# MATERIAL AND EQUIPMENT STANDARD

# FOR

# EXPANSION TURBINES

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## 0. INTRODUCTION

This Standard specification contains minimum requirements for radial expansion turbines or expanders. The compressive energy that is stored in gas can be used for different applications. Turbo expanders recover this energy and can be configured with centrifugal compressor or electric generator.

Expansion turbines are also used for the generation of low temperatures in cryogenic process (see Appendix B for typical application).

## 1. SCOPE

**1.1** This Standard specification covers minimum requirements for expansion turbines for use in refinery services, gas, chemical and petrochemical plant and where applicable in production and new ventures.

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

**1.3** The turbine shall be the product of a manufacturer regularly engaged in manufacture of expansion turbines at least for three years.

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

## 2. CONFLICTING REQUIREMENTS

In case of conflict between this Standard and the inquiry or order, the following priority of documents shall apply:

| | |
|---|---|
| **First Priority:** | Purchase Order and Variations |
| **Second Priority:** | Data Sheet and Drawings |
| **Third Priority:** | This Standard |

All conflicting requirements shall be submitted to the Purchaser in writing.

## 3. DEFINITION OF TERMS

Terms used in this Standard are defined in 3.1 through 3.19.

### 3.1 Maximum Continuous Speed

Maximum continuous speed (in revolutions per minute) is the speed at least equal to 105 percent of the highest speed required by any of the specified operating conditions.

### 3.2 Maximum Allowable Working Pressure

Maximum allowable working pressure is the maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when operating at the maximum allowable temperature.

### 3.3 Maximum Inlet Pressure and Temperature

Maximum inlet pressure and temperature refer to the highest inlet gas pressure and temperature conditions at which the turbine is required to operate continuously.

### 3.4 Maximum Exhaust Pressure

Maximum exhaust pressure is the highest exhaust gas pressure at which the turbine is required to operate continuously.

### 3.5 Minimum Allowable Speed

Minimum allowable speed (in revolutions per minute) is the lowest speed at which the manufacturer's design will permit continuous operation.

### 3.6 Minimum Inlet Pressure and Temperature

Minimum inlet pressure and temperature refer to the lowest inlet gas pressure and temperature conditions at which the turbine is required to operate continuously.

### 3.7 Normal

Normal applies to the power, speed and gas conditions at which the equipment will usually operate. These conditions are the ones at which the highest efficiency is desired. This point is usually the point at which the Vendor certifies that performance is within the tolerances stated in this Standard.

### 3.8 Normal Speed

The normal speed is the speed corresponding to the requirements of the normal operating point.

### 3.9 Pressure Casing

The pressure casing is the composite of all stationary pressure-containing parts of the unit, including all nozzles and other attached parts.

### 3.10 Axially Split

Axially split refers to casing joints that are parallel to the shaft centerline.

### 3.11 Rated

Rated applies to the greatest turbine power specified and the corresponding speed. It includes all of the margin required by the driven-equipment specifications.

### 3.12 Rated Speed (One-Hundred-Percent Speed)

The rated (one-hundred-percent) speed is the highest speed required for any specified operating point above the normal speed curve.

### 3.13 Hydrodynamic Bearings

A hydrodynamic bearings are bearings that use the principles of hydrodynamic lubrication. Their surfaces are oriented so that relative motion forms an oil wedge to support the load without journol-to-bearing contact.

### 3.14 Total Indicated Runout (TIR)

Total indicated runout (TIR), also known as total indicator reading, is the runout of a diameter or face determined by measurement. With a dial indicator. The indicator reading implies an out-of-squareness equal to the reading or an eccentricity equal to half the reading.

### 3.15 Trip Speed

Trip speed (in revolutions per minute) is the speed at which the independent emergency overspeed device operates to shut down the turbine.

**3.16** The use of the word design in any term (such as design power, design pressure, design temperature, or design speed) should be avoided in the purchaser’s specifications. This terminology should be used only by the equipment designer and the manufacturer.

### 3.17 Settling-Out Pressure

The settling-out pressure is the pressure of the expander system when the expander is shut down.

### 3.18 Inlet Cubic Meter per Hour (Inlet Volume)

The inlet volume refers to the flow rate determined at the conditions of pressure, temperature, compressibility, and gas compositions including moisture, at the compressor inlet flange.

### 3.19 Normal Cubic Meter per Hour (mm/hr)

Normal cubic meter per hour refers to the flow rate at any location corrected to a pressure of 1.013 bar and a temperature of 0°C with a compressibility factor of 1.0 and in a dry condition.

## 4. UNITS

This Standard is based on International System of Units (SI), except where otherwise specified.

## 5. REFERENCED CODES AND STANDARDS

In this Standard the following codes, Standards and specifications are referred to. The edition of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard.

The applicability of changes in Standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor.

**ANSI (AMERICAN NATIONAL STANDARD INSTITUTE)**

| | |
|---|---|
| B 31.3 | "Chemical Plant and Petroleum Refinery Piping" |
| B 16.5 | "Pipe Flanges and Flanged Fittings, Steel, Nickel Alloy and Other Special Alloys" |
| B 16.11 | "Forged Steel Fittings, Socket-Welding and Threaded" |
| B 1.20.1 | "Pipe Threads, General Purpose" |
| Y 14.2M | "Line Conventions and Lettering" |

**API (AMERICAN PETROLEUM INSTITUTE)**

| | |
|---|---|
| RP 550 | "Manual on Installation of Refinery Instruments and Control Systems" |
| 678 | "Accelerometer-Based Vibration Monitoring System" |
| 615 | "Sound Control of Mechanical Equipment for Refinery Services" |
| 670 | "Vibration, Axial-Position, and Bearing Temperature Monitoring Systems" |

**ASME (AMERICAN SOCIETY OF MECHANICAL ENGINEERS)**

"Boiler and Pressure Vessel Code", Section VIII,
"Rules for Construction of Pressure Vessels" and Section IX "Welding and Brazing Qualification"

**ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIAL)**

| | |
|---|---|
| A 193 | "Alloy Steel and Stainless Steel Bolting Materials for High-Temperature Service" |
| A 194 | "Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service" |
| A 320 | "Alloy-Steel Bolting Materials for Low-Temperature Parts" |
| E 125 | "Reference Photographs for Magnetic Particle Indications on Ferrous Castings" |

**IPS (IRANIAN PETROLEUM STANDARDS)**

| | |
|---|---|
| M-PM-170 | "Centrifugal Compressors for Process Services" |
| M-PM-310 | "Special-Purpose Couplings" |
| M-PM-320 | "Lubrication, Shaft Sealing and Control Oil System for Special Purpose Application" |

**ISA (INSTRUMENT SOCIETY OF AMERICA)**

| | |
|---|---|
| S 12.4 | "Instrument Purging for Reduction of Hazardous Area Classification" |

**NACE (NATIONAL ASSOCIATION OF CORROSION ENGINEERS)**

| | |
|---|---|
| MR-01-75 | "Sulfide Stress Corrosion Cracking Resistant Metallic Material for Oil Field Equipment" |

**NEMA (NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION)**

| | |
|---|---|
| SM 23 | "Steam Turbines for Mechanical Drive Services" |

**NFPA (NATIONAL FIRE PROTECTION ASSOCIATION)**

| | |
|---|---|
| 70 | "National Electrical Code" |
| 496 | "Purged Enclosures for Electrical Equipment in Hazardous Locations" |

## 6. BASIC DESIGN

### 6.1 General

**6.1.1** The equipment (including auxiliaries) covered by this Standard shall be designed and constructed for a minimum service life of 20 years and at least 3 years of uninterrupted operation. It is recognized that this is a design criterion. Turbine ratings shall be well within the range of the manufacturer's actual experience. Only equipment which has proven its reliability in service is acceptable. Manufacturer shall prepare the lists showing expansion turbines of the same frame size or model previously manufactured and operating under similar conditions of service, speed and power and location of such installations.

**6.1.2** If necessary the purchaser will specify the equipment's normal operating point on the data sheets.

**6.1.3** Turbine shall be capable of the following:

**a)** Operation at normal power and speed with normal gas conditions. The manufacturer's certified gas rate shall be at these conditions, the limits of variation from rated gas conditions which the turbine can accept shall be specified by the manufacturer.

**b)** Continuous operation at rated power and speed with maximum inlet gas conditions and maximum or minimum exhaust gas conditions.

**c)** Continuous operation at maximum continuous speed and at any other speed within the range specified.

**d)** Continuous operation of the lowest speed (minimum allowable speed) at which maximum torque is required with minimum inlet and maximum exhaust conditions. The Purchaser or driven vendor will specify both the speed and torque value required.

**e)** Operation uncoupled within gas inlet conditions range (Governing instability may occur and require action such as throttling of inlet).

**6.1.4** Equipment shall be designed to run up to the trip speed without damage.

**6.1.5** The combined performance of the turbine and the driven equipment after installation shall be the responsibility of the Vendor who has been nominated as main Vendor.

**6.1.6** The arrangement of the equipment including piping and auxiliaries shall be developed by the Vendor. The arrangement shall provide adequate clearance areas and safe access for operation and maintenance.

**6.1.7** All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearing housings shall be designed (shouldered or doweled) and manufactured to ensure accurate alignment or reassembly.

**6.1.8** Oil reservoirs and housings that enclose moving lubricated parts (such as bearings, shaft seals, highly polished parts, instruments, and control elements) shall be designed to minimize contamination by moisture, dust, and other foreign matter during periods of operation or idleness.

**6.1.9** Unless otherwise specified, cooling water systems shall be designed for the following conditions:

| | | |
|---|---|---|
| Velocity Over Heat Exchange Surfaces | 5-8 Ft/S | 1.5-2.5 M/S |
| Maximum Allowable Working Pressure | ≥ 75 Psig | ≥ 5.2 Bar (Ga) |
| Test Pressure | ≥ 115 Psig | ≥ 7.9 Bar (Ga) |
| Maximum Pressure Drop | 15 Psi | 1 Bar |
| Maximum Inlet Temperature | 90°F | 32°C |
| Maximum Outlet Temperature | 120°F | 49°C |
| Maximum Temperature Rise | 30°F | 17°C |
| Minimum Temperature Rise | 20°F | 11°C |
| Fouling Factor On Water Side | 0.002 hr-Ft² -°F/Btu | 0.35 m² K/kW |
| Shell Corrosion Allowance | 0.125 in | 3.2 mm |

Provision shall be made for complete venting and draining of the system.

**Note:**

**The Vendor shall notify the Purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflicting design. The criterion for velocity over heat exchange surfaces is intended to minimize water-side fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water. The Purchaser will approve the final selection.**

**6.1.10** Unless otherwise specified, the following limits shall be met at any measuring location in 1 m from the equipment surface:

**SOUND PRESSURE LIMIT IN dB RE 20 $\pi$ Pa**

| | |
|---|---|
| Turbine | 87 d B (A) |
| Turbine and driven equipment | 90 d B (A) |

If the equipment produces impulsive and/or narrow band noise, the above limits shall be taken 5 dB (A) lower, thus 82 dB (A) for the turbine and 85 dB (A) for the turbine and driven equipment.

**6.1.11** Electrical components and installations shall be suitable for the area classification (class, group,and division) specified by the purchaser on the data sheets and shall meet the requirement of NFPA 70, article 500 and 501 as well as local codes specified and furnished by the Purchaser.

**6.1.12** The Purchaser will specify whether the installation is indoors (heated or unheated) or outdoors (with or without a roof) as well as the weather and environmental conditions in which the equipment must operate (including maximum and minimum temperatures and unusual humidity or dust problems). The unit and its auxiliaries shall be suitable for operation under these specified conditions. For the purchaser's guidance, the Vendor shall list in the proposal any special protection that the Purchaser is required to supply.

**6.1.13** Spare parts for the machine and all furnished auxiliaries shall meet all the criteria of this Standard.

**6.1.14** The Vendor shall assume responsibility for the engineering coordination of the equipment all auxiliary systems included in the scope of the order.

## 6.2 Pressure Casings

**6.2.1** All pressure parts shall be at least suitable for operation at the most severe coincident of pressure and temperature expected with the specified gas conditions.

**6.2.2** The hoop-stress values used in the design of the casing shall not exceed the maximum allowable stress values in tension specified in Section VIII, Division I, of the ASME Code at the maximum operating temperature of the material used.

**6.2.3** The maximum allowable working pressure of the casing shall be at least equal to the maximum expected turbine inlet pressure which will be specified by the Purchaser.

**6.2.4** Casings and supports shall be designed to have sufficient strength and rigity to limit any change of shaft alignment, caused by the worst combination of allowable pressure, temperature, torqe, and piping forces and moments to 0.002 inch (50 micrometers). Supports and alignment bolts shall be rigid enough to permit the machine to be moved by the use of its lateral and axial jackscrews.

**6.2.5** Jackscrews, guide rods, and casing alignment dowels shall be provided to facilitate disassembly and reassembly. When jackscrews are used to part contacting faces, one of the faces shall be relieved (counter bored or recessed) to prevent a leaking joint or an improper fit caused by marring of the face. Guide rods shall be of sufficient length to prevent damage to the internals or casing studs by the casing during disassembly and reassembly.

Lifting Lugs or eyebolts shall be provided for lifting only the top half of the casing methods of the assembled machine shall be specified by the Vendor.

**6.2.6** Casing shall be provided with connections to ensure complete drainage. Drains shall be DN 40 (1½" flanged minimum.).

**6.2.7** Tapped holes in pressure parts shall be kept to a minimum. To prevent leakage in pressure sections of casings, sufficient metal, in addition to the allowance for corrosion shall be left around and below the bottom of drilled and tapped holes. Through bolting is preferred in areas of the casing where the temperature may exceed 413°C.

**6.2.8** Studded connections shall be furnished with studs installed. Blind stud holes should be drilled only deep enough to allow a preferred tap depth of 1½ times the major diameter of the stud, the first 1½ threads at both ends of each stud shall be removed.

**6.2.9** Bolting shall be furnished as specified in 6.2.9.1 through 6.2.9.4 .

**6.2.9.1** The details of threading shall conform to ANSI B1.1.

**6.2.9.2** Studs are preferred to cap screws.

**6.2.9.3** Adequate clearance shall be provided at bolting locations to permit the use of socket or box wrenches.

**6.2.9.4** Socket-slotted-nut-or spanner-type bolting shall not be used unless specifically approved by the Purchaser.

**6.2.9.5** ANSI B31.3 paragraph 309 shall govern the material limits for pressure bolting based upon the actual bolting temperature. Nuts shall conform to ASTM A 194, Grade 2H (or ASTM A 307, Grade B, casehardened where space is limited).

**6.2.10** The machined finish of the mounting surface shall be 3.2-6.4 micrometers arithmetic average roughness (Ra). Hold down or foundation bolt holes shall be drilled perpendicular to the mounting surface or surfaces and spot faced to a diameter three times that of the hole.

## 6.3 Casing Connections

**6.3.1** Inlet and outlet connections shall be flanged or machined and studded and oriented as specified in the data sheets.

**6.3.2** Connections welded to the casing shall meet the material requirements of the casing, including impact values, rather than the requirements of the connected piping.

**6.3.3** Casing openings for piping connections shall be at least ¾ inch nominal pipe size and shall be flanged or machined and studded. Where flanged or machined and studed openings are impractical, threaded openings in sizes, ¾ inch through 1½ inches nominal pipe size are permissible. These threaded openings shall be installed as specified in 6.3.3.1 through 6.3.3.6.

**6.3.3.1** A pipe nipple, preferably not more than 6 inches (152 millimeters) long, shall be screwed into the threaded opening.

**6.3.3.2** Pipe nipples shall be a minimum of schedule 160 seamless for sizes 1 inch and smaller and a minimum of schedule 80 for a size of 1½ inches.

**6.3.3.3** The pipe nipple shall be provided with a welding neck or socket-weld flange.

**6.3.3.4** The threaded connection shall be seal welded in accordance with ASME B 31.3. Seal welding is not permitted on instruments or where disassembly is required for maintenance.

**6.3.3.5** Tapped openings and bosses for pipe threads shall conform to ANSI B 16.5.

**6.3.3.6** Pipe threads shall be taper threads conforming to ASME B 1.20.1.

**6.3.4** Openings for pipe size of 1¼, 2½, 3½, 5, 7 and 9 inches shall not be used.

**6.3.5** Tapped openings not connected to piping shall be plugged with solid steel plugs furnished in accordance with ANSI B 16.11. Plugs that may later require removal shall be of corrosion-resistant material. Threads shall be lubricated. Tape shall not be applied to threads of plugs inserted into oil passages. Plastic plugs are not permitted.

**6.3.6** Flanges shall conform to ANSI B16.5, B 16.11, or B 16.42 as applicable.

**6.3.6.1** Flanges that are thicker or have a larger outside diameter than that required by ANSI are acceptable, but they shall be drilled and faced as specified by related ANSI Standard.

**6.3.6.2** For nozzle connections over DN 600 (24"). Vendor shall furnish mating pipe flanges per the following:

**a)** Flanges shall be welding neck type with bolt hole spacing and bolt circle diameter exactly matching the machine flanges.

**b)** Each flange shall be furnished with at least 2 dowel pins, each machined with a close fit tolerance to the diameter of the bolt holes bore.

