helium tested.

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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.	
● 4.3.8.3 Sound-level test The sound-level test shall be performed in accordance with PURCHASER requirements.	Unless otherwise specified, 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 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 mechanical running tests, the compressor shall not be dismantled.
● 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 Job 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.

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● 4.3.8.8 Spare-parts test Spare parts such as rotors, gears, diaphragms, bearings and seals shall be tested as specified.	Unless otherwise 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 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.	In addition, all spare rotors and/or bundles shall be provided with N2 pressurized container suitable for several years of storage. This paragraph is applicable to chapters 2, 3 and 4.
● 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 Job 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	A coordination meeting shall be held at the VENDOR's plant within 4 weeks after order commitment.

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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, SUBVENDOR 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, piping and auxiliary systems. Operating and maintenance access areas shall be reviewed. Access for any parts required for maintenance shall be detailed. - Coupling selections and rating. - Thrust- and journal-bearing sizing, estimated loading and specific configurations. - The rotor dynamics analysis (lateral, torsional, and transient torsional, as required). - Machine performance for normal and other specified conditions and other operating conditions, such as start-up, shutdown, and any operating limitations. - Instrumentation and controls. - Items for design reviews. - Other technical items. - Seal operation and controls.	
• 5.1.4 When specified, a design audit/review meeting shall be held at the VENDORS plant	Several meetings at regular intervals for design audit, review and coordination

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within 16 weeks after order commitment. The PURCHASER/OWNER shall prepare and distribute the agenda prior to the meeting.	purposes shall be held at the VENDOR's plant during the life of the order.
5.2 Proposals	
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.
5.2.4.2 Curves and data for fixed speed compressors shall include the following: - Discharge pressure; power; polytropic head; and polytropic efficiency versus capacity (from surge point to 115% rated capacity) at normal speed, indicating the effect of specified molecular weights, suction pressures, and temperatures. Alternate operating conditions requiring throttling shall be shown. - Speed versus torque to overcome friction and windage for the compressor and gear unit, if any, for normal starting conditions for emergency starting (open suction). - Motor torque versus speed at rated voltage and at 80% of rated voltage. - Motor current versus speed at rated voltage and at 80% of rated voltage. - WK2 of the compressor, the gear, the motor, and the coupling(s) referred to motor speed. - Estimated times for acceleration to rated speed for throttled suction and for open suction at 80% of the nameplate motor voltage unless otherwise specified.	

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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.
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 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.	Refer to the Contract.
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	



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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.

Chapter 2 - Centrifugal and axial compressors

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2. Basic design	
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 Job 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.	Unless otherwise specified, connections for boroscopic examination are not requested. In addition, axial split casings with several inlet process connections (typically refrigeration compressors) shall be provided with permanent tapping points for temperature measurement in the mixing area downstream each intermediate inlet connection.
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.
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	This paragraph is applicable with in addition, a valve position transmitter and close position adjustable limiting device.

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as specified shall be provided.	
• 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. The original proposed machine shall not include provision only for shunt holes either the division wall labyrinth or at the balance piston. No open shunt holes are allowed at the design stage.
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.	The original proposed machine shall not include any anti-swirl or honeycomb type seals.
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 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(se 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.	In addition, the balancing line shall be provided with a flow element device and flow indication shall be made available at unit control panel. The connection shall not be in the process piping but on the balance line itself and shall conform to ISO 5167, flange taps.

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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 Job 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.
• 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.	Unless otherwise specified, shaft end seals shall be as per here above paragraph 2.8.4 of chapter 1. Unless otherwise specified, 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

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	with the settle out pressure without any partial venting. Whenever technically feasible, the dry gas seals shall be able to be statically pressurized at the pressure equal to the gas leakage test pressure as defined in here after paragraph 4.3.2.3 of chapter 2.
• 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. • 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	SI units shall be shown on the nameplate.

