INTERNATIONAL STANDARD

ISO 10439-4

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Petroleum, petrochemical and natural gas industries — Axial and centrifugal compressors and expander-compressors —

Part 4: Expander-compressors

Industries du pétrole, de la pétrochimie et du gaz naturel — Compresseurs axiaux et centrifuges et compresseurs-détenteurs —

Partie 4: Compresseurs-détenteurs

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 118, *Compressors and pneumatic tools, machines and equipment*, Subcommittee SC 1, *Process compressors*.

This first edition, together with ISO 10439-1, ISO 10439-2, and ISO 10439-3, cancels and replaces ISO 10439:2002.

ISO 10439 consists of the following parts, under the general title *Petroleum, petrochemical and natural gas industries — Axial and centrifugal compressors and expander-compressors*:

— *Part 1: General requirements*

— *Part 2: Non-integrally geared centrifugal and axial compressors*

— *Part 3: Integrally geared centrifugal compressors*

— *Part 4: Expander-compressors*

Introduction

This International Standard is based on the 7th edition of the American Petroleum Institute standard API 617.

Further or differing requirements might be needed for individual applications. This International Standard is not intended to inhibit a supplier from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This can be particularly appropriate where there is innovative or developing technology. Where an alternative is offered, the supplier should identify any variations from this International Standard and provide details.

An asterisk (*) at the beginning of the paragraph of a clause or subclause indicates that either a decision is required or further information is to be provided by the purchaser. This information is indicated on data sheets or stated in the enquiry or purchase order (see examples in Annex A, ISO 10439-2:2015, Annex A, ISO 10439-3:2015, Annex A).

This International Standard includes the following annexes:

— Annex A: Datasheets;

— Annex B: Vendor (Supplier) data and drawing requirements (VDDR);

— Annex C: Nomenclature;

— Annex D: Typical materials;

— Annex E: Inspector's checklist;

— Annex F: Nozzle forces and moments;

— Annex G: Lubrication and sealing requirements.

Annex A forms a normative part of this part of ISO 10439. Annexes B to G are for information only.

In this International Standard, where practical, US customary units are included in parentheses for information.

Petroleum, petrochemical and natural gas industries — Axial and centrifugal compressors and expander-compressors —

Part 4: Expander-compressors

1 Scope

This part of ISO 10439 specifies minimum requirements and gives recommendations for axial compressors, single-shaft, and integrally geared process centrifugal compressors and expander-compressors for special purpose applications that handle gas or process air in the petroleum, petrochemical, and natural gas industries. This part of ISO 10439 specifies requirements for expander-compressors, in addition to the general requirements specified in ISO 10439-1:2015.

This scope covers only expanders and compressors on a common shaft (expander-compressor). This scope does not apply to expanders with separate output shafts (e.g. generator drives). Hot gas expanders over 300 °C (570 °F) are not covered in this part of ISO 10439.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10438 (all parts), *Petroleum, petrochemical and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries*

ISO 10439-1:2015, *Petroleum, petrochemical and natural gas industries — Axial and centrifugal compressors and expander-compressors — Part 1: General requirements*

API 670, *Machinery protection systems*

3 Terms, abbreviated terms, and definitions

For the purposes of this document, the terms, abbreviated terms, and definitions given in ISO 10439-1:2015 apply.

4 General

NOTE A cross-section showing nomenclature of an expander-compressor can be found in Annex C.

4.1 Dimensions and units

The dimensional and unit requirements shall be in accordance with ISO 10439-1:2015, 4.1.

4.2 Statutory requirements

The statutory requirements shall be in accordance with ISO 10439-1:2015, 4.2.

4.3 Unit responsibility

The unit responsibilities shall be in accordance with ISO 10439-1:2015, 4.3.

4.4 Basic design

4.4.1 The expander shall meet at least 98 % of the predicted efficiency at the certified point (see 6.3.5.1.1). The compressor shall deliver at least 98 % of the normal head at the normal capacity. The compressor power at the normal condition shall not be more than 106 % of that available from the expander, nor shall it be less than 96 % of that available from the expander.

NOTE Compressor-loaded expanders achieve a power balance that determines the speed of the machine. There is generally no speed control governor to control the speed the way other turbine-driven compressors are controlled. If the expander power is more than expected, then the speed of the machine will be higher than predicted. If the compressor power is more than expected, then the speed of the machine will be lower than predicted. The above tolerances are needed to set limits beyond which hardware changes will be required to achieve a reasonable normal speed.

4.4.2 The compressor head-capacity characteristic curve at the rated speed shall rise continuously from the rated point to surge. The compressor shall be suitable for continuous operation at any capacity on the predicted performance curve(s) at least 10 % greater than the predicted surge capacity shown in the proposal.

NOTE It is common for flow to be bypassed around the compressor during normal operation.

4.5 Materials

4.5.1 Materials shall be in accordance with ISO 10439-1:2015, 4.5. Refer to Annex D for a table of typical materials.

4.5.2 If traces of mercury have been specified, aluminium impellers shall be treated by anodizing or other approved methods.

4.6 Casings

Casings shall be in accordance with ISO 10439-1:2015, 4.6 and 4.6.1 to 4.6.7.7.

4.6.1 Pressure-containing casings

4.6.1.1 * The maximum allowable working pressure of the casing(s) shall be at least equal to the relief valve set pressure(s) specified by the purchaser.

4.6.1.1.1 If a relief valve set pressure is not specified, the maximum allowable working pressure of an expander casing shall be at least 1,1 times the maximum specified inlet pressure (gauge). System pressure protection shall be furnished by the purchaser.

4.6.1.1.2 If a relief valve set pressure is not specified, the maximum allowable working pressure of the compressor casing of an expander-compressor shall be at least 1,25 times the maximum specified discharge pressure (gauge). System pressure protection shall be furnished by the purchaser.

4.6.1.1.3 When the purchaser has not supplied a relief valve setting, he shall be responsible for insuring that furnished relief valves are compatible with casing ratings as set by 4.6.1.1.1 and 4.6.1.1.2.

4.6.1.2 O-rings, gaskets, or other sealing devices which can be used on radially spilt casings shall be confined in machined grooves