**c)** The turbine shall be shipped with flanges bolted in place and with dowel pins installed. Each flange (turbine and pipe), dowel pin and bolt replacement for the dowel pin shall be positively identified.

**6.3.6.3** The concentricity of the bolt circle and the bore of all casing flanges shall be such that the area of the machined gasket-seating surface is adequate to accommodate a complete standard gasket without protrusion of the gasket into the fluid flow.

**6.3.6.4** The finish of all steel flanges and nozzles shall conform to ANSI B 16.5 except for flange finish roughness requirements. The arithmetic average roughness (Ra) of flange contact surfaces shall conform to the following values.

**6.3.7** Machined and studded connections shall conform to the facing and drilling requirements of ANSI B 16.1 and B 16.5. Studs and nuts shall be furnished installed. Connections larger than those covered by ANSI shall meet the requirements of 6.3.6.2

| FINISH (Ra) | | | |
|---|---|---|---|
| **Flange Type** | **Service** | **Microinches** | **Micrometers** |
| Ring Joint | **All** | **<63** | **1.6** |
| Flat and Raised Face | **All** | **125-500** | **3.2-12.7** |

**6.3.8** Unless otherwise specified, pipe-flange gaskets shall be spiral-wound metal or metal-jacketed with nonhazardous filler.

## 6.4 External Forces and Moments

The expander shall be designed to withstand external forces and moments on each nozzle at least equal to 3 times the values calculated in accordance with NEMA SM 23. The Vendor shall furnish the allowable forces and moments for each nozzle in tabular form.

## 6.5 Inlet Nozzles

Expansion turbine must be capable of efficient off-design performance to compensate for the variable operating processes. Adjustable inlet nozzle shall be used to produce optimum flow patterns and provide precise continuous control between 0% and %150 design flow. Nozzles should be controlled manually or by an automatic actuator. Actuator shall receive control signals from related process local or remote instruments.

## 6.6 Rotating Elements

**6.6.1** Shafts shall be made of one-piece, heat-treated steel that is suitably machined. Shafts that have a finished diameter larger than 8 inches (200 millimeters) shall be forged steel. Shafts that have a finished diameter of 8 inches (200 millimeter) or less shall be forged steel or, with the purchaser’s approval, hot rolled barstock, providing that the barstock meets all quality and heat-treatment criteria established for shaft forgings. Shaft assembly (rotor) shall be capable of safe operation at momentary speeds up to %110 percent of the trip speed at normal operating temperature.

**6.6.2** Shaft ends for coupling fits shall conform to standard IPS-M-PM-310.

**6.6.3** Unless otherwise specified, shaft sleeves shall be furnished under all shaft seals.

These sleeves shall be made of a material that is corrosion resistant in the specified service. The sleeves under close-clearance bushing end seals shall be suitably treated to resist wear and it shall be sealed to prevent leakage between the shaft and sleeve.

**6.6.4** The rotor shaft sensing areas to be observed by radial-vibration probes shall be concentric with the bearing journals. All shaft sensing areas (both radial vibration and axial position) shall be free from stencil and scrible marks or any other surface discontinuity, such as an oil hole or a keyway. These areas shall not be metallized, sleeved, or plated. The final surface finish shall be 16-23 microinches (0.4-0.8 micrometer) Ra, preferably obtained by honing or burnishing.

These areas shall be properly demagnetized or otherwise treated so that the combined total electrical and mechanical runout does not exceed 25 percent of the maximum allowed peak-to-peak vibration amplitude or the following value, whichever is greater:

**a)** For areas to be observed by radial-vibration probes, 0.25 mil (6 micrometers).
**b)** For areas to be observed by axial-position probes, 0.5 mil (13 micrometers).

**6.6.5** Each rotor shall be clearly marked with a unique identification number. This number shall be on the end of the shaft opposite the coupling.

**6.6.6** Impeller(s) may be closed or semiopen and shall be of welded, milled or casting construction. Paddle type impellers i.e., without front and back plate shall not be used. Welded impellers may consist of forged and cast components. Welds in the gas passageway shall be smooth and free from weld spatter. Impellers shall be heat treated and stress relieved after welding. Vane entrances and exits shall not have knife edges.

**6.6.7** Upgrade or repair welding and welding as a means of balancing an impeller are not permitted.

**6.6.8** 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. (Areas of concern include the impeller, vane-to-disk intersections, keyways, and shaft section changes.)

**6.6.9** Replaceable thrust collars shall be furnished and they shall be positively locked to the shaft to prevent fretting. Face of thrust collars shall have a surface finish of not more than 16 microinches (0.4 micrometer) Ra, and the axial total indicated runout of each face shall not exceed 0.0005 inch (12.7 micrometers).

**6.6.10** To prevent the build-up of potential voltages in the shaft, residual magnetism of the rotating element shall not exceed 5 gauss (0.0005 tesla).

**6.6.11** The method of attaching the impeller shall adequately maintain concentricity and balance under all specified operating conditions, including overspeed to trip speed.

## 6.7 Bearings and Bearing Housings

### 6.7.1 General

**6.7.1.1** Hydrodynamic radial and thrust bearings shall be provided unless specific approval to the contrary is obtained from the purchaser.

**6.7.1.2** Unless otherwise specified, thrust bearings and radial bearings shall be fitted with bearing-metal temperature sensors installed in accordance with API Standard 670.

### 6.7.2 Radial bearings

**6.7.2.1** Radial bearings of the sleeve or pad type shall be used and shall be split for ease of assembly. The use of nonsplit designs requires the purchaser's approval. The bearings shall be precision bored with steel-backed, babbitted replaceable liners, pads, or shells. The bearings shall be equipped with antirotation pins and shall be positively secured in the axial direction.

**6.7.2.2** The bearing design shall suppress hydrodynamic instabilities and provide sufficient damping over the entire range of allowable bearing clearances to limit rotor vibration to the maximum specified amplitudes while the equipment is operating loaded or unloaded at specified operating speeds.

**6.7.2.3** Expanders equipped with sleeve-type journal bearings shall be designed for installation of tilting-pad-type bearings without remachining of the bearing housing.

**6.7.2.4** Bearings shall be suitable for lubrication supplied from a lube oil system common with the driven equipment.

### 6.7.3 Thrust bearings

**6.7.3.1** Hydrodynamic thrust bearings shall be of the steel-backed, babbitted multiple-segment type, designed for equal thrust capacity in both directions and arranged for continuous pressurized lubrication to each side. Both sides shall be of the tilting-pad type, incorporating a self-leveling feature which assures that each pad carries an equal share of the thrust load, even with minor variation in pad thickness.

**6.7.3.2** Each pad shall be designed and manufactured with dimensional precision (thickness variation) that will allow interchange or replacement of the individual pads.

**6.7.3.3** Thrust bearings shall be sized for continuous operation under the most adverse specified operating conditions. Calculation of the thrust load shall include but shall not be limited to the following factors:

**a)** Fouling and variation in seal clearances up to twice the desiginternal clearances;
**b)** step thrust from all diameter changes;
**c)** inlet and exhaust differential pressure;
**d)** variations in inlet and exhaust pressure;
**e)** external loads from the driven equipment as described in 6.7.3.4 through 6.7.3.6.

**6.7.3.4** For gear-type couplings, the external thrust force shall be calculated from the following formula:

$$F = \frac{(0.25)\,(63.000)}{(N_r\,D)} P_r$$

**In SI units, this translates to::** $$F = \frac{(0.25)\,(95{,}54{,}000)}{(N_r\,D)} P_r$$

**Where:**

$\boldsymbol{F}$ = external thrust force, in pounds (Newtons)
$\boldsymbol{P_r}$ = rated power, in horse power (kilowatt)
$\boldsymbol{N_r}$ = rated speed, in revolutions per minute
$\boldsymbol{D}$ = shaft diameter at the coupling, in inches (millimeters)

**Note:**

**Shaft diameter is an approximation of the coupling pitch radius.**

**6.7.3.5** Thrust forces for diaphragm-type couplings shall be calculated on the basis of the maximum allowable deflection permitted by the coupling manufacturer.

**6.7.3.6** If two or more rotor thrust forces are to be carried by one thrust bearing (such as in a gear box), the resultant of the forces shall be used provide the directions of the forces make them numerically additive; otherwise, the largest of the forces shall be used.

**6.7.3.7** Thrust bearing shall be selected at no more than 50 percent of the bearing manufacturer's ultimate load rating. The ultimate load rating of a thrust bearing is the load that will produce the minimum acceptable oil film thickness without inducing failure in continuous service or the load that will not exceed the creep-initiation or yield strength of the babbitt at the maximum temperature location on the pad, whichever load is less. In sizing thrust bearings, consideration shall include but shall not be limited to the following for each specific application:

**a)** The shaft speed;
**b)** the temperature of the bearing babbitt;
**c)** the deflection of the bearing pad;
**d)** the minimum oil film thickness;
**e)** the feed rate, viscosity, and supply temperature of the oil;
**f)** the design configuration of the bearing;
**g)** the babbitt alloy;
**h)** the shoe material;
**i)** the turbulence of the oil film.

The basis for the bearing manufacturer's sizing of thrust bearings shall be reviewed and approved by the purchaser.

**6.7.3.8** Thrust bearings shall be arranged to allow axial positioning of each rotor relative to the casing and setting of the thrust bearings' clearance.

### 6.7.4 Bearing housings

**6.7.4.1** Bearing housings, bearing shells and bearings shall be axially split and if required, furnished with plugged connections for inert-gas purge to any atmospheric labyrinth seals.

**6.7.4.2** Bearing housings shall be equipped with replaceable labyrinth-type end seals and deflectors where the shaft passes through the housing; lip-type seals shall not be used. The seals and deflectors shall be made of nonsparking materials. The design of the seals and deflectors shall effectively retain oil in the housing and prevent entry of foreign material into the housing.

**6.7.4.3** Provision shall be made for mounting two radial vibration probes in each bearing housing, two-axial position probes at the thrust end of each machine, and a one-event-per-revolution probe in each machine. The probe installation shall be as specified in API Standard 670.

**6.7.4.4** Shaft support structures bolted to casings shall be steel.

**6.7.4.5** Bearing housings for hydrodynamic bearings designed for pressure lubrication shall be arranged to minimize foaming. The drain system shall be adequate to maintain the oil and foam level below shaft end seals. The rise in oil temperature through the bearing and housings shall not exceed 50°F (28°C) under the most adverse specified operating conditions.

The bearing oil outlet temperature shall not exceed 180°F (82°C). Oil outlets from thrust bearings shall be tangential and in the upper half of the control ring or, if control rings are not used, in the thrust-bearing cartridge. Nonpressurized bearing housings shall be furnished with either vendor’s Standard breather or a DN 25 minimum vent connection fitted with a steel pipe plug.

**6.7.4.6** When specified, thrust bearings and radial bearings shall be fitted with bearing-metal temperature sensors in accordance with 7.3.7.

**6.7.4.7** Machine equipped with sleeve-type journal bearings shall be designed for field installation of tilting-pad-type radial bearing without remachining of the bearing bracket.

## 6.8 Shaft Seals

**6.8.1** Shaft seals shall be provided to restrict or prevent process-gas leakage to the lubrication system and atmosphere and seal-fluid leakage into the process-gas stream over the range of specified operating conditions, including start-up and shutdown or settling out, and during any other special operation specified by the purchaser. 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 expander pressurization with the seal system in operation prior to process start-up. For the compressor loaded compact design (Fig. C1) application (using pressurized Oil reservoir) that use buffer gas as sealing media, provision shall be provided by vendor to prevent the build up of condensate and contamination of the Oil system.

**6.8.2** Shaft seals may be one or a combination of the types described in 6.8.2.1 through 6.8.2.4.

**6.8.2.1** The labyrinth seal include the labyrinths may be stationery or rotating. Ports may be added for scavenging and/or buffered gas.

**6.8.2.2** The mechanical (contact)seal shall be provided with labyrinth and slingers. Unless otherwise specified, seal oil shall be supplied from an independent seal system. Mechanical seals shall be designed to prevent gas leakage while the expander being shut down and after it is stopped in the event of seal oil failure.

**6.8.2.3** The restrictive-ring seal shall include rings of carbon or another suitable material mounted in retainers or in spacers. The seal may be operated dry, with a sealing liquid or with a buffer gas.

**6.8.2.4** The liquid-film seal shall be provided with sealing rings or bushings and labyrinths. A sealing liquid shall be supplied as in the mechanical type. Liquid-film seals may be of the cylindrical-bushing type or the pumping type. An elevated tank to maintain a static head in excess of the sealing pressure shall be provided. The Vendor shall state the height of the tank above the machine centerline. Other means of maintaining this differential pressure and positive seal may be used with the purchaser’s approval.

**6.8.3** Unless otherwise specified, the seal design shall have provisions for buffer-gas injection. 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. When buffer-gas injection is required the Vendor shall state the gas requirements, and, when specified, furnish the complete control-system schematic and bill of material. The method of control will be specified by the Purchaser.

**6.8.4** For any shaft seal that use sealing oil, the inward leakage shall be piped to an independent drain pot. Oil contaminated by process gas that would damage components such as bearings, seal rings, o-rings, shall be piped away separately to allow disposal or reconditioning.

## 6.9 Dynamics

### 6.9.1 Critical speeds

**6.9.1.1** When the frequency of periodic forcing phenomenon (exciting frequency) applied to a rotor-bearing support system corresponds to a natural frequency of that system, the system may be in a state of resonance.

**6.9.1.2** A rotor-bearing support system in resonance will have its normal vibration displacement amplified. The magnitude of amplification and the rate of phaseangle change are related to the amount of damping in the system and the mode shape taken by the rotor.

**Note:**

**The mode shapes are commonly referred to as the first rigid (translatory or bouncing) mode, the second rigid (conical or rocking) mode, and the (first, second, third, ...., nth) bending mode.**

**6.9.1.3** When the rotor amplification factor as measured at the vibration probe, is greater than or equal to 2.5, that frequency is called critical and the corresponding shaft rotational frequency is called a critical speed. For the purposes of this Standard, a critically damped system is one in which the amplification factor is less than 2.5.

**Note:**

**Amplification factor shall be calculated from the following formula:**

$$AF = \frac{NC1}{N2 \quad N1}$$

*NC1* = **Rotor first critical speed (cycles per minute).**
*N1* = **Initial (lesser) speed at 0.707 × peack amplitude (critical).**
*N2* = **Initial (greater) speed at 0.707 × peack amplitude (critical).**

**6.9.1.4** Critical speeds shall be determined analytically by means of a damped unbalanced rotor response analysis and shall be confirmed by test-stand data.

**6.9.1.5** An exciting frequency may be less than, equal to, or greater than the rotational speed of the rotor.

Potential exciting frequencies considered in system design shall include but are not limited to the following sources:

**a)** Unbalance in the rotor system.
**b)** oil-film instabilities (whirl);
**c)** internal rubs;
**d)** blade, vane, nozzle, and diffuse passing frequencies;
**e)** gear-tooth meshing and side bands;
**f)** coupling misalignment;
**g)** loose rotor-system components.
**h)** hysteretic and friction whirl;
**i)** boundary-layer flow separation;

**j)** acoustic and aerodynamic cross-coupling forces;
**k)** asynchronous whirl.

**6.9.1.6** Resonances of support systems within the vendor's scope of supply shall not occur within the specified operating speed range or the specified separation margins, unless the resonances are critically damped.

**6.9.1.7** The Vendor who is specified to have unit responsibility shall determine that the drive-train critical speeds (rotor lateral, system torsional, blading modes, and the like) are compatible with the critical speeds of the machinery being supplied and that the combination is suitable for the specified operating speed range, including any starting-speed detent (hold-point) requirements of the train. A list of all undesirable speeds from zero to trip shall be submitted to the Purchaser for his review and included in the instruction manual for his guidance.

### 6.9.2 Lateral analysis

**6.9.2.1** The Vendor shall provide a damped unbalanced response analysis for each machine to assure acceptable amplitudes of vibration at any speed from zero to trip. Calculated lateral critical speed completely with full detail procedure shall be submitted by Vendor.

**6.9.2.2** The damped unbalanced response analysis shall include but shall not be limited to the following considerations:

**a)** Support (base, frame, and bearing-housing) stiffness, mass, and damping characteristics, including effects of rotational speed variation. The vendor shall state the assumed support system values.

**b)** Bearing lubricant-film stiffness and damping changes due to speed, load, preload, oil temperatures, accumulated assembly tolerances, and maximum to minimum clearances.

**c)** 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.

**d)** Rotor masses, including the mass moment of coupling halves, stiffness, and damping effects (for example, accumulated fit tolerances, fluid stiffening and damping, and frame and casing effects).

**e)** Asymmetrical loading (for example, partial arc admission, gear forces, and eccentric clearances).

**6.9.2.3** The effects of other equipment in the train shall be included in the damped unbalanced response analysis (that is a train lateral analysis shall be performed).

**6.9.2.4** As a minimum, the damped unbalanced response analysis shall include items a through e below:

**a)** A plot and identification of the mode shape at each resonant speed (critically damped or not) from zero to trip, as well as the next mode occurring above the trip speed.