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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.	In all cases, the machine control system shall be designed and provided by VENDOR, including the suction control valve in the compressor inlet piping. This valve must then conform to PVV 112 and INS 101 The extent of process control by the machine control system, if required, shall be indicated in the Job 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 provided that will be visible during operation of the machine.	

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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 and each journal bearing shall be provided with shaft vibration detection and the associated monitoring system based on X and Y non contact vibration probes. In addition, each shaft shall be provided with dual axial position detection and a key phasor 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.	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.
• 3.4.7.4 When specified, a bearing temperature monitor shall be supplied and calibrated according to API Std 670.	Both outboard and inboard thrust bearings shall be provided with dual temperature detection and monitoring system consisting of two RTD embedded in one of the pads (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.
• 3.4.7.5 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	
• 3.5.1.2 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 Job 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	
4.3.1.1.10 When specified, the user may furnish his own vibration equipment to record baseline readings.	COMPANY reserve the right to use his own vibration equipment during the test.
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.	This paragraph is applicable.
4.3.3 Optional tests The PURCHASER will specify whether any of the following shop tests shall be performed. Test details shall be mutually agreed upon by the PURCHASER and the VENDOR prior to the test.	Refer to the Job Specification.
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	Performance test shall be a type 2 as per ASME PTC 10-1997

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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 PTC 10-1997 for the selection of the appropriate test code to be used.	For constant speed compressor, a minimum of six points, evenly spaced, from surge to stonewall at the normal speed, are required. For variable speed compressor, two additional sets of points shall be taken at maximum continuous speed (5 points) and at 80% (4 points) of the rated 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 mixing temperature downstream each side stream. Balancing line flow and seal gas flow shall be measured during the 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 inaccuracy based on instrumentation and procedures. These test inaccuracies are already included in the above tolerance and, therefore not to be further additive	<i>At the guaranteed point:</i> - The absorbed power at compressor shaft coupling with all losses and API margin (but not to exceed 4%) included, with no positive tolerance. <i>For each compressor section:</i> - Flow and head values with no negative tolerance, - Speed within $\pm 2\%$. <i>At rated speed as specified in the data sheets, for each compressor section:</i> - At surge +5% in flow: The flow with no positive tolerance and the head with no negative tolerance, - At stonewall: The flow with no negative tolerance and the head with no negative tolerance. <i>At any other operating point as specified in the data sheets for each compressor section:</i> - Flow and head values with no

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	tolerance, Speed must be below 97% of maximum continuous operating speed.
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 point: - The absorbed power at compressor shaft coupling with all losses, extra power required to cover positive head tolerance, and API margin (but not to exceed 4%) included, with no positive tolerance. For each compressor section: - Flow and head values with no negative tolerance and +4% tolerance on head. - At surge +5% in flow: The flow with no positive tolerance and the head with no negative tolerance, - At stonewall: The flow with no negative tolerance and the head with no negative tolerance. In case of compressors fitted with IGVs, the above requirements shall apply with IGVs set such as flow to impeller inlet is fully radial.
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	Refer to Annex 2F.



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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.	
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.

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

$$\text{In SI units} \quad F_r + 1.09 M_r \leq 145.9 D_e \quad (2.E-1a)$$

$$\text{In U.S. Customary units} \quad 3F_r + M_r \leq 2500 D_e \quad (2.E-1b)$$

- 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:

$$\text{In SI units} \quad F_r + 1.09 M_r \leq 73 D_e \quad (2.E-5a)$$

$$\text{In U.S. Customary units} \quad 3F_r + M_r \leq 1250 D_e \quad (2.E-5b)$$

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

In SI units:

$$F_x = 1.09 \quad M_x = 73 D_c$$

$$F_y = 1.09 \quad M_y = 36.5 D_c$$

$$F_z = 1.09 \quad M_z = 36.5 D_c$$

In U.S. Customary units:

$$F_x = 250 \quad M_x = 1250 D_c$$

$$F_y = 625 \quad M_y = 625 D_c$$

$$F_z = 500 \quad M_z = 625 D_c$$

Annex 2F Complete Unit Tests

1. General

These tests shall consist of:

- Pre commissioning and commissioning activities
- Unit auxiliary system operating tests
- Performance and mechanical tests themselves.

These activities shall:

- Commence only once all engineering documents are approved by COMPANY and ready for construction
- Be performed in accordance with the requirements of the COMPANY (Refer to **GS EXP 101**)
- Be witnessed by COMPANY.

2. Pre-commissioning and commissioning activities

As a minimum, pre commissioning and commissioning activities shall consist of:

- Calibration of all the job instruments
- Equipment and component tagging and labeling checks
- Electrical and instrumentation component insulation and continuity tests
- Loops checks
- Loop functional test checks using contract Trouble Shooting Diagrams
- Serial link tests
- Hydraulic piping tests
- Gas leakage tests
- Mechanical equipment alignment checks
- Oil systems cleaning and flushing.

3. Unit auxiliary system operating tests

As a minimum, all unit auxiliary systems shall be operationally tested.

All job special tools shall be used for the erection of the units or shall be tested.

All lifting devices shall be statically and dynamically tested in accordance with the applicable regulations.

4. Performance and mechanical tests

Unless otherwise specified, these tests shall be carried out on units fully erected and commissioned and shall involved all job equipment as listed in the scope of supply.

4.1 Complete unit no load test

The test shall consist of:

- A four hours continuous test at maximum continuous speed
- Hot restart of the unit and speed increase up to maximum continuous speed for 15 minutes
- Ancillary operating tests such as but not limited to duty/stand-by switch over motors, dual filters, dual auxiliaries
- Check with the unit in operation of the some emergency trips such as but not limited to: over speed, manual stop, low lube oil temperature, etc.
- Emergency stop sequences
- Unit noise intensity measurements.

Unless manually initiated, any shutdown occurring during the test shall invalidate the test.

Should the test be performed under vacuum, the seals shall be pressurized with an external source of filtered (3 µm) and dry instrumentation air.

The unit shall use the job instruments and any additional shop instrumentation deemed necessary by the VENDOR.

All running parameters shall be recorded every thirty minutes.

During these tests all the requirements of:

- The paragraph 4.3.6 of Chapter 1 and the paragraph 4.3.1 of the Chapter 2 with all referred paragraphs, all of them as amended by the present document.
- **API 616** in case of gas turbine drive and as amended by **GS MEC 212**.
- **IEC** standards in case of electric motor drive,

shall apply in particular for the vibration level acceptance criteria.

4.2 Complete unit load test

The test shall be performed in a close loop filled with the rated gas and incorporating the job anti surge valves in parallel with shop process control valve, and the job suction throttling valve when applicable.

The test shall consist of:

- One hour at stable conditions at the rated point.
- Two hours at stable conditions at the maximum continuous speed and maximum power corresponding to the ambient conditions prevailing at the time of the test.
- The excursion of the performance of the compressor at maximum continuous speed from stonewall to surge with recording of 4 points, each point shall be stabilized for a minimum of 30 minutes.
- The determination of the surge line at maximum continuous, minimum operating speed and at rated speed.
- The test of the behavior of anti-surge controller, start, normal and emergency shutdowns, switchover between job anti-surge valve and shop process control valve, with the anti-surge controller in automatic mode.

- Hot restart of the unit and speed increase up to maximum continuous speed for 15 minutes.
- Ancillary operating tests such as but not limited to duty/stand-by switch over motors, dual filters, and dual auxiliaries.
- Check with the unit in operation of the some emergency trips such as but not limited to: over speed, manual stop, low lube oil temperature, etc.
- Emergency stop sequences.
- Unit noise intensity measurements.
- When the driver is a fixed speed electric motor, the test of the capability of the motor to start under the settle out pressure as defined in the data sheet.

Unless manually initiated, any shutdown occurring during the test shall invalidate the test.