**b)** Frequency, phase, and response amplitude data at the vibration probe locations through the range of each critical speed, using the following arrangement of unbalance for the particular mode. This unbalance shall be sufficient to raise the displacement of the rotor at the probe locations to the vibration limit defined by the following equation:

$$LV = \sqrt{\frac{12.000}{N}} \qquad \textbf{(Eq. 1)}$$

**In SI units,** $LV = 25.4\sqrt{12.000}$

**Where:**

***Lv*** = Vibration limit (amplitude of unfiltered vibration), in mils (micrometers) peak to peak.
***N*** = Operating speed nearest the critical of concern, in revolutions per minute.

This unbalance shall no less than two times and no more than eight times the unbalance limit specified in 6.9.5.2. The Unbalance weight or weights shall be placed at the location or locations within the bearing span that have been analytically determined to affect the particular mode most adversely (for example, at mid span for translatory modes, or near both ends and 180 degrees out of phase for conical modes). For bending modes with maximum deflections at the shaft's ends, the amount of unbalance shall be based on the overhung mass rather than the static bearing loading.

**c)** Modal diagrams for each response in Item b above, indicating the phase and major-axis amplitude at each coupling engagement plane, the centerlines of the bearings, the locations of the vibration probes, and each seal area throughout the machine. The minimum design diametral running clearance of the seals shall also be indicated.

**d)** For the purposes of the verification test (see 6.9.3), an additional plot of a test unbalance, as specified in Item b above (based on static bearing loading for rigid modes or based on overhung mass for bending modes). This test weight shall be at least two times and no more than eight times the unbalance limit specified in 6.9.5.2 and shall be placed at a location determined by the Vendor.

**e)** The generation of a stiffness map of the undamped rotor response from which the damped unbalanced response analysis specified in Item C above was derived. This plot shall show frequency versus support system stiffness, with the calculated support system stiffness curves superimposed.

**6.9.2.5** The damped unbalance response analysis shall indicate that the machine in the unbalanced condition described in 6.9.2.4, Item b, will meet the following acceptance criteria.

**a)** If the amplification factor is less than 2.5 the response is considered critically damped and no separation margin is required.

**b)** If the amplification factor is 2.5-3.55, a separation margin of 15 percent above the maximum continuous speed and 5 percent below the minimum operating speed is required.

**c)** If the amplification factor is greater than 3.55 and the critical response peak is below the minimum operating speed, the required separation margin (a percentage of minimum speed) is equal to the following:

$$SM = 100 - \left(84 + \frac{6}{AF - 3}\right) \qquad \textbf{(Eq. 2)}$$

**d)** If the amplification factor is greater than 3.55 and the critical response peak is above the trip speed, the required separation margin (a percentage of maximum continuous speed) is equal to the following:

$$SM = \left(126 - \frac{6}{AF - 3}\right) - 100 \qquad \textbf{(Eq. 3)}$$

**6.9.2.6** The calculated unbalanced peak-to-peak rotor amplitudes (see 6.9.2.4, Item b) at any speed from zero to trip shall not exceed 75 percent of the minimum design diametral running clearances throughout the machine (with the exception of floating-ring seal locations).

### 6.9.3 Shop verification of unbalanced response analysis

**6.9.3.1** The actual critical speed responses, as revealed on the test stand with a rotor unbalance magnitude in accordance with 6.9.2.4, Item d, placed at a location (usually the coupling) determined by the Vendor, shall be the criteria for confirming the validity of the damped unbalanced response analysis.

**Note:**

**It is recognized that the dynamic response of the machine on the test stand will be a function of the agreed-upon test conditions and that unless the test-stand results are obtained at the conditions of pressure, temperature, speed, and load expected in the field, they may not be the same as the results expected in the field.**

**6.9.3.2** The parameters to be measured during the test shall be speed and shaft vibration amplitudes with corresponding phase from each pair x-y vibration probes, shall be vectorially summed at each response peak to determine the maximum amplitude of vibration. The major-axis amplitude of each response peak shall not exceed the limits specified in.

**6.9.3.3** The gain of the recording instrumentation used shall be predetermined and preset before the test so that the highest response peak is within 60-100 percent of the recorder's full scale on the test-unit coast-down (deceleration).

**Notes:**

**1) It is recognized that vectorial subtraction of slow-roll (300-600 revolutions per minute) total electrical and mechanical runout is always required for this verification and that vectorial subtraction of bearing-housing motion is normally required.**

**2) The phase on each vibration signal, x or y, is the angular measure, in degrees, of the phase difference (lag) between a phase reference signal (from a phase transducer sensing a once-per-revolution mark on the rotor, as described in API Standard 670) and the next positive peak, in time, of the synchronous (1x) vibration signal. (When proximity probes are used, this is the lag angle between the vibration probe and the high spot on the rotor.)**

**3) The major-axis amplitude is properly determined from a lissajous (orbit) display on an oscilloscope, oscillograph, or equivalent. When the phase angle between the x and y signals is not 90 degrees, the major-axis amplitude can be approximated by (x2+y2)1/2. When the phase angle between the x and y signals is 90 degrees, the major-axis value is the greater of the two vibration signals.**

**6.9.3.4** Additional testing and correction of the original damped unbalanced rotor response analysis will be required if, from the test data described above and/or a phase or amplitude indication in the damped unbalanced response analysis (based on the unbalance conditions described in 6.9.2.4, Item b) it appears that either of the following conditions exists:

**a)** Any critical response will fail to meet the separation margin requirements (see 6.9.2.5) or will fall within the operating speed range.

**b)** The requirements of 6.9.2.6 have not been met.

**6.9.3.5** Unbalance weights shall be determined and placed as mutually agreed upon by the Purchaser and the Vendor (see 6.9.2.4, Items b and d). Unbalance magnitudes shall be achieved by adjusting the residual unbalance that exists in the rotor from the initial run to raise the displacement of the rotor at the probe locations to the vibration limit defined by Equation 1 (see 6.9.2.4, Item b) at the maximum continuous speed. The measurements from this test, taken in accordance with 6.9.3.2, shall indicate the following acceptance criteria for the machine:

**a)** At no speed shall the shaft deflections exceed 90 percent of the minimum design running clearances.
**b)** At no speed within the operating speed range shall the shaft deflections exceed 55 percent of the minimum design running clearances or 150 percent of the allowable vibration limit at the probes (see 6.9.2.4, Item b).

The internal deflection limits specified in Items a and b above shall be based on the calculated displacement ratios between the probe locations and the areas of concern identified in 6.9.2.4, Item c. Actual internal displacements for these tests shall be calculated by multiplying these ratios by the major-axis amplitudes (see 6.9.3.2). Acceptance will be based on these calculated displacements, not on inspection of seals after testing; however, damage to any portion of the machine as a result of this testing shall constitute failure of the test. Minor internal seal rubs that do not cause clearance changes outside the vendor's new-part tolerance do not constitute damage.

### 6.9.4 Torsional analysis

**6.9.4.1** Excitations of torsional resonances may come from many sources, which should be considered in the analysis. These sources may include but are not limited to the following:

**a)** Gear problems such as unbalance and pitch line runout.
**b)** Start-up conditions such as speed detents (under inertial impedances) and other torsional oscillations.
**c)** Torsional transients such as start-ups of synchronous electric motors.

**6.9.4.2** The torsional resonances of the complete train shall be at least 10 percent above or 10 percent below any possible excitation frequency within the specified operating speed range (from minimum to maximum continuous speed).

**6.9.4.3** Torsional critical 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. In addition to multiples of running speeds, torsional excitations that are not a function of operating speeds or that are non-synchronous in nature shall be considered in the torsional analysis when applicable identification of these frequencies shall be the mutual responsibility of the Purchaser and the Vendor.

**6.9.4.4** The Vendor shall perform a torsional vibration analysis of the complete coupled train (including gears, if any) and shall be responsible for directing the modifications necessary to meet the requirements of 6.9.4.1 through 6.9.4.3. Calculated torsional critical speed completely with full detail procedure shall be submitted by Vendor.

### 6.9.5 Vibration and balancing

**6.9.5.1** Major parts of the rotating element, such as the shaft, balancing drum, and impellers, shall be dynamically balanced. When a bare shaft with a single keyway is dynamically balanced, the keyway shall be filled with a fully crowned half-key. The initial balance correction to the bare shaft shall be recorded. A shaft with keyways 180 degrees apart but not in the same transverse plane shall also be filled as described above.

**6.9.5.2** If rotor arrangement permits, the rotating element shall be multiplane dynamically balanced during assembly. This shall be accomplished after the addition of no more than two major components. Balancing correction shall be applied only to the elements added. Minor correction of other components may be required during the final trim balancing of the completely assembled element. In the sequential balancing process, any half-keys used in the balancing of the bare shaft (see 6.9.5.1) shall continue to be used until they are replaced with the final key and mating element. The weight of all half-keys used during final balancing of the assembled element shall be recorded on the residual unbalance work sheet . The maximum allowable residual unbalance per plane (journal) shall be calculated as follows:

$$U_{max.} = 4\ W/N$$

**In SI Units:,** $$U_{max.} = 6350\ W/N$$

**Where:**

| | | |
|---|---|---|
| $U_{max.}$ | = | residual unbalance, in ounce-inches (gram-millimeters). |
| $W$ | = | journal static weight load, in pounds (kilograms). |
| $N$ | = | maximum continuous speed, in revolutions per minute. |

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

**6.9.5.3** After the final balancing of each assembled rotating element has been completed, a residual unbalance check shall be performed and recorded.

**6.9.5.4** High-speed balancing (balancing in a high-speed balancing machine at the operating speed) shall be done only with the purchaser’s specific approval. The acceptance criteria for this balancing shall be mutually agreed upon by the Purchaser and the Vendor.

**6.9.5.5** During the shop test of the machine, assembled with the balanced rotor, operating at its maximum continuous speed or at any other speed within the specified operating speed range, the peak-to-peak amplitude of unfiltered vibration in any plane, measured on the shaft adjacent and relative to each radial bearing, shall not exceed the following value or 2.0 mils (50 micrometers), whichever is less:

$$A = \sqrt{\frac{12.000}{N}}$$

**In SI Units:** $A = 25.4\sqrt{\frac{12.000}{N}}$

**Where:**

> ***A*** = amplitude of unfiltered vibration, in mils (micrometers) peak to peak.
> ***N*** = maximum continuous speed, in revolutions per minute.

At any speed greater than the maximum continuous speed, up to and including the trip speed of the driver, the vibration shall not exceed 150 percent of the maximum value recorded at the maximum continuous speed.

**Note:**

**These limits are not to be confused with the limits specified in 6.9.3 for shop verification of unbalanced response.**

**6.9.5.6** Electrical and mechanical runout shall be determined and recorded by recorded by rolling the rotor in V blocks while measuring runout with a noncontacting vibration probe and a dial indictor at the same shaft location.

**6.9.5.7** If the Vendor can demonstrate that electrical or mechanical runout is present, a maximum of 25 percent of the test level calculated from above equation or 0.25 mil (6.4 micrometers), whichever is greater, may be vectorially subtracted from the vibration signal measured during the factory test.

## 6.10 Lube-Oil and Seal-Oil Systems

**6.10.1** Unless otherwise specified, a pressurized common lube oil system shall be furnished to supply oil at a suitable pressure to turbine, driven equipment, and all train accessories as necessary, the turbine Vendor and driven equipment Vendor shall mutually decide on oil characteristics.

**6.10.2** Oil reservoirs and housings that enclose moving lubricated parts (such as bearings, shaft seals, highly polished parts, instruments, and control elements) shall be designed to minimize contamination by moisture, dust, and other foreign matter during periods of operation or idleness.

**6.10.3** Seal Oil system shall be separate, therefore the means of preventing the interchange of oil between the seal and Oil systems shall be described in the Vendor's proposal.

**6.10.4** Unless otherwise specified, pressurized Oil systems shall conform to the requirements of IPS-M-PM-320.

**Note:**

**When approved by the purchaser a pressurized integral Oil system may be provided for closed loop, turbo expander compressor loaded compact design. In this case a continuous indicator of actual lubricant viscosity at the bearing inlet shall be required.**

**6.10.5** The Vendor shall state in the operating manual the required amount, specifications, and supply temperature and pressure ranges for the lubricating oil.

## 6.11 Materials

### 6.11.1 General

**6.11.1.1** Materials of construction shall be the Manufacturer's Standard for the specified operating conditions, except as required or prohibited by the data sheets or by this Standard.

**6.11.1.2** Materials shall be identified in the proposal with their applicable ASTM, AISI, ASME, or SAE numbers, including the material grade. When no such designation is available, the vendor's material specification, giving physical properties, chemical composition, and test requirements, shall be included in the proposal.

**6.11.1.3** Copper and copper alloys excluding monel or its equivalent, bearing babbitt, and precipitation hardened stainless steels shall not be used for parts of expander or auxiliaries in contact with corrosive gas or with gases capable of forming explosive copper compounds. It will be the responsibility of the purchaser to note such gas characteristics on the inquiry or data sheets.

**6.11.1.4** The Vendor shall specify ASTM optional tests and inspection procedures necessary to ensure that materials are satisfactory for the service. Such tests and inspections shall be listed in the proposal. The Purchaser should consider specifying additional tests and inspections, especially for materials in critical service.

**6.11.1.5** Unless otherwise specified casing shall be made of steel.

**6.11.1.6** Materials exposed to $H_2S$ gas service 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 be limited to a yield strength not exceeding 90,000 pounds per square inch (6200 bar) and a hardness not exceeding rockwell C 22. Components that are fabricated by welding shall be stress relieved, if required, so that both the welds and the heat-affected zones meet the yield strength and hardness requirements. The purchaser will specify on the data sheets the presence of $H_2S$ in the process gas.

**6.11.1.7** The purchaser will specify the presence of any corrosive agents in the process gas, the process stream, and the environment, including constituents that may cause stress corrosion cracking.

**6.11.1.8** If parts made from austenitic stainless steels are exposed to a process gas or environmental condition that promotes intergranular corrosion, stabilized or low-carbon grades shall be used. Austenitic steels shall not be used in services where stress corrosion cracking is a possibility.

**Note:**

**Overlays or hard surfaces that contain more than 0.10 percent carbon can sensitize both low-carbon and stabilized grades of austenitic stainless steel unless a buffer layer that is not sensitive to intergranular corrosion is applied.**

**6.11.1.9** In hydrogen service at partial pressures greater than 100 pounds per square inch gage (6.89 bar) or at concentrations greater than 90 molal percent at any pressure, impeller materials that have a yield strength in excess of 120,000 pounds per square inch or a hardness in excess of rockwell C 34 are prohibited.

**6.11.1.10** For the pressure casing materials, casting factors, and the quality of any welding shall be equal or superior to those required by Section VIII, Division 1, of the ASME Code. The manufacturer's data report forms, as specified in the code are not required .

**6.11.1.11** External parts that are subject to rotary or sliding motions (such as control linkage joints and adjusting mechanisms) shall be of corrosion-resistant materials suitable for the site environment.

**6.11.1.12** Minor parts that are not identified (such as nuts, springs, washers, gaskets, and keys) shall have corrosion resistance at least equal to that of specified parts in the same environment.

**6.11.1.13** Unless otherwise specified the minimum quality bolting material for pressure joints shall be high temperature alloy steel (ASTM 193, grade B7). Nuts shall conform to ASTM A 194, grade 2 H for temperatures below -20°F (-29°C), low temperature bolting material in accordance with ASTM A 320 shall be used.

**6.11.1.14** Where mating parts such as studs and nuts of AISI Standard type 300 stainless steel or materials with similar galling tendencies are used, they shall be lubricated with a suitable antiseizure compound.

**6.11.1.15** O-rings shall be compatible with all specified services. For high-pressure services, special consideration shall be given to the selection of O-rings to ensure that they will not be damaged upon rapid de-pressuring of the turbine.

### 6.11.2 Pressure containing parts

**6.11.2.1** Welding of piping and pressure-containing parts, as well as any dissimilar-metal welds and weld repairs, shall be performed and inspected by operators and procedures qualified in accordance with Section IX of the ASME code.

**6.11.2.2** The Vendor shall be responsible for establishing weld repair procedures that are in compliance with the applicable requirements of the ASME code and for the implementation of repairs in accordance with these procedures, including post-repair heat treatment, if required, and nondestructive examination of repairs. Such procedures are subject to review by the purchaser before repair is made.

**6.11.2.3** Castings shall be sound and free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters, and similar injurious defects. Surfaces of castings shall be cleaned by sandblasting, shotblasting, chemical cleaning, pickling, or any other Standard method. Mold-parting fins and remains of gates and risers shall be chipped, filed, or ground flush.

**6.11.2.4** The use of chaplets in pressure castings shall be held to a minimum. The chaplets shall be clean and corrosion free (plating permitted) and of a composition compatible with the casting.

**6.11.2.5** Weldable grades of steel castings may be required by welding, using a qualified welding procedure based on the requirements of Section VIII, Division I, and Section IX of the ASME Code, all repairs shall meet the inspection requirement.

**6.11.2.6** Pressure-containing casings made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 6.11.2.6.1 through 6.11.2.6.4.

**6.11.2.6.1** Plate edges shall be inspected by magnetic particle or liquid penetrant examination as required by Section VIII, Division 1, UG-93(d)(3), of the ASME Code.

**6.11.2.6.2** Accessible surfaces of welds shall be inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after stress relieving (see 6.11.4.1).