During the test at the compressor rated point, deviations of the test conditions from the rated conditions shall be as per PTC 10 table 3.1.

Gas composition shall be checked before each point recording.

The unit shall use the job instruments and any additional shop instrumentation deemed necessary to evaluate both compressor and driver performances.

Any inlet, any side stream shall be fitted with flow measuring device.

All running parameters shall be recorded every thirty minutes.

During these tests all the requirements of:

- The paragraph 4.3.6 of Chapter 1 and the paragraph 4.3.1 of the Chapter 2 with all referred paragraphs, all of them as amended by the present document
- **API 616** in case of gas turbine drive and as amended by **GS MEC 212**
- **IEC** standards in case of electric motor drive

shall apply in particular for the vibration level acceptance criteria.

Performance of both compressor and driver based on the test conditions and adjusted to the site conditions shall be within +/- 2% of those found during the individual machinery performance tests, otherwise, the test shall be invalidated and redone after proper evaluation of the discrepancy and correction.

4.3 Post test inspections

After the successful test, the following inspection shall be done:

- Gas turbine: Boroscopic inspection of the hot gas path.
- Compressors: Bearings and seals disassembly, casing drains check for any liquid.

Should the compressors exhibit during steady state operation or hot restart any vibration level higher than twice the acceptance level criteria, COMPANY shall be entitled to request the removal of the compressor bundle and the inspection of the compressor internal labyrinths before retesting.

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 Job 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.
2.4 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.
2.7 Bearing and bearing housing	
2.7.2 Hydrodynamic bearing	
2.7.2.2 When specified, tilting pad bearings	VENDOR's standard shall apply.

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shall be copper alloy backed and shall have hardened steel inserts for supports	
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 customary units are to be shown	This paragraph is applicable.

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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. The complete control system shall be supplied by VENDOR, including the pressure control valve and associated accessories in accordance with P&IDs and INS 101. This valve must conform to PVV 112. 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 and each journal bearing shall be provided with shaft vibration detection and the associated monitoring system based on X and Y non contact vibration probes. In addition, each shaft shall be provided with dual axial position detection and a key phasor 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 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

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	terminal when the latter is integrated in the skid. Both sides of thrust bearings shall be provided with dual temperature detection and monitoring system consisting of two RTD embedded in one of the pads (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.
• 3.4.7.5 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 extend of the piping system supplied by the VENDOR.	Refer to the Job 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 Job Specification.
3.5.2 Process piping	
• 3.5.2.2 When specified, the PURCHASER shall provide specification for process heat exchanger and interconnecting piping e provided by the VENDOR with API std 614 chapters 1.5.5.	This paragraph is applicable. Refer to the Job Specification.

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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 vibration data as mutually agreed by the PURCHASER and the VENDOR shall be recorded and a copy provided to the PURCHASER.	This paragraph is applicable.
• 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 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.	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 Job 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	Performance test shall be a type 2 as per ASME PTC 10-1997 For constant speed compressor, a minimum

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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 PTC 10-1997 for the selection of the appropriate test code to be used.	of six points, evenly spaced, from surge to stonewall at the normal speed, are required. For variable speed compressor, two additional sets of points shall be taken at maximum continuous speed (5 points) and at 80% (4 points) of the rated speed. For computation of the performance, Reynolds number correction is not permitted. When multi-stage compressors are tested, inlet flow at each stage shall be measured.
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 point: - The absorbed power at compressor shaft coupling with all losses and API margin (but not to exceed 4%) included, with no positive tolerance. For each compressor stage: - Flow and head values with no negative tolerance - Speed within $\pm 2\%$. At rated speed as specified in the data sheets, for each compressor stage: - At surge +5% in flow: The flow with no positive tolerance and the head with no negative tolerance - At stonewall: The flow with no negative tolerance and the head with no negative tolerance. At any other operating point as specified in the data sheets for each compressor stage: - Flow and head values with no tolerance, Speed must be below 97% of maximum continuous operating speed.
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	At the guaranteed point: The absorbed power at compressor shaft coupling with all losses, extra power required to cover positive head tolerance, and API margin (but not to exceed 4%) included, with no positive tolerance.