**6.11.2.6.3** Pressure-containing welds, including welds of the case to horizontal-and vertical-joint flanges, shall be full-penetration (complete-joint) welds unless otherwise approved by the Purchaser prior to any fabrication. For exceptions, see 6.3.

**6.11.2.6.4** Fabricated casings, including main nozzles, shall be post-weld heat treated, regardless of thickness. For exceptions, see 6.3.

**6.11.2.7** Welded casings shall be examined radiographically or ultrasonically. (See 6.11.4.1 for required procedures and acceptance criteria.) 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 the Purchaser.

### 6.11.3 Low temperature

For operating temperatures below 20°F (-29°C) or when specified for other low ambient temperatures, steels shall have, at the lowest specified temperature, an impact strength sufficient to qualify under the minimum charpy V-notch impact energy requirements of Section VIII, Division 1, UG-84, of the ASME Code. For materials and thicknesses not covered by the code, the Purchaser will specify the requirements on the data sheets.

### 6.11.4 Material inspection of pressure containing parts

**6.11.4.1** When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the procedures and acceptance criteria in 6.11.4.1.1 through 6.11.4.1.4 shall apply, except as noted.

**6.11.4.1.1** Radiographic examination shall be in accordance with Section VIII, Division 1, UW-51 (%100) and UW-52 (spot), of the ASME Code, spot radiography shall consist of a minimum of one 6-inch (152-millimeter) spot radiograph for each 25 feet (7.6 meters) of weld on each casing. As a minimum, one spot radiograph is required for each welding procedure and welder used for pressure-containing welds.

**6.11.4.1.2** Ultrasonic examination shall be in accordance with Section VIII, Division 1, UW-53 and Appendix 12, of the ASME Code.

**6.11.4.1.3** Magnetic particle examination shall be in accordance with Section VIII, Division 1, Appendix 6, of the ASME Code and ASTM A 709. Linear indications shall be considered relevant only if the major dimension exceeds 1/16 inch (1.6 millimeters). Individual indications that are separated by less than 1/16 inch (1.6 millimeters) shall be considered continuous.

**6.11.4.1.4** Liquid penetrant examination shall be in accordance with Section VIII, Division 1, Appendix 8, of the ASME Code.

**6.11.4.2** Cast steel casing parts shall be examined by magnetic particle methods. Acceptability of defects shall be based on a comparison with the photographs in ASTM E 125. For each type of defect, the degree of severity shall not exceed the limits specified in the following Table. Regardless of these generalized limits, it shall be the vendor's responsibility to review the design limits of all castings in the event that more stringent requirements are specified. Defects that exceed the limits imposed in Table bellow shall be cleaned out to meet the quality standards cited above, as determined by additional magnetic particle inspection before repair welding.

**MAXIMUM SEVERITY OF DEFECTS IN CASTINGS**

| TYPE | DEFECT | DEGREE |
|---|---|---|
| I | Linear Discontinuities | 1 |
| II | Shrinkage | 2 |
| III | Inclusions | 2 |
| IV | Chills and Chaplets | 1 |
| V | Porosity | 1 |
| VI | Welds | 1 |

### 6.11.5 Impellers

**6.11.5.1** All accessible areas of welds on welded impellers shall be inspected by magnetic particle or liquid penetrant examination.

**6.11.5.2** Cast impellers shall be inspected by radiographic or ultrasonic means prior to finish machining. Details of inspection techniques and acceptance criteria shall be mutually agreed upon by the Vendor and the Purchaser.

**6.11.5.3** After the overspeed test described in 8.3.2, each impeller shall be examined all over by means of magnetic particle or liquid penetrant methods.

## 6.12 Nameplates and Rotation Arrows

**6.12.1** A nameplate shall be securely attached at an easily accessible point on the equipment and on any other major piece of auxiliary equipment.

**6.12.2** Rotation arrows shall be cast in or attached to each major item of rotating equipment. Nameplates and rotation arrows (if attached) shall be of AISI Standard type 300 stainless steel or of nickel-copper alloy (monel or its equivalent). Attachment pins shall be of the same material.

**6.12.3** The purchaser's item number, the vendor's name, the machine's serial number ,and the machine's size and type, as well as its minimum and maximum allowable design limits and rating data (including pressures, temperatures, speeds, and power), maximum allowable working pressures and temperatures, hydrostatic test pressures, and critical speeds, shall appear on the machine's nameplate.

**Note:**

**Any lateral critical speeds determined on the running tests shall be stamped on the nameplate followed by the word test. Critical speeds that are predicted by calculation up to and including the critical speed above trip speed and are not identifiable by test shall be stamped on the nameplate followed by the abbreviation calc.**

# 7. ACCESSORIES

## 7.1 Couplings and Guards

**7.1.1** Unless otherwise specified, flexible couplings shall be furnished.

**7.1.2** Couplings and guards shall conform to Standard IPS-M-PM-310, the make, type, and mounting arrangement of the coupling shall be agreed upon by the Purchaser and the Vendors.

**7.1.3** Idling adapter's/solo plates in accordance with 8.3.4 shall be furnished by the manufacturer of the coupling to the turbine manufacturer along with the half-coupling. Upon completion of all testing, the idling adapters/solo plates shall be furnished to the owner a part of the special tools.

## 7.2 Mounting Plates

**7.2.1** Unless otherwise specified the equipment shall be furnished with baseplate, the data sheets shall indicate the major equipment to be mounted on it.

**7.2.2** The upper and lower surfaces of bearing pedestals and mounting plates shall be machined parallel to within 0.0005 inch per foot (0.042 millimeter per meter). These surface finishes shall be 125 to 250 microinches (3.2 to 6.4 micrometers) Ra .

**7.2.3** The equipment feet and mounting plates shall be equipped with vertical jackscrews.

**7.2.4** When the equipment supported weighs more than 1000 pounds (453 kilograms), the mounting plates shall be furnished with horizontal jackscrews the same size as or larger than the vertical jackscrews.

**7.2.5** Machinery supports shall be designed to limit a change of alignment caused by the worst combination of pressure, torque, and allowable piping stress to 0.002 inch (50 micrometers) at the coupling flange (see 6.4 for allowable piping forces).

**7.2.6** When epoxy grout is specified on the data sheet, the Vendor shall prepare all grouting surfaces to a degreased near-white-metal finish and coat them with a catalyzed epoxy primer as specified by the Vendor and approved by the Purchaser. The method of application shall be submitted by Vendor for approval.

**7.2.7** Mounting plates shall not be drilled for equipment to be mounted by others. Mounting plates intended for installation on concrete shall be supplied with leveling screws. Mounting plates that are to be grouted shall have 2-inch-radiused (50-millimeter-radiused) outside corners (in the plan view).

**7.2.8** Anchor bolts, fasteners for attaching the components to the mounting plates and jackscrews for leveling the pedestal soleplate shall be supplied by the Vendor.

**7.2.9** The equipment feet shall be drilled with pilot holes that are accessible for use in final dwelling.

**7.2.10** Mounting surfaces that are not to be grouted shall be coated with rust preventive immediately after machining.

**7.2.11** The vendor shall furnish stainless steel shim packs at least 1/8 inch (3.2 millimeters) thick between the equipment feet and baseplate. All shim packs shall straddle hold down bolts.

**7.2.12** 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 dwelled mating surfaces to ensure accurate field reassembly.

**Note:**

**A baseplate with a nominal length of more than 40 feet (12 meters) or a nominal width of more than 12 feet (3.6 meters) may have to be fabricated in multiple sections because of shipping restrictions.**

**7.2.13** When specified, the baseplate shall be provided with leveling pads or targets protected with removable covers. The pads or targets shall be accessible for field leveling after installation, with the equipment mounted and the baseplate on the foundation.

**7.2.14** When specified, the baseplate shall be suitable for column mounting (that is, of sufficient rigidity to be supported at specified points) without continuous grouting under structural members. The baseplate design shall be mutually agreed upon by the purchaser and the Vendor.

**7.2.15** The baseplate shall be provided with lifting lugs for at least a four-point lift. Lifting the baseplate complete with all equipment mounted shall not permanently distort or otherwise damage the baseplate or the machinery mounted on it.

**7.2.16** The bottom of the baseplate between structural members shall be open. When the baseplate is installed on a concrete foundation, accessibility shall be provided for grouting under all load-carrying structural members. The mounting pads on the bottom of the baseplate shall be in one plane to permit use of a single-level foundation. When specified, subsoleplates shall be provided by the Vendor.

**7.2.17** Unless otherwise specified, nonskid decking covering all walk and work areas shall be provided on the top of the baseplate.

**7.2.18** The baseplate shall be extended as necessary to support the driven, gear units, and/or the control panel.

## 7.3 Control and Instrumentation

### 7.3.1 General

**7.3.1.1** Unless otherwise specified, controls and instrumentation shall be suitable for outdoor installation.

**7.3.1.2** Where applicable, control and instrumentation shall conform to API recommended practice 550, API Standard 670 and API Standard 678.

**7.3.1.3** All conduit on the equipment shall be designed so that it can be easily removed without damage/removal of bearings, seals, or the expander internals.

### 7.3.2 Control Systems

**7.3.2.1** The machinery may be controlled on the basis of inlet pressure, discharge pressure, intermediate pressure (when a compressor loaded compact design is used), flow or some combination of these parameters. Unless otherwise specified, control will be accomplished by variable inlet guide vanes.

**7.3.2.2** The control system may be pneumatic, hydraulic, electric, or any combination thereof. The system may be manual, or it may be automatic with a manual override. The Purchaser will specify the source of the control signal, its sensitivity and range, and the equipment to be furnished by the Vendor.

**7.3.2.3** The turbine shall be equipped with an independent emergency overspeed system that shuts off gas to turbine when running speed reaches trip speed as per NEMA SM 23 standard.

The emergency trip system shall have the following characteristics:

**a)** Easy accessibility.
**b)** The capability to be manually tripped with maximum inlet gas pressure and flow in the line.
**c)** The capability to stop the turbine under any load condition of the turbine.
**d)** The capability to be reset with maximum inlet pressure on the line.
**e)** Sparkproof components and suitability for use in hazardous gas and outdoor locations.

**Notes:**

**The Purchaser should provide a block valve on the inlet gas line to close the turbine.**
**This valve should be closed before the overspeed trip system is reset.**

**7.3.2.4** Unless otherwise specified, speed shall be adjusted by means of a hand speed changer.

**7.3.2.5** When a control signal is specified for speed adjustment, the Vendor shall provide a speed-setting mechanism arranged so that, the full range of the purchaser's specified control signal shall correspond to the required operating range of the driven equipment. Unless otherwise specified the maximum control signal shall correspond to the maximum continuous speed.

### 7.3.3 Instrument and control panels

**7.3.3.1** A panel shall be provided and shall include all panel-mounted instruments for the driven equipment and the driver. Such panels shall be designed and fabricated in accordance with the purchaser's description. The Purchaser will specify whether the panel is to be freestanding, located on the base of the unit, or in another location. The instruments on the panel shall be clearly visible to the operator from the driver control point. A lamp test push button shall be provided. The instruments to be mounted on the panel will be specified by the Purchaser on the data sheets.

**7.3.3.2** Panels shall be completely piped and wired, requiring only connection to the purchaser's external piping and wiring circuits. When more than one wiring point is required on a unit for control or instrumentation, the wiring to each switch or instrument shall be provided from a single terminal box with terminal posts mounted on the unit (or its base, if any). Wiring shall be installed in metal conduits or enclosures. All leads and posts on terminal strips, switches, and instruments shall be tagged for identification.

### 7.3.4 Instrumentation

#### 7.3.4.1 General

**7.3.4.1.1** Unless otherwise specified, all leads on terminal strips, switches, and instruments shall be permanently tagged for identification. All terminal boards in junction boxes and control panels shall have at least 20 percent spare terminal points.

**7.3.4.1.2** When specified, air purging shall be used to avoid moisture problems, even when weatherproof and watertight housings are used. Purge air will be clean and dry, conforming to ISA S12.4, Type X or Y and NFPA 496, as specified.

#### 7.3.4.2 Thermometers and temperature gages

**7.3.4.2.1** Dial-type temperature gages shall be heavy duty and corrosion resistant. They shall be at least 5 inches (172 millimeters) in diameter and bimetallic or mercury filled. Black printing on a white background is Standard for gages.

**7.3.4.2.2** When specified, metal-case, glass-front, stem-type mercury thermometers shall be furnished.

**7.3.4.2.3** The sensing elements of thermometers and temperature gages shall be in the flowing fluid.

#### 7.3.4.3 Thermowells

Thermometers and temperature gages that are in contact with flammable or toxic fluids or that are located in pressurized or flooded lines shall be furnished with AISI Standard type 300 stainless steel separable-flange-type solid-bar thermowells at least ¾ inch (19 millimeters) in diameter.

#### 7.3.4.4 Thermocouples and resistance temperature detectors

Where practical, the design and location of thermocouples and resistance temperature detectors, except bearing temperature sensors, shall permit replacement while the unit is operating. The lead wires of thermocouples and resistance temperature detectors shall be installed as continuous leads between the thermowell or detector and the terminal box. Conduit runs from thermocouple heads to a pull box or boxes located on the baseplate shall be provided.

#### 7.3.4.5 Pressure gages

Pressure gages (not including built-in instrument air gages) shall be furnished with AISI Standard type 316 stainless steel bourdon tubes and stainless steel movements, 4½ -inch (114-millimeter) dials [6-inch (152-millimeter) dials for the range over 800 pounds per square inch (55 bar)] and 1½ -inch national pipe thread (NPT) male alloy steel connections. Black printing on a white background is Standard for gages. When specified, oil-filled gages shall be furnished in locations subject to vibration. Gage ranges shall preferably be selected so that the normal operating pressure is at the middle of the gage's range. In no case, however, shall the maximum reading on the dial be less than the applicable relief valve setting plus 10 percent. Each pressure gage shall be provided with a device such as a disk insert or blowout back designed to relieve excess case pressure.

#### 7.3.4.6 Solenoid valves

Direct-solenoid-operated valves shall be used only in clean, dry instrument air service, shall have class F insulation or better, and shall have a continuous service rating. When required for other services, the solenoid shall act as a pilot valve to pneumatic valves, hydraulic valves, and the like. Solenoid valves shall not be used in continuous services that may affect normal operations, such as fuel controls. They may be used in intermittent instrument services, such as starting-cycle controls

### 7.3.5 Alarms and shutdowns

#### 7.3.5.1 General

**7.3.5.1.1** Each alarm switch and each shutdown switch shall be furnished in a separate housing located to facilitate inspection and maintenance. Hermetically sealed, single-pole, double-throw switches with a minimum capacity of 5 amperes at 120 volts AC shall be used. Mercury switches shall not be used.

**7.3.5.1.2** Unless otherwise specified, electric switches that open (deenergize) to alarm and close (energize) to trip shall be furnished by the Vendor.

**7.3.5.1.3** The sequence of alarm and shutdown operation shall be as described in 7.3.5.1.3.1 through 7.3.5.1.3.5.

**7.3.5.1.3.1** Any alarm or shutdown condition shall be initiated by the action of field contacts.

**7.3.5.1.3.2** Alarm and shutdown indications shall consist of a corresponding panel-light illumination and the sounding of a horn.

**7.3.5.1.3.3** Acknowledgment of the alarm and/or shutdown condition shall be accomplished by operating a common horn silence push button suitably located on the panel. This shall silence the horn.

**7.3.5.1.3.4** After the alarmed field condition has been corrected, the corresponding panel alarm light shall remain lit until a common panel-mounted reset push button is operated (a manual reset). In the interim, any additional field alarm condition or conditions will again sound the horn and illuminate the corresponding additional panel light or lights.

**7.3.5.1.3.5** Shutdown panel lights shall contain a first-out feature (that is, only the first shutdown light shall be illuminated). After a shutdown occurs, operation of the reset push button shall be required before the unit can be restarted.

**7.3.5.1.4** Connections shall be provided to actuate a remote alarm when any of the locally displayed machine alarms or shutdowns operate.

**7.3.5.1.5** The Vendor shall furnish a first-out annunciator when an annunciator system is specified.

#### 7.3.5.2 Alarm and trip

**7.3.5.2.1** Alarm and trip switch settings shall not be adjustable from outside the housing. Alarm and trip switches shall be arranged to permit testing of the control circuit, including, when possible, the actuating element, without interfering with normal operation of the equipment. The Vendor shall provide a clearly visible light on the panel to indicate when trip circuits are in a test bypass mode. Unless otherwise specified, shutdown systems shall be provided with switches or another suitable means to permit testing without shutting down the unit.

**7.3.5.2.2** Pressure-sensing elements shall be of AISI Standard Type 300 stainless steel. Low-pressure alarms shall be equipped with a valved bleed or vent connection to allow controlled depressurizing so that the operator can note the alarm set pressure on the associated pressure gage. High-pressure alarms shall be equipped with valved test connections so that a portable test pump can be used to raise the pressure.

**7.3.5.3** All instruments and controls other than shutdown sensing devices shall be installed with sufficient valving to permit their removal while the system is in operation.

**7.3.5.4** Particular attention is called to the requirements of 6.1.12 concerning the characteristics of housings for arcing-type switches outlined in the applicable codes.

### 7.3.6 Electrical systems

**7.3.6.1** The characteristics of electrical power supplies for motors, heaters, and instrumentation will be specified by the Purchaser. A pilot light shall be provided on the incoming side of each supply circuit to indicate that the circuit is energized. The pilot lights shall be installed on the control panels.

**7.3.6.2** Electrical equipment located on the unit or on any separate panel shall be suitable for the hazard classification specified (see 6.1.12). Electrical starting and supervisory controls may be either AC or DC.

**7.3.6.3** Power and control wiring within the confines of the baseplate shall be resistant to heat, moisture, and abrasion. Stranded conductors shall be used within the confines of the baseplate and in other areas subject to vibration. Measurement and remote-control panel wiring may be solid conductor. Where rubber insulation is used, a neoprene or equivalent high-temperature thermoplastic sheath shall be provided for insulation protection. Wiring shall be suitable for environmental temperatures.

**7.3.6.4** Unless otherwise specified, all leads on terminal strips, switches, and instruments shall be permanently tagged for identification. All terminal boards in junction boxes and control panels shall have at least 20 percent spare terminal points.

**7.3.6.5** To facilitate maintenance, liberal clearances shall be provided for all energized parts (such as terminal blocks and relays) on equipment. The clearances required for 600 Volt service shall also be provided for lower voltages.

**7.3.6.6** Electrical materials including insulation shall be corrosion resistant and nonhygroscopic insofar as is possible. When specified for tropical location, materials shall be given the treatments specified in 7.3.6.6.1 and 7.3.6.6.2.

**7.3.6.6.1** Parts (such as coils and windings) shall be protected from fungus attack.

**7.3.6.6.2** Unpainted surfaces shall be protected from corrosion by plating or another suitable coating.

**7.3.6.7** Control, instrumentation, and power wiring (including thermocouple leads) within the limits of the baseplate shall be installed in rigid metallic conduits and boxes, properly bracketed to minimize vibration and isolated or shielded to prevent interference between voltage levels. Conduits may terminate (and in the case of temperature element heads, shall terminate) with a flexible metallic conduit long enough to permit access to the unit for maintenance without removal of the conduit. If thermocouple heads will be exposed to temperatures above 140°F (60°C), a ¾ inch (19 millimeter) bronze hose with four-wall interlocking construction and joints with packed-on (heatproof) couplings shall be used.

**7.3.6.8** For Division 2 locations, flexible metallic conduits shall have a liquidtight thermosetting or thermoplastic outer jacket. For division 1 locations, and NFPA approved connector shall be provided.

**7.3.6.9** Motors for auxiliary equipment shall be suitable for the area classification specified and shall be in accordance with article 500 of NFPA 70. Auxiliary equipment motors shall be explosion proof.

### 7.3.7 Vibration, position, and bearing temperature detectors

**7.3.7.1** Shaft vibration and axial-position transducers shall be supplied, installed, and calibrated in accordance with API Standard 670.

**7.3.7.2** Vibration and axial-position monitors shall be supplied and calibrated in accordance with API Standard 670.

**7.3.7.3** A bearing-temperature monitor shall be supplied and calibrated according to API Standard 670.

**7.3.7.4** Accelerometer-based vibration transducers shall be supplied, installed and calibrated in accordance with API Standard 678.

## 7.4 Piping and Appurtenances

### 7.4.1 General

**7.4.1.1** Piping design and joint fabrication, examination, and inspection shall be in accordance with ASME B31.3.

**7.4.1.2** Auxiliary systems are defined as piping systems that are in the following services:

**a)** Instrument and control air,
**b)** lubricating oil,
**c)** control oil,
**d)** seal oil,
**e)** cooling water,
**f)** balance gas,
**g)** buffer gas,
**h)** drains.

**Note:**

**Casing connections are discussed in 6.2.6.**

**7.4.1.3** Piping systems shall include piping, isolating valves, control valves, relief valves, pressure reducers, orifices, thermometers and thermowells, pressure gages, sight flow indicators, and all related vents and drains.

**7.4.1.4** The Vendor shall furnish all piping systems, including mounted appurtenances, located within the confines of the main unit's base area, any console base area, or any auxiliary base area. The piping shall terminate with flanged connections at the edge of the base. The Vendor shall furnish interconnecting piping between equipment groupings and off base facilities.

**7.4.1.5** The piping specification of Standard IPS-M-PM 320 shall apply to all lube, seal, and control-oil piping provided by the Vendor.

**7.4.1.6** Instrument lines containing flammable or toxic gas or oil shall be provided with shutoff valves at the points of measurement

**7.4.1.7** 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.

**7.4.1.8** When a buffer-gas manifold is specified, the required components such as valves, flow meters, check valves, pressure indicators, throttle valves, differential pressure indicators, controllers, and control valves shall be furnished by the Vendor.

**7.4.1.9** Provision for bypassing the bearings (and seals if applicable) of turbine and driven during oil-system flushing operations shall be provided.

### 7.4.2 Instrument piping

Connections on equipment and piping for pressure instruments and test points shall conform to IPS-M-PM-320. Beyond the initial ¾ inch isolating valve, ½ inch piping, valves, and fittings may be used. Where convenient, a common connection may be used for remotely mounted instruments that measure the same pressure. Separate secondary ½ inch isolating valves are required for each instrument on a common connection. Where a pressure gage is to be used for testing pressure alarm or shutdown switches, common connections are required for the pressure gage and switches.

### 7.4.3 Process piping

**7.4.3.1** The extent of process piping to be supplied by the Vendor will be specified by the Purchaser.

**7.4.3.2** Except for the material specified by the Purchaser, the requirements of 7.4.1 (if applicable) shall apply to process piping supplied by the Vendor.

## 7.5 Special Tools

**7.5.1** When special tools and fixtures are required to disassemble, assemble, or maintain the unit, they shall be included in the quotation and furnished as part of the initial supply of the machine. For multiunit installations, the requirements for quantities of special tools and fixtures shall be mutually agreed upon by the Purchaser and the Vendor. These or similar special tools shall be used during shop assembly and post-test disassembly of the equipment.

**7.5.2** When special tools are provided, they shall be packaged in separate, rugged boxes and marked "special tools for (tag/item number)". Each tool shall be stamped or tagged to indicate its intended use.

# 8. INSPECTION, TESTING, AND PREPARATION FOR SHIPMENT

## 8.1 General

**8.1.1** After advance notification of the Vendor by the Purchaser, the Purchaser's representative shall have entry to all Vendor and subvendor plants where manufacturing, testing, or inspection of the equipment is in progress.

**8.1.2** Auxiliary equipment such as gears, and oil systems shall be inspected and tested in accordance with the specified IPS Standards for the equipment as well as the requirements of this Standard.

**8.1.3** The Vendor shall provide at least two weeks advance notice to the purchaser before conducting any inspection or test that the Purchaser has specified to be witnessed or observed.

**8.1.4** The Vendor shall notify subvendors of the Purchaser's inspection and testing requirements.

**8.1.5** The Purchaser will specify the extent of his participation in the inspection and testing.

**8.1.5.1** Witnessed means that a hold shall be applied to the production schedule and that the inspection or test shall be carried out with the Purchaser or his representative in attendance. For mechanical running or performance tests, this requires written notification of a successful preliminary test.

**8.1.5.2** Observed means that the purchaser shall be notified of the timing of the inspection or test; however, the inspection or test shall be performed as scheduled, and if the Purchaser or his representative is not present, the Vendor shall proceed to the next step. (The Purchaser should expect to be in the factory longer than for a witnessed test.)

**8.1.6** Equipment for the specified inspection and tests shall be provided by the Vendor.

## 8.2 Inspection

**8.2.1** The Vendor shall keep the following data available for at least 5 years for examination by the Purchaser or his representative upon request:

**a)** Necessary certification of materials, such as mill test reports.
**b)** Purchase specifications for all items on bills of materials.
**c)** Test data to verify that the requirements of the specification have been met.
**d)** Fully identified records of all heat treatment, whether performed in the normal course of manufacture or as part of a repair procedure.

**e)** Results of quality-control tests and inspections.
**f)** Running test data (see 8.3.3.2).
**g)** Final-assembly maintenance and running clearances.

**8.2.2** Pressure-containing parts shall not be painted until the specified inspection of the parts is completed.

**8.2.3** The Purchaser will specify the following:

**a)** Parts that shall be subjected to surface and subsurface examination.
**b)** The type of examination required, such as magnetic particle, liquid penetrant, radiographic, and ultrasonic examination.

**8.2.4** During assembly of the equipment and before testing, each component (including cast-in passages of these components) and all piping and appurtenances shall be cleaned by pickling or by another appropriate method to remove foreign materials, corrosion products, and mill scale.

**8.2.5** Any portion of the Oil system furnished shall meet the cleanliness requirements of IPS-M-PM-320.

**8.2.6** When specified, the Purchaser may inspect for cleanliness of the equipment and all piping and appurtenances furnished by or through the vendor before heads are welded to vessels, openings in vessels or exchangers are closed, or piping is finally assembled.

**8.2.7** The hardness of parts, welds, and heat-affected zones shall be verified as being within the allowable values by testing of the parts, welds, or zones. The method, extent, documentation, and witnessing of the testing shall be mutually agreed upon by the Purchaser and the Vendor.

**8.2.8** When specified by the Purchaser, the Purchaser's representative shall have access to the Vendor's quality-control program for review.

## 8.3 Testing

### 8.3.1 Hydrostatic test

**8.3.1.1** Pressure-containing parts (including auxiliaries) shall be tested hydrostatically with liquid at a minimum of 1½ times the maximum allowable working pressure but not less than 20 pounds per square inch gage (1.4 bar gage). The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested.

**8.3.1.2** Tests shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The hydrostatic test shall be considered satisfactory when neither leaks nor seepage through the casing or casing joint is observed for a minimum of 1 hour. Large, heavy castings may require a longer testing period to be agreed upon by the Purchaser and the Vendor. Seepage past internal closures required for testing of segmented cases and operation of a test pump to maintain pressure are acceptable.

**8.3.1.3** The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 50 parts per million. To prevent deposition of chlorides as a result of evaporative drying, all residual liquid shall be removed from tested parts at the conclusion of the test.

**8.3.1.4** If the part tested is to operate at a temperature at which the strength of a material is below the strength of that material at room temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at room temperature by that operating temperature. The stress values used shall conform to those given in ASME B31.3 for piping. For expander casings and pressure vessels, the stress values shall conform to those given in Section VIII, Division 1 or 2, as applicable, of the ASME Code. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The data sheets shall list actual hydrostatic test pressures.

### 8.3.2 Impeller test

**8.3.2.1** Each impeller shall be subjected to an overspeed test at not less than 115 percent of maximum continuous speed for a minimum duration of 1 minute. Impeller dimensions identified by the manufacturer as critical (such as bore, eye seal, and outside diameter) shall be measured before and after each overspeed test. All such measurements and the test speeds 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.

**8.3.2.2** To make sure that there will be no natural frequencies (critical speeds) within the operating speed range of the machine, Vendor shall do a frequency test on a test piece before manufacturing the impellers. In case natural frequencies are found within the operating range, the test piece and impeller pattern shall be modified.

### 8.3.3 Mechanical running test

**8.3.3.1** The requirement of 8.3.3.1.1 through 8.3.3.1.10 shall be met before the mechanical running test is performed.

**8.3.3.1.1** The contract shaft seals and bearings shall be used in the machine for the mechanical running test.

**8.3.3.1.2** All oil pressures, viscosities, and temperatures shall be within the range of operating values recommended in the Vendor's operating instructions for the specific unit being tested. Oil flow rates for each oil supply line shall be determined.

**8.3.3.1.3** Test-stand oil filtration shall be 10 microns nominal or better. Oil-system components downstream of the filters shall meet the cleanliness requirements of standard IPS-M-PM-320 before any test is started.

**8.3.3.1.4** All joints and connections shall be checked for tightness, and any leaks shall be corrected.

**8.3.3.1.5** All warning, protective, and control devices used during the test shall be checked, and adjustments shall be made as required.

**8.3.3.1.6** Facilities shall be installed to prevent the entrance of oil into the machine during the mechanical running test. These facilities shall be in operation throughout the test.

**8.3.3.1.7** Testing with the contract coupling is preferred. If this is not practical, the mechanical running test shall be performed with coupling-hub idling adapters in place, resulting in moments equal (±10 percent) to the moment of the contract coupling hub plus one-half that of the coupling spacer. When all testing is completed, the idling adapters shall be furnished to the Purchaser as part of the special tools.

**8.3.3.1.8** Unless otherwise specified all purchased vibration probes, transducers, oscillator-demodulators, and accelerometers shall be in use during the test.

**8.3.3.1.9** Shop test facilities shall include instrumentation with the capability of continuously monitoring and plotting revolutions per minute, peak-to-peak displacement, and phase angle (x-y-y′). Presentation of vibration displacement and phase marker shall also be by oscilloscope.

**8.3.3.1.10** The vibration characteristics determined by the use of the instrumentation specified in 8.3.3.1.8 and 8.3.3.1.9 shall serve as the basis for acceptance or rejection of the machine (see 6.9.5.5).

**8.3.3.2** The mechanical running test of the equipment shall be conducted as specified in 8.3.3.2.1 through 8.3.3.2.4.

**8.3.3.2.1** The equipment shall be operated at speed increments of approximately 10 percent from zero to be maximum continuous speed and run at the maximum continuous speed until bearings, lube-oil temperatures, and shaft vibrations have stabilized.

**8.3.3.2.2** The speed shall be increased to trip speed and the equipment shall be run for a minimum of 15 minutes.

**8.3.3.2.3** The speed shall be reduced to the maximum continuous speed, and the equipment shall be run for 4 hours.

**8.3.3.2.4** The inner seal oil leakage rate shall be measured during 4 hours test. The maximum leakage shall not exceed the guarantee rate specified by Vendor on the data sheet.

**8.3.3.3** During the mechanical running test, the requirements of 8.3.3.3.1 through 8.3.3.3.5 shall be met.

**8.3.3.3.1** The mechanical operation of all equipment being tested and the operation of the instrumentation shall be satisfactory. The measured unfiltered vibration shall not exceed the limits of 6.9.5.5 and shall be recorded throughout the operating speed range.

**8.3.3.3.2** The equipment shall be operated at speeds specified on data sheet. The spectrum vibration at frequency range from 0.25 to 8 times the maximum continuous speed but not more than 90,000 cycles per minute (1500 hertz) while the equipment is operating at specified speed(s) shall be recorded and submitted by the Vendor.

**8.3.3.3.3** Plots showing synchronous vibration amplitude and phase angle versus speed for acceleration and deceleration shall be made before and after the 4 hours run.

**8.3.3.3.4** The mechanical running test shall verify that lateral critical speeds conform to the requirements of 6.9.2 and 6.9.3.

**8.3.3.3.5** Rotor insensitivity shall be demonstrated in accordance with 6.9.3.

**8.3.3.4** Unless otherwise specified the requirements of 8.3.3.4.1 through 8.3.3.4.3 shall be met after the mechanical running test is completed.

**8.3.3.4.1** All bearings shall be removed, inspected and reassembled after the mechanical running test is completed. Shaft end seals shall be removed for inspection following a successful running.

**8.3.3.4.2** If replacement or modification of bearings or seals or dismantling of the case to replace or modify other parts is required to correct mechanical or performance deficiencies, the initial test will not be acceptable, and the final shop tests shall be run after these replacements or corrections are made.

**8.3.3.4.3** When spare rotors are ordered to permit concurrent manufacture, each spare rotor shall also be given a mechanical running test in accordance with the requirements of this Standard.

### 8.3.4 Assembled expander gas leakage test

**8.3.4.1** After the mechanical running test is completed, each completely assembled expander casing intended for toxic, hazardous, flammable or hydrogen rich services shall be tested as specified in 8.3.4.2 through 8.3.4.8.

**8.3.4.2** The casing (including end seals) shall be pressurized with an inert gas to the maximum sealing pressure or the maximum seal design pressure, as agreed upon by the Purchaser and the Vendor. The test shall be considered satisfactory when no casing or casing-joint leaks are observed.

**8.3.4.3** When specified the casing with end seal installed shall be pressurized to the rated inlet pressure, held at this pressure for a minimum of 30 minutes, and subjected to a soap-bubble test or another approved test to check for gas leaks. The test shall be considered satisfactory when no casing or casing-joint leaks are observed.

**8.3.4.4** The requirements of 8.3.4.2 and 8.3.4.3 may necessitate two separate tests.

**8.3.4.5** Such components as driven equipment, gears and auxiliaries that make up a complete unit shall be tested together during the mechanical running test.

**8.3.4.6** When specified the main gear (if applicable) shall be tested with the machine unit during the mechanical running test.

**8.3.4.7** The expander shall be dismantled, inspected and reassembled after satisfactory completion of the mechanical running test.

**8.3.4.8** After the mechanical running tests, the shrink fit of hydraulically mounted couplings (if applicable) shall be inspected by comparing hub/shaft match marks to ensure that the coupling hub has not moved on the shaft during the tests.

#### 8.3.5 Performance test

The expander shall be performance tested in the factory in accordance with manufacturer test procedure which has been approved by the purchaser. If conduct of the performance test is not applicable in the factory, test shall be performed at the job site and at the actual conditions. Details as to method and acceptance criteria shall be mutually agreed upon by the Purchaser and the Vendor.