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head may be removed by trimming impellers at the PURCHASER's option.	<i>For each compressor stage:</i> • Flow and head values with no negative tolerance and +4% tolerance on head. • At surge +5% in flow: The flow with no positive tolerance and the head with no negative tolerance. • At stonewall: The flow with no negative tolerance and the head with no negative tolerance. In case of compressors fitted with IGVs, the above requirements shall apply with IGVs set such as flow to impeller inlet is fully radial.
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 Job Specification.

Chapter 4 - Expander

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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 data sheet.
2.5 Rotating Elements	
2.5.4 Impellers For impellers requirements see 2.5.10 of Chapter 1	Unless otherwise specified, 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 $U = \text{residual unbalance, in g-mm (oz,-in)}$ $W = \text{weight of the rotor, in kg (lb.), apportioned to the balance planes so that the sum of the weight apportionment for both planes equals the total weight of the rotor.}$	This paragraph is applicable.

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N = maximum continuous operating speed, in rpm Assembled rotors that fail to meet these criteria shall be balance corrected by 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	
• 2.7.1.2 When specified, magnetic bearings shall be supplied in accordance with Annex 4F.	Active magnetic bearings shall be provided.
2.8 Expander-compressor shaft seals	
2.8.1.1 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 H₂S 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 and each journal bearing shall be provided with shaft vibration detection and the associated monitoring system based on X and Y non contact vibration probes.

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• 3.4.2.3 When specified, vibration monitors shall be supplied and calibrated in accordance with API Std 670.	In addition, each shaft shall be provided with dual axial position detection and a key phasor 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.	These paragraphs are applicable in case of oil lubricated 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.	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.	Both sides of thrust bearings shall be provided with dual temperature detection and monitoring system consisting of two RTD embedded in one of the pads (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.
3.4.3 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.	This paragraph is applicable.

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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 tapping 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 point 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 designed to peak at U/C ratio (a	Performance test shall be a type 2 as per ASME PTC 10-1997. A minimum of six points, evenly spaced, from surge to stonewall at the normal speed, are required. Two additional sets of points shall be taken at maximum continuous speed (5 points) and at 80% (4 points) of the rated speed. For computation of the performance, Reynolds number correction is not permitted.

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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	
4.3.5.1.3 The expander shall be performance tested at the normal Q/N ratio, where: Q = compressor inlet volume flow N = normal speed of the machine. A minimum of five points shall be taken to either side to establish a curve of the compressor head and efficiency vs. flow. The surge point shall be established and the observed surge point indicated on the performance test head curve. Other than this, the performance test shall be in accordance with AASME PTC 10. The compressor shall deliver at least 98% of the normal head at the normal capacity. The compressor power at the normal condition shall not be more than 106% of that available from the expander, nor shall it be less than 96% of that available from expander. Note: Refer to the applicable test code for general instructions ASME PTC 10-1997 may nit apply to some low-pressure ratio compressors. Refer to 1.2.2 of PTC10-1997 for the selection of the appropriate test code to be used.	At the guaranteed point: - The absorbed power at compressor shaft coupling with all losses and API margin (but not to exceed 4%) included, with no positive tolerance. - Flow and head values with no negative tolerance, - Speed within $\pm 2\%$. At rated speed as specified in the data sheets: - At surge +5% in flow: The flow with no positive tolerance and the head with no negative tolerance. - At stonewall: The flow with no negative tolerance and the head with no negative tolerance. At any other operating point as specified in the data sheets: - Flow and head values with no tolerance. Speed must be below 97% of maximum continuous operating speed.
• 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	Any spare complete mechanical center section including seals and bearings shall be



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specified. Note: A mechanical test of the spare center section is mandated in 4.3.3.3.6.	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 and the following.	
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.