#### 8.3.6 Gear test

When specified the gear shall be tested with expander during mechanical running test.

#### 8.3.7 Helium test

When specified, the expander casing shall be tested for gas leakage with helium at the max. allowable working pressure.

#### 8.3.8 Sound-level test

The sound-level test shall be performed in accordance with API Standard 615.

### 8.4 Preparation for Shipment

**8.4.1** Equipment shall be suitably prepared for the type of shipment specified, including blocking of the rotor when necessary. The preparation shall be mutually agreed upon and, unless otherwise specified, shall make the equipment suitable for 12 months of 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.

**8.4.2** The Vendor shall provide the Purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up.

**8.4.3** The equipment shall be prepared for shipment after all testing and inspection has been completed and the equipment has been approved by the Purchaser. The preparation shall include that specified in 8.4.3.1 through 8.4.3.12.

**8.4.3.1** Exterior surfaces, except for machined surfaces, shall be given at least one coat of the manufacturer's Standard paint.

**8.4.3.2** Exterior machined surfaces shall be coated with a suitable rust preventive.

**8.4.3.3** The interior of the equipment shall be clean and free from scale, welding spatter, and foreign objects. The selection and application of preservatives or rust preventives shall be mutually agreed upon by the Purchaser and the Vendor.

**8.4.3.4** Internal steel areas of bearing housings and carbon steel oil systems' auxiliary equipment such as reservoirs, vessels, and piping shall be coated with a suitable oil-soluble rust preventive.

**8.4.3.5** Flanged openings shall be provided with metal closures consisting of one or two plates with a combined thickness of at least 3/16 inch (4.8 millimeters), with rubber gaskets and at least four full-diameter bolts. For studded openings, studs should be shipped loose to avoid being damaged. If studs are installed for shipment, all nuts needed for the intended service shall be used to secure closures. Each opening shall be car sealed so that the protective cover cannot be removed without the seal being broken.

**8.4.3.6** Threaded openings shall be provided with steel caps or solid shank steel plugs whose metallurgy is equal to or better than that of the pressure casing. In no case shall nonmetallic (such as plastic) caps or plugs be used.

**8.4.3.7** Openings that have been beveled for welding shall be provided with closures designed to prevent entrance of foreign materials and damage to the bevel.

**8.4.3.8** Lifting points and lifting lugs shall be clearly identified.

**8.4.3.9** The equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with securely affixed, corrosion-resistant metal tag indicating the item and serial number of the equipment for which it is intended. In addition, crated equipment shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container.

**8.4.3.10** When a spare rotor is purchased, the rotor shall be prepared for unheated indoor storage for a period of at least 3 years. The rotor shall be treated with a rust preventive and shall be housed in a vapor-barrier envelope with a slow-release vapor-phase inhibitor. The rotor shall be suitably crated for domestic or export shipment, as specified. Suitable lead sheeting, at least 1/8 inch (3.2 millimeters) thick, or other suitable material [not tetrafluoroethylene (TFE) or polytetrafluoroethylene (PTFE)], shall be used between the rotor and the cradle at the support areas. The rotor shall not be supported at journals.

**8.4.3.11** When specified, the fit-up and assembly of machine-mounted piping, intercoolers, and so forth, shall be completed in the vendor's shop prior to shipment.

**8.4.3.12** Exposed shafts and shaft couplings shall be wrapped with waterproof, moldable waxed cloth or vapor-phase-inhibitor paper. The seams shall be sealed with oilproof adhesive tape.

**8.4.4** Auxiliary piping connections furnished on the purchased equipment shall be impression stamped or permanently tagged to agree with the vendor's connection table or general arrangement drawing.

**8.4.5** One copy of the manufacturer's Standard installation instructions shall be packed and shipped with the equipment.

## 9. VENDOR'S DATA

### 9.1 Proposals

The vendor's proposal shall include the information specified in Items a through v below:

**a)** A copy of the vendor drawing and data requirements form indicating the schedule according to which the Vendor agrees to furnish the data requested by the Purchaser (see 9.2).

**b)** Copies of the purchaser's data sheets with complete vendor's information entered thereon.

**c)** Complete performance curves to fully define the envelope of operations and the point at which the manufacturer has rated the equipment.

**d)** Utility requirements such as steam, water, electricity, air, gas, and lube oil, including the quantity of lube oil required at the supply pressure, the heat load to be removed by the oil, and the nameplate power rating and operating-power requirements of auxiliary drivers. (Approximate data shall be defined and clearly identified as such.) This information shall be entered on the data sheets.

**e)** Net and maximum operating weights, maximum shipping and erection weights with identification of the item, and the maximum normal maintenance weight with identification of the item. These data shall be stated individually where separate shipments, packages, or assemblies are involved. These data shall be entered on the data sheets where applicable.

**f)** A summary of the materials of construction for the equipment, including hardness for materials exposed to $H_2S$ (see 6.11.2) and a detailed description of the impeller (type of construction,materials, and method of attachment to the shaft).

**g)** A preliminary dimensional outline drawing showing the location of inlet and discharge connections and the direction of rotation.

**h)** Schematic diagrams of the lube-and seal-oil systems.

**i)** Typical cross-sectional drawings and literature to fully describe details of the offering or offerings, including shaft sealing details, bearing details, and internal construction.

**j)** Indications of maximum seal-gas rates (injection or education) and rated and/or expected inner seal-oil leakage rates. The inner seal-oil leakage shall be given on the basis of volume per day per machine at design-gas or oil-differential pressures and normal expander speed.

**k)** Drawings, details, and descriptions of the operations of instrumentation and controls, as well as the makes, materials, and types of auxiliary equipment. The Vendor shall also include a complete description of the alarm and shutdown facilities to be provided.

**l)** A specific statement that the system and all its components are in strict accordance with this Standard. If the system and components are not in strict accordance, the Vendor shall include a specific list that details and explains each deviation.

**m)** A list of spare parts recommended for start-up and normal maintenance purposes. (The Purchaser will specify any special requirements for long-term storage). A description of the tests and procedures for materials as required by 6.11.1.4.

**n)** A statement of the manufacturer's capability regarding testing (including performance testing) of the expander and any other specified items on the train. Details of each test specified shall be included.

**p)** A description of special requirements as outlined in 6.10.3 and 6.11.1.2.

**q)** An outline of all necessary special weather and winterizing protection required by the equipment, its auxiliaries, and the driver (if furnished by the Vendor) for start-up, operation, and idleness. The Vendor shall list separately the protective items he proposes to furnish.

**r)** A list of similar machines installed and operating under analogous conditions.

**s)** Any start-up, shutdown, or operating restrictions required to protect the integrity of the equipment.

**t)** Typical sound pressure levels for each item of equipment in the train covered by the proposal.

**u)** A description of the buffer-gas system for the seals, when required.

**v)** Maximum and minimum allowable seal pressures for each expander.

## 9.2 Contract Data

### 9.2.1 General

**9.2.1.1** The following paragraphs specify information to be furnished by the Vendor. The Vendor shall complete and forward the Vendor Drawing and Data Requirements form to the address or addresses noted on the order. This form shall detail the schedule for transmission of drawings, curves, and data as agreed to at the time of the order, as well as the number and type of copies required by the Purchaser.

**9.2.1.2** The data shall be identified on transmittal (cover) letters and in title blocks or pages with the following information:

**a)** The Purchaser/user's corporate name,
**b)** the job/project number,
**c)** the equipment name and item number,
**d)** the purchase order number,
**e)** any other identification specified in the Purchase order,
**f)** the Vendor's identifying shop order number, serial number, or other reference required to identify return correspondence completely.

### 9.2.2 Coordination meeting

Unless otherwise specified, a coordination meeting shall be held, preferably at the Vendor's plant, within 4-6 weeks after the purchase commitment. An agenda shall be prepared and distributed prior to this meeting and, as a minimum, should include the following items:

**a)** The Purchase Order, scope of supply, and subvendor items,
**b)** the data sheets,
**c)** schedules for transmittal of drawings, production, and testing,
**d)** inspection, expediting, and testing,
**e)** the physical orientation of the equipment, piping, and auxiliary systems,
**f)** schematics of the lube-oil and cooling systems,
**g)** a review of applicable specifications and previously agreed-upon exceptions to specifications.

### 9.2.3 Drawings

**9.2.3.1** The Purchaser will state in the inquiry and in the order the number of prints and/or reproducibles required and the times within which they are to be submitted by the Vendor (see 9.1, Item a).

**9.2.3.2** The purchaser will promptly review the Vendor's drawings when he receives them; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the drawings have been reviewed, the vendor shall furnish certified copies in the quantity specified. Drawings shall be clearly legible and in accordance with ANSI Y 14.2M.

**9.2.3.3** The Vendor shall indicate in the drawings or in cross-reference lists the equipment item numbers of various components, connection points and locations, instrumentation, and other data as required by the Purchaser.

**9.2.3.4** The drawings furnished shall contain sufficient information, when combined with the manuals covered in 9.2.7 to enable the Purchaser to properly install, operate, and maintain the ordered equipment.

**9.2.3.5** The following information shall be provided on the drawings (typical drawings are not acceptable):

**a)** The Purchaser's order number (on every drawing).

**b)** The Purchaser's equipment item number (on every drawing).

**c)** The weight and center of gravity of the machine, of the heaviest piece of equipment that must be handled for erection, and of significant items to be handled for maintenance.

**d)** Principal dimensions, including those required for the piping design, maintenance clearances, and dismantling clearances, and the maximum loading limit on the main process flanges (both forces and moments).

**e)** The direction of rotation.

**f)** The size, type, rating, location, and identification of all the purchaser's connections, including vents, drains, lubricating oil, conduits, and instruments. (The Vendor's plugged connections shall be identified.)

**g)** When shaft couplings are furnished, their make, size, and type, and the style of the coupling guards.

**h)** Complete bills of materials covering the Vendor's entire scope of supply.

**i)** A list of reference drawings

**j)** A list of any special weather-protection and climatization features.

**k)** Cold-alignment setting data for equipment furnished by the Vendor. A composite diagram of data on expected thermal growth, including transient effects, shall be included.

**l)** Complete information to permit adequate foundation design by the Purchaser. This shall include but shall not be limited to the following:

1) Grouting details
2) The size and location of foundation bolts.
3) The weight distribution for each bolt/subsoleplate location.

m) The location of the center of gravity and rigging provisions to permit removal of the casing, the rotor and any subassemblies that weigh more than 300 pounds (136 kilograms).

n) Equipment furnished by the Vendor for mounting by the Purchaser.

**9.2.3.6** The Vendor shall supply schematic diagrams and bills of materials for all auxiliary systems within the vendor's scope of supply, including control, shaft-sealing, and lubricating-oil systems, and dimensional outline drawings for accessories and instrument panels. The bills of materials shall include and identify all components by make, type, size, capacity, pressure rating, materials, and other data as applicable.

**9.2.3.7** Each drawing and diagram shall have a title block in the lower right-hand corner with certification, reference to all identification data specified in 9.2.1.2, revision number, date, and drawing title. All of the title block shall be visible when the drawing is folded to 8½ × 11 inches. Bills of material shall be similarly identified.

**9.2.3.8** A complete list of all vendor drawings shall be included with first-issue major drawings. This list shall contain titles and the schedule for transmission of all drawings the Vendor will furnish.

**9.2.3.9** The Vendor shall supply cross-sectional or assembly-type drawings for all equipment furnished, showing all parts, running fits, clearances, and balancing data required for erection and maintenance. (Typical drawings are not acceptable.)

**9.2.3.10** The Vendor shall supply a schematic of a suggested control system for the seal-buffer system.

### 9.2.4 Curves

**9.2.4.1** In accordance with the schedule set at the coordination meeting, the Vendor shall provide complete performance curves to encompass the map of operations, with any limitations indicated thereon. The curves shall comply with the requirements of 9.2.4.2 through 9.2.4.6.

**9.2.4.2** The equipment serial number shall be shown on all curves.

**9.2.4.3** All curves submitted prior to final performance testing shall be marked "PREDICTED". Any set of curves resulting from a test shall be marked "TESTED".

**9.2.4.4** The Vendor shall provide performance test data and curves when the test has been completed. The rated point shall be shown on the performance curves.

### 9.2.5 Data

**9.2.5.1** The Vendor shall provide full information to enable completion of the data sheets for the train and auxiliary equipment, first for "as purchased" and then for "as built". This should be done by the Vendor correcting and filling out the data sheets and submitting copies to the Purchaser.

**9.2.5.2** The Vendor shall make the following information available to the Purchaser:

a) Certified shop logs of the mechanical running test.
b) Certified copies of the test data, which shall be furnished to the Purchaser before shipment.
c) A lateral critical analysis (damped unbalanced response) report including the following:

1) The items specified in 6.9.2.4.
2) A complete description of the method used to determine the critical speed.
3) Journal static loads.
4) Stiffness and damping coefficients.
5) Tilting-pad geometry and configuration (pad angle, pivot clearance, pad clearance, preload, and load on pad or between pads).

**d)** When required by 6.9.2.4, Item e, a graphic display of bearing and support stiffness and its effect on critical speeds with actual stiffness superimposed.

**e)** A torsional critical analysis report including the following:

**1)** A complete description of the method used to determine the critical speed.

**2)** A graphic display of the mass elastic system.

**3)** A table identifying the mass moment and torsional stiffness of each component identified in the mass elastic system.

**4)** A graphic display of exciting sources versus speed and frequency.

**5)** A graphic display of torsional critical speeds and deflections (that is, a mode shape diagram).

**f)** Optional test data and reports specified by the Purchaser.

**g)** ASME pressure vessel fabrication data including the manufacturer's data report, rubbings of the code stamp, stress relief charts, and mill test reports.

**h)** Electrical and mechanical runout record.

**i)** A list of all undesirable speeds from zero to trip.

**9.2.5.3** The Vendor shall provide as-built thrust-bearing, radial-bearing, and seal-running clearances.

**9.2.5.4** The Vendor shall specify radial/thrust bearing manufacturer's ultimate load rating.

**9.2.5.5** The Vendor shall provide lube-and seal-Oil specifications and requirements.

**9.2.5.6** The Vendor shall submit a supplementary list of spare parts other than those included in his original proposal. This supplementary list shall include recommended spare parts, cross-sectional or assembly-type drawings, parts numbers, materials, prices, and delivery times. Parts number shall identify each part for purposes of interchangeability. Standard purchased items shall be identified by the original manufacturer's numbers. The Vendor shall forward this supplementary list to the purchaser promptly after receipt of the approved drawings and in time to permit order and delivery of parts before field start-up.

**9.2.5.7** At least 8 weeks before shipment, the vendor shall submit his preservation, packaging, and shipping procedures to the Purchaser for his review.

**9.2.6** The Vendor shall submit progress reports to the Purchaser at the specified frequency. The reports shall include engineering and manufacturing information on all major components.

### 9.2.7 Installation and instruction manuals

**9.2.7.1** The Vendor shall provide sufficient written instructions, including a cross-referenced list of all drawings, to enable the purchaser to correctly install, operate, and maintain the complete equipment ordered. This information shall be compiled in a manual (or manuals) with a cover sheet containing all identifying data required in 9.2.1.2 and an index sheet containing section titles and a complete list of referenced and enclosed drawings by title and drawing number.

**9.2.7.2** All special information required for proper installation that is not on the drawings shall be compiled in a manual that is separate from the operating and maintenance instructions. This manual shall be forwarded at a time mutually agreed upon in the order but not later than the final-issue prints. It shall contain such information as special alignment or grouting procedures, utility specifications (including quantity), and all installation design data. It shall also contain the following:

**a)** Instructions for erecting, piping, aligning [including the expected thermally induced shaft centerline shift between the 60°F (15°C) ambient temperature position and that at normal operating temperature], and preparing the expander and auxiliary equipment for use.

**b)** A description of rigging procedures, including the lifting of the assembled machine, and methods of disassembly, repair, adjustment, inspection, and reassembly of the expander and auxiliaries.

**9.2.7.3** The manual containing operating and maintenance data shall be forwarded not later than 2 weeks after the successful completion of all specified tests. It shall include a section, if required, to cover special instructions for operations at specified extreme environmental conditions (such as temperature). The following shall be included in this manual:

**a)** Instructions covering start-up, normal shutdown, emergency shutdown, operating limits, and routine operational procedures.

**b)** A description of expander construction features and the functioning of component parts or systems (such as control, lubrication, and seal oil).

**c)** Outline and sectional drawings (in nonreduced format), schematics, and illustrative sketches in sufficient detail to identify all parts and clearly show the operation of all equipment and components and the methods of inspection and repair. Standardized sectional drawings are acceptable only if they represent the actual construction of the expander.

**d)** As-built data sheets.

**e)** The following maintenance information:

**1)** Maximum and minimum bearing, labyrinth, and seal clearances.

**2)** Instructions for measuring and adjusting cold clearances.

**3)** Rotor float allowance.

**4)** Interference fits on parts that are required to be removed or replaced for maintenance of normally consumable spares.

**5)** Runout and concentricity tolerances on parts of assembled rotors.

**6)** Balancing tolerances.

**f)** The following reassembly information:

**1)** Bolting sequence and torque values for such items as casing bolting and internal bolting.
**2)** Reassembly sequences together with required inspection checks.
**3)** Adjustment procedures to achieve required positions, clearances, float, and so forth.
**4)** Detailed procedures for preoperational checks, including settings and adjustments.
**5)** Coupling installation procedures.

**9.2.7.4** The Vendor shall furnish a parts list for all equipment supplied. The list shall include pattern, stock, or production drawing numbers and materials of construction. The list shall completely identify each part so that the Purchaser may determine the interchangeability of the part with other equipment furnished by the same manufacturer. Standard purchased items shall be identified by the original manufacturer's name and part number.

# APPENDICES

## APPENDIX A

**EXPANDER**
**DATA SHEET**
**SI UNITS**

PAGE ____1___OF___6__
JOB NO.__________________ITEM NO.____________________
PURCH. ORDER NO.________DATE______________________
INQUIRY NO.________________BY________________________
REVISION__________________DATE______________________
BY _______________________

APPLICABLE TO: c PROPOSAL c PURCHASE c AS BUILT
FOR ____________________ UNIT ____________________
SITE ____________________ SERIAL No. ____________________
SERVICE ____________________ No. REQUIRED ____________________
c CONTINUOUS c INTERMITTENT c STANDBY ______
MANUFACTURER ________________ c MODEL ______________________ DRIVEN ITEM No. ____________________
NOTE: INFORMATION TO BE COMPLETED: c BY PURCHASER b BY MANUFACTURER

**OPERATING CONDITIONS**

| (ALL DATA ON PER UNIT BASIS) | NORMAL | RATED | OTHER CONDITIONS | | | |
|---|---|---|---|---|---|---|
| | | | A | B | C | D |
| c GAS HANDLED (ALSO SEE PAGE _____) | | | | | | |
| c $nm^3/h$ (1.013 BAR & 0°C DRY) | | | | | | |
| c WEIGHT FLOW, kg/h (WET) (DRY) | | | | | | |
| **INLET CONDITIONS** | | | | | | |
| c PRESSURE (BAR) (kPa abs) | | | | | | |
| c TEMPERATURE (°C) | | | | | | |
| c RELATIVE HUMIDITY % | | | | | | |
| c MOLECULAR WEIGHT (%) | | | | | | |
| c Cp/Cv ($K_1$) OR ($K_{AVG}$) | | | | | | |
| b COMPRESSIBILITY ($Z_1$) OR ($Z_{AVG}$) | | | | | | |
| b INLET VOLUME, ($m^3/h$) (WET/DRY) | | | | | | |
| *** INTERMEDIATE CONDITIONS** | | | | | | |
| b PRESSURE (BAR) (kPa abs) | | | | | | |
| b TEMPERATURE (°C) | | | | | | |
| b Cp/Cv ($K_1$) OR ($K_{AVG}$) | | | | | | |
| b COMPRESSIBILITY ($Z_1$) OR ($Z_{AVG}$) | | | | | | |
| b MOLECULAR WEIGHT (%) | | | | | | |
| **DISCHARGE CONDITIONS** | | | | | | |
| b PRESSURE (BAR) (kPa abs) | | | | | | |
| b TEMPERATURE (°C) | | | | | | |
| b Cp/Cv ($K_1$) OR ($K_{AVG}$) | | | | | | |
| b COMPRESSIBILITY ($Z_1$) OR ($Z_{AVG}$) | | | | | | |
| b POWER (BHP) | | | | | | |
| b SPEED (RPM) | | | | | | |
| b HEAD (N-m/kg) | | | | | | |
| b EFFICIENCY (%) | | | | | | |
| c GUARANTEE POINT | | | | | | |
| b PERFORMANCE CURVE NUMBER | | | | | | |

**PROCESS CONTROL**

METHOD c VARIABLE INLET GUIDE VANES c OTHERS

SIGNAL c SOURCE ________________________________
TYPE c ELECTRONIC c PNEUMATIC c OTHER ______________________
RANGE _________ MA __________ (BARG) (k Pa G)

*** REMARK:** Intermediate conditions is defined as compressor inlet conditions for expander compressor loaded compact design application.

(to be continued)

## APPENDIX A - (continued)

### EXPANDER
### DATA SHEET
### SI UNITS

PAGE __2__ OF __6__
JOB NO.________________________ ITEM NO.__________________
REVISION ________________________ DATE__________________
BY ________________________

| OPERATING CONDITIONS (Continued) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| GAS ANALYSIS: c MOL % c | | NORMAL | RATED | OTHER CONDITIONS | | | | REMARKS: |
| | | | | A | B | C | D | |
| | MW | | | | | | | |
| AIR | 28.966 | | | | | | | |
| OXYGEN | 32.000 | | | | | | | |
| NITROGEN | 28.016 | | | | | | | |
| WATER VAPOR | 18.016 | | | | | | | |
| CARBON MONOXIDE | 28.010 | | | | | | | |
| CARBON DIOXIDE | 44.010 | | | | | | | |
| HYDROGEN SULFIDE | 34.076 | | | | | | | |
| HYDROGEN | 2.016 | | | | | | | |
| METHANE | 16.042 | | | | | | | |
| ETHYLENE | 28.052 | | | | | | | |
| ETHANE | 30.068 | | | | | | | |
| PROPYLENE | 42.078 | | | | | | | |
| PROPANE | 44.094 | | | | | | | |
| I-BUTANE | 58.120 | | | | | | | |
| n-BUTANE | 72.146 | | | | | | | |
| I-PENTANE | 72.146 | | | | | | | |
| n-PENTANE | | | | | | | | |
| HEXANE PLUS | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| TOTAL | | | | | | | | |
| AVG. MOL. WT. | | | | | | | | |

**LOCATION:**
c INDOOR c HEATED c UNDER ROOF
c OUTDOOR c UNHEATED c PARTIAL SIDES
c GRADE MEZZANINE c ______________
c ELEC. AREA CLASSIFICATION CL____GR_____DIV_____ c TROPICALIZATION REQD.

**SITE DATA:**
c ELEVATION ______ m BAROMETER ______ (BAR abs)
c RANGE OF AMBIENT TEMPS:

| | DRY BULB | WET BULB |
|---|---|---|
| SITE RATED °C | ________ | ________ |
| NORMAL °C | ________ | ________ |
| MAXIMUM °C | ________ | ________ |
| MINIMUM °C | ________ | ________ |

**UNUSUAL CONDITIONS:** c DUST c FUMES
c OTHER ____________________________________________
____________________________________________________
____________________________________________________

**REMARKS:**____________________________________________
____________________________________________________
____________________________________________________
____________________________________________________

**NOISE SPECIFICATIONS:**
c APPLICABLE TO MACHINE:
SEE SPECIFICATION ___________________________
c APPLICABLE TO NEIGHBORHOOD:
SEE SPECIFICATION ___________________________
ACOUSTIC HOUSING: c YES c NO

**APPLICABLE SPECIFICATIONS:**
c VENDOR HAVING UNIT RESPONSIBILITY
____________________________________________
c GOVERNING SPECIFICATION (IF DIFFERENT)
____________________________________________

**PAINTING:**
c MANUFACTURER'S STD.
c OTHER ____________________________________
____________________________________________

**SHIPMENT:**
c DOMESTIC c EXPORT c EXPORT BOXING REQD.
c OUTDOOR STORAGE MORE THAN 6 MONTHS.
SPARE ROTOR ASSEMBLY PACKAGED FOR
c HORIZONTAL STORAGE c VERTICAL STORAGE

(to be continued)

**APPENDIX A - (continued)**

**EXPANDER**
**DATA SHEET**
**SI UNITS**

PAGE __3__ OF __6__
JOB NO.________________________ ITEM NO.________________
REVISION ______________________ DATE___________________
BY _____________________

| CONSTRUCTION FEATURES | |
|---|---|
| **b SPEEDS:**<br>MAX. CONT.________RPM TRIP___________ RPM<br>MAX. TIP SPEEDS:_________ m/s @ RATED SPEED<br>_________ m/s @ MAX. CONT. SPEED<br>**b LATERAL CRITICAL SPEEDS (DAMPED)**<br>FIRST CRITICAL ________RPM__________MODE<br>SECOND CRITICAL______RPM__________MODE<br>THIRD CRITICAL________RPM__________MODE<br>FOURTH CRITICAL _____RPM __________MODE<br>**b TORSIONAL CRITICAL SPEEDS:**<br>FIRST CRITICAL __________________________RPM<br>SECOND CRITICAL________________________RPM<br>THIRD CRITICAL_________________________RPM<br>FOURTH CRITICAL________________________RPM<br>**b VIBRATION:**<br>ALLOWABLE TEST LEVEL, __________________ mm<br>(PEAK TO PEAK) | TYPE (OPEN, ENCLOSED, ETC.)__________________________<br>TYPE FABRICATION ___________________________________<br>MATERIAL _________________________________________<br>MAX. YIELD STRENGTH (N)_____________________________<br>BRINNEL HARDNESS: MAX.___________ MIN.______________<br>SMALLEST TIP INTERNAL WIDTH (mm) __________________<br>MAX. IMPELLER HEAD @ RATED SPD (N-m/kg)_____________<br><br>**b SHAFT:**<br>MATERIAL______________________________________<br>DIA@IMPELLERS (mm) _____DIA@COUPLING (mm)______<br>SHAFT END: TAPERED CYLINDRICAL<br>MAX. YIELD STRENGTH (BAR)________________________<br>SHAFT HARDNESS (BNH)(Rc)_________________________<br>STRESS AT COUPLING (BAR)_________________________<br><br>**b SHAFT SLEEVES:**<br>AT SHAFT SEALS _________________MATL_____________ |
| **b ROTATION, VIEWED FROM DRIVEN END** | |
| **b MATERIALS INSPECTION REQUIREMENTS**<br>__ c SPECIAL CHARPY TESTING ___________________<br>__ c RADIOGRAPHY REQUIRED FOR _______________<br>__ c MAGNETIC PARTICLE REQUIRED FOR__________<br>__ c LIQUID PENETRANT REQUIRED FOR___________<br>**b CASING:**<br>MODEL_______________________________________<br>CASING SPLIT_________________________________<br>MATERIAL____________________________________<br>THICKNESS (mm)______CORR.ALLOW.(mm)________<br>MAX.WORKING PRESS____________________BARG<br>MAX. DESIGN PRESS ____________________BARG<br>TEST PRESS (BARG): HELIUM _______HYDRO______<br>MAX.OPER.TEMP. _____°C MIN. OPER.TEMP. ____°C<br>MAX.CASING CAPACITY ($M^3$/H).__________________<br>RADIOGRAPHY QUALITY c YES c NO<br>c SYSTEM RELIEF VALVE SET PT._____________BARG<br>MATERIAL_____________________________________<br>**b IMPELLERS:**<br>DIAMETERS_________________________________<br>NO. VANES EA. IMPELLER______________________<br>_____________________________________________<br>_____________________________________________ | **b LABYRINTHS:**<br>TYPE ___________________ MATERIAL ________________<br><br>**SHAFT SEALS:**<br>c SEAL TYPE_______________________________________<br>c SETTLING OUT PRESSURE (BARG)____________________<br>c SPECIAL OPERATION________________________________<br>c BUFFER GAS SYSTEM REQUIRED_____________________<br>c TYPE BUFFER GAS__________________________________<br>c BUFFER GAS CONTROL SYSTEM SCHEMATIC BY VENDOR<br>_______________________________________________<br><br>b INNER OIL LEAKAGE GUAR, (m3/DAY/SEAL)_____________<br>BUFFER GAS REQUIRED FOR:<br>**b** AIR RUN-IN **b** OTHER ___________________<br>**b** BUFFER GAS FLOW (PER SEAL):<br>NORM:_________kg/MIN @________BAR ΔP ________<br>MAX.: _________kg/MIN @________BAR ΔP_________<br><br>**b BEARING HOUSING CONSTRUCTION:**<br>TYPE (SEPARATE, INTEGRAL)__________SPLIT_________<br>MATERIAL_________________________________________ |

**(to be continued)**

## APPENDIX A - (continued)

**EXPANDER**
**DATA SHEET**
**SI UNITS**

PAGE ____4__ OF ___6__
JOB NO.________________________ ITEM NO.______________________
REVISION ______________________ DATE________________________
BY ____________________________

**CONSTRUCTION FEATURES (CONTINUED)**

**BEARINGS AND BEARING HOUSINGS**

| RADIAL | INLET | EXHAUST |
|---|---|---|
| b TYPE | | |
| b MANUFACTURER | | |
| b LENGTH (mm) | | |
| b SHAFT DIA (mm) | | |
| b UNIT LOAD (ACT/ALLOW) | | |
| b BASE MATERIAL | | |
| b BABBIT THICKNESS (mm) | | |
| b No. PADS | | |
| b LOAD : B'TWN/ON PAD | | |
| b PIVOT : CTR/OFFSET, % | | |
| b | | |
| b | | |

| THRUST | ACTIVE | INACTIVE |
|---|---|---|
| b TYPE | | |
| b MANUFACTURER | | |
| b UNIT LOADING (MAX. BAR) | | |
| b UNIT LOAD (ULT.) (BAR) | | |
| b AREA ($mm^2$) | | |
| b No. PADS | | |
| b PIVOT : CENTER/OFFSET, % | | |
| b PAD BASE MATL | | |

LUBRICATION : c FLOODED c DIRECTED
THRUST COLLAR : c INTEGRAL c REPLACEABLE
MATERIAL ________________________________________

**BEARING TEMPERATURE DEVICES** c SEE ATTACHED
c RESISTOR
c TYPE ____ POS TEMP COEFF ____ NEG TEMP COEFF
c TEMP SWITCH & INDICATOR BY : ____ PURCH___MFR
c THERMOCOUPLES
c SELECTOR SWITCH & IN BY : _______ PURCH___MFR
c RESISTANCE TEMP DETECTORS
c RESISTANCE MAT'L __________ b ____________OHMS
c SELECTOR SWITCH & INDICATOR BY :
c LOCATION-JOURNAL BRG ________ PURCH___MFR
No. _____ EA PAD _____ EVERY OTH PAD ____ PER BRG
OTHER ____________________________________________
c LOCATION-THRUST BRG
No. _____ EA PAD _____ EVERY OTH PAD ____ PER BRG
OTHER ____________________________________________
No.(INACT) __ EA PAD __ EVERY OTH PAD ____ PER BRG
OTHER ____________________________________________
c MONITURED SUPPLIED BY __________________________
c LOCATION ___________ ENCLOSURE ______________
c MFR. _______________ b MODEL ________________
b SCALE RGE ____ALARM b SET @ ______________°C
c SHTDWN : b SET @ ____°C c TIME DELAY ___ SEC

**VIBRATION DETECTORS :** c SEE ATTACHED API-670 DATA SHEET
c TYPE _________________ b MODEL ________________
c MFR ___________________________________________
c No. AT EA SHAFT BEARING ________ TOTAL No. ______
c OSCILLATOR-DETECTORS SUPPLIED BY _____________
c MFR _________________ b MODEL ______________
MONITORED SUPPLIED BY _________________
c LOCATION ___________ ENCLOSURE ____________
c MFR. _______________ b MODEL ____________
b SCALE RGE ____ALARM b SET @ __________
c SHTDWN : b SET @ ____mm c TIME DELAY _

**AXIAL POSITION DETECTOR :**
c TYPE _________________ b MODEL ________________
c MFR _________________ c No. REQUIRED__________
c OSCILLATOR-DEMODULATOR SUPPLIED BY __________
c MFR _________________ b MODEL ______________
MONITORED SUPPLIED BY _________________
c LOCATION ___________ ENCLOSURE ____________
c MFR. _______________ b MODEL ____________
b SCALE RGE ____ALARM b SET @ __________
c SHTDWN : b SET @ ____mm c TIME DELAY _

**CASING CONNECTIONS**

| CONNECTION | c DESIGN APPROVAL REQ' D | b SIZE | b FACING | c POSITION | b FLANGED OR STUDDED | c MATING FLG & GASKET BY VENDOR | b GAS VELOCITY m/sec |
|---|---|---|---|---|---|---|---|
| INLET (EXP.) | | | | | | | |
| OUTLET (EXP.) | | | | | | | |
| *INLET (COMP.) | | | | | | | |
| *OUTLET (COMP.) | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

* Applicable for expander compressor loaded compact design.

(to be continued)

**APPENDIX A - (continued)**

**EXPANDER**
**DATA SHEET**
**SI UNITS**

PAGE 5 OF 6
JOB NO.________ ITEM NO.________
REVISION ________ DATE________
BY ________

b **OTHER CONNECTIONS**
**SERVICE:**

| SERVICE | NO. | SIZE | TYPE |
|---|---|---|---|
| LUBE-OIL INLET | | | |
| LUBE-OIL OUTLET | | | |
| SEAL-OIL INLET | | | |
| SEAL-OIL OUTLET | | | |
| CASING DRAINS | | | |
| VENTS | | | |
| COOLING WATER | | | |
| PRESSURE | | | |
| TEMPERATURE | | | |
| PURGE FOR: | | | |
| BRG. HOUSING | | | |
| BTWN BRG & SEAL | | | |
| BTWN SEAL & GAS | | | |
| SOLVENT INJECTION | | | |

c INDIVIDUAL STAGE DRAINS REQUIRED
c VALVED & BLINDED
c VALVED & BLINDED & MANIFOLD

b **ALLOWABLE PIPING FORCES AND MOMENTS:**

| | INLET | | DISCHARGE | | | |
|---|---|---|---|---|---|---|
| | FORCE N | MOMET N-M | FORCE N | MOMET N-M | FORCE N | MOMET N-M |
| AXIAL | | | | | | |
| VERTICAL | | | | | | |
| HORIZ, 90° | | | | | | |
| | FORCE N | MOMET N-M | FORCE N | MOMET N-M | FORCE N | MOMET N-M |
| AXIAL | | | | | | |
| VERTICAL | | | | | | |
| HORIZ, 90° | | | | | | |

c ACCELEROMETER
c SEE ATTACHED API-678 DATA SHEET
cTYPE ________b MODEL________
c MFR________NO. REQUIRED________
c LOCATION________
c OSCILATOR-DEMODULATORS SUPPLIED BY________
c MFR________b MODEL________
c MONITOR SUPPLIED BY ________
c LOCATION________ENCLOSURE________
c MFR________b MODEL________
b SCALE RANGE ____c ALARM:b SET@_____mm/SEC$^2$
c SHTDWN b SET@_____mm/SEC$^2$c TIME DELYA ________SEC

**ACCESSORIES**

**COUPLINGS AND GUARDS**

**NOTE: SEE ROTATING ELEMENTS-SHAFT ENDS**
c SEE ATTACHED DATA SHEET
COUPLING FURNISHED BY________
MANUFACTURER ________TYPE ________MODEL________
COUPLING GUARD FURNISHED BY:________
TYPE: c FULLY ENCLOSED c SEMI-OPEN c OTHER
COUPLING DETAILS

c VENDOR MOUNT HALF COUPLING
b MAX O.D.________mm c IDLING ADAPTER/SOLO PLATE REQ'D
b HUB WEIGHT ________kg c LUBRICATING REQUIREMENTS:
b SPACER LENGTH ________mm LUBRICATING REQUIREMENTS:
b SPACER WEIGHT ________kg c NON-LUBE c GREASE c CONT. OILc OTHER
QUANTITY PER HUB________kg OR m$^3$/h

**MOUNTING PLATES**

c BASEPLATES: FURNISHED BY ________
c OTHER________
c DRIP TRIM c LEVELING PADS
c COLUMN MOUNTING
c SUB-SOLE PLATES REQ'D
b STAINLESS STEEL SHIM THICKNESS ________mm
PRIMER FOR EPOXY GROUT REQ'D
TYPE ________

(to be continued)

## APPENDIX A - (continued)

**EXPANDER**
**DATA SHEET**
**SI UNITS**

PAGE __6__ OF __6__
JOB NO.________________________ ITEM NO.________________
REVISION ______________________ DATE__________________
BY _____________________

**UTILITIES**

c **UTILITY CONDITIONS:**

| **STEAM:** | **DRIVERS** | | **HEATING** | |
|---|---|---|---|---|
| INLET MIN | ____ BARG | ____ °C | ____ BARG | ____ °C |
| NORM | ____ BARG | ____ °C | ____ BARG | ____ °C |
| EXHAUST. MIN | ____ BARG | ____ °C | ____ BARG | ____ °C |
| NORM | ____ BARG | ____ °C | ____ BARG | ____ °C |
| MAX | ____ BARG | ____ °C | ____ BARG | ____ °C |

**ELECTRICITY:**

| | DRIVERS | HEATING | CONTROL | SHUTDOWN |
|---|---|---|---|---|
| VOLTAGE | ______ | ______ | ______ | ______ |
| HERTZ | ______ | ______ | ______ | ______ |
| PHASE | ______ | ______ | ______ | ______ |

**COOLING WATER:**
TEMP.INLET__________°C MAX RETURN ________°C
PRESS NORM_________BARGDESIGN_________ARG
MIN RETURN__________BARG MAX ALLOW ΔP___BAR
WATER SOURCE ______________________________
**INSTRUMENT AIR:**
MAX PRESS ____________BARG MIN PRESS_______BARG

b **TOTAL UTILITY CONSUMPTION:**
COOLING WATER__________________________$m^3/h$
STEAM, NORMAL__________________________kg/h
STEAM, MAX.____________________________kg/h
INSTRUMENT AIR_________________________$mm^3/h$
HP (DRIVEN)____________________________kW
HP (AUXILIARIES)_______________________kW
HEATERS________________________________kW
PURGE (AIR OR $N_2$)___________________$mm^3/h$

**MISCELLANEOUS:**
c VENDOR'S REVIEW & COMMENTS ON PURCHASER'S PIPING & FOUNDATION
c VENDOR'S REVIEW & COMMENTS ON PURCHASER'S CONTROL SYSTEMS
c EXTENT OF PROCESS PIPING BY VENDOR
c SHOP FITUP OF VENDOR PROCESS PIPING
c WELDING HARDNESS TESTING
c AUXILIARY EQUIPMENT MOTORS EXPLOSION PROOF
c ______________________________________________

**SHOP INSPECTION AND TESTS:**

| | REQ'D | WITNESSED | OBSERVED |
|---|---|---|---|
| SHOP INSPECTION | c | | |
| CLEANLINESS | | c | |
| QC PROGRAM REVIEW | | c | |
| HYDROSTATIC | 3 | c | |
| IMPELLER OVERSPEED | 3 | c | |
| MECHANICAL RUN | 3 | c | |
| b CONTRACT COUPLING b IDLING ADAPTOR(S) | | | |
| b CONTRACT PROBES b SHOP PROBES | | | |
| POLAR FORM VIB DATA | 3 | | |
| SHAFT END SEAL INSP | 3 | | |
| GAS LEAK TEST INLET PRESS | 3 | c | c |
| cBEFORE cAFTER MECH RUN | | | |
| PERFORMANCE TEST(GAS)(AIR) | 3 | c | c |
| COMPLETE UNIT TEST | c | c | c |
| TORSIONAL VIB MEAS | c | c | c |
| GEAR TEST | c | c | c |
| HELIUM LEAK TEST | c | c | c |
| SOUND LEVEL TEST | 3 | c | c |
| FULL LOAD/SPEED/PRESS TEST | c | c | c |
| HYDRAULIC COUPLING INSP | c | c | c |
| CERTIFIED COPIES OF TEST DATA | 3 | c | c |

b **WEIGHTS (kg):**
EXPANDER______GEAR_______DRIVEN_____BASE____
ROTOR__________________________________
EXPANDER CASE__________________________
LO. CONSOLE____________________________
MAX. FOR MAINTENANCE (IDENTIFY)________________
TOTAL SHIPPING WEIGHT c_______________________
____________________ c ____________________
c
______________________________________________

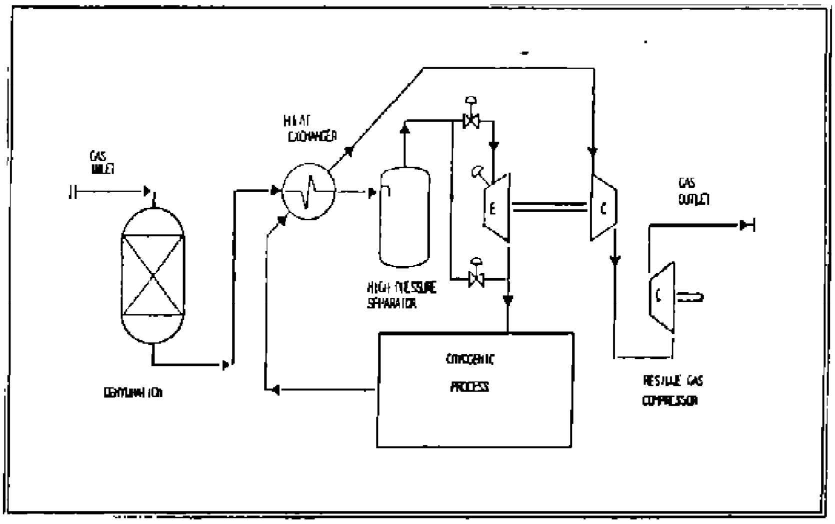
b **SPACE REQUIREMENTS (m):**

| | L | W | H |
|---|---|---|---|
| COMPLETE UNIT: | L________ | W_______ | H_______ |
| LO. CONSOLE: | L________ | W_______ | H_______ |

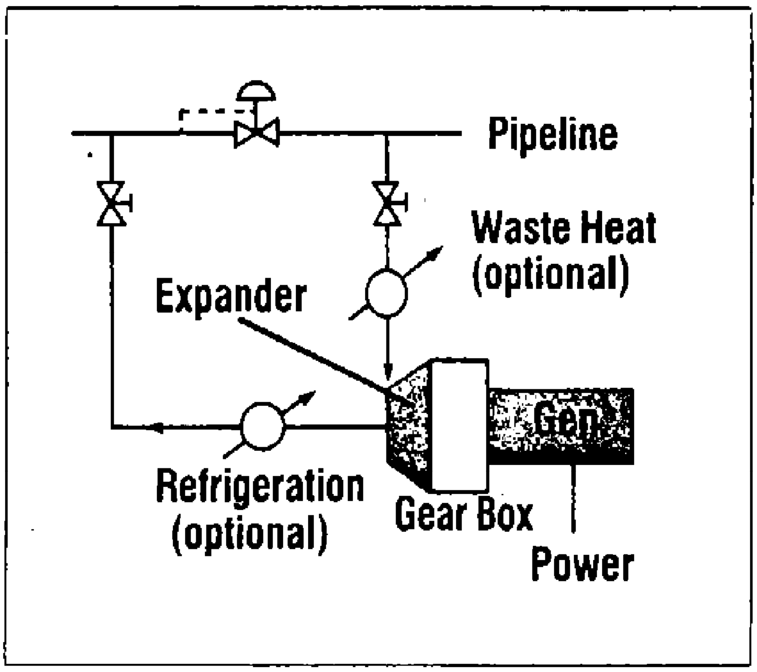
______________________________________________

**REMARKS:**
______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________

## APPENDIX B
## EXPANDERS TYPICAL APPLICATION



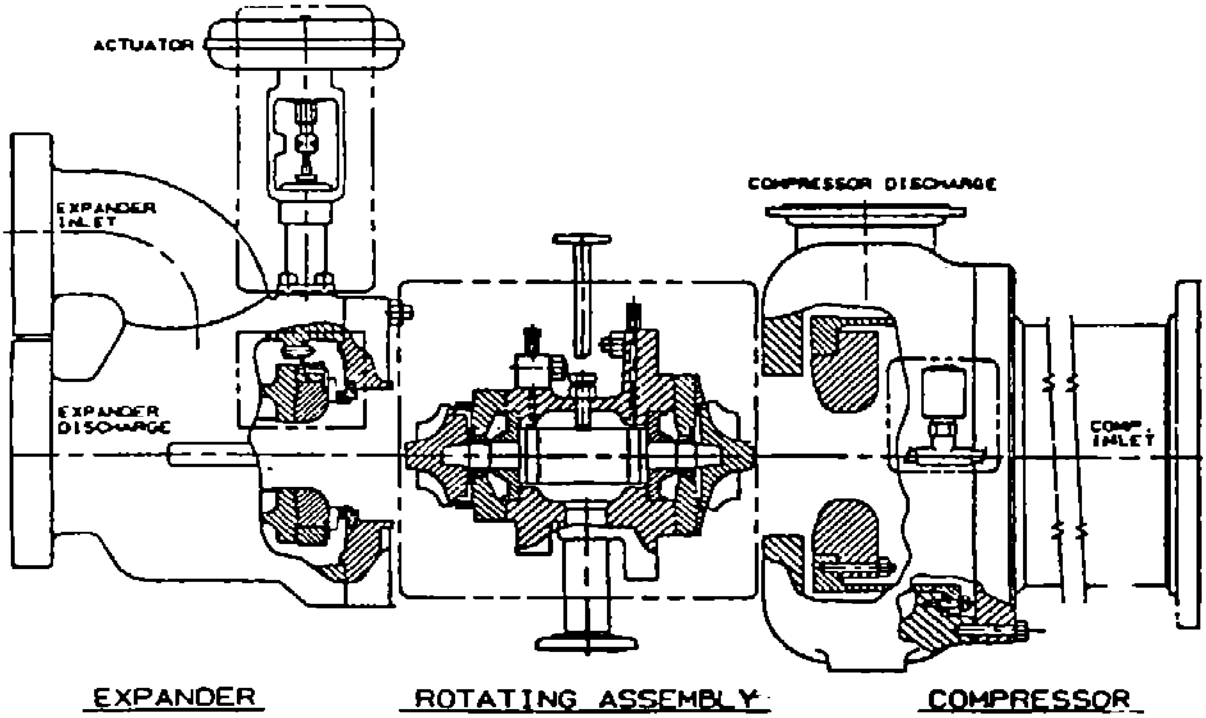
**SIMPLIFIED SCHEMATIC OF CRYOGENIC TURBO EXPANDER PLANT**
**Fig. B.1**




**GAS PRESSURE LETDOWN IN NATURAL GAS PIPELINE TRANSMISSION, SIGNIFICANT ENERGY CAN BE RECOVERED BY USING TURBOEXPANDERS TO REPLACE THROLTTLE VALVES**
**Fig. B.2**

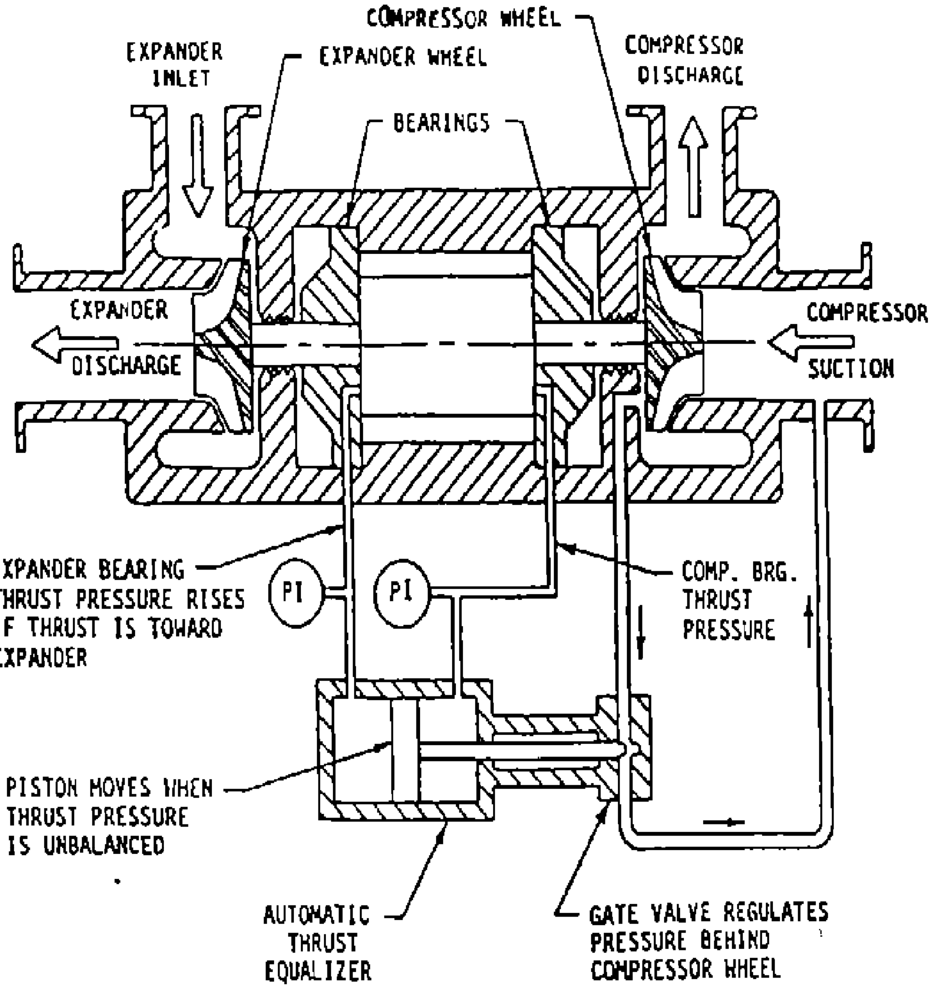
## APPENDIX C
## EXPANDER COMPRESSOR LOADED COMPACT DESIGN

For the above application (Fig. C.1), the shaft power is absorbed and used by a single stage centrifugal compressor mounted on the same shaft as the expander. In this case, process induced variations, off design operation and also unforeseen transient process condition can cause thrust overloads. To prevent this, automatically thrust load system shall be provided to ensures that the shaft remains centered between the bearings at all times as shown schematically in Fig. C.2.




**EXPANDER COMPRESSOR LOADED COMPACT DESIGN (TYPICAL)**

**Fig. C.1**




**Oil pressure is transmitted from small openings in the bearing thrust faces to the respective cavities in the thrust equalizing chamber. The thrust balancer piston operates the gate valve to regulate the pressure behind the compressor wheel.**

**AUTOMATICALLY THRUST LOAD CONTROL SYSTEM FOR EXPANDER COMPRESSOR COMPACT DESIGN (TYPICAL)**
**Fig. C.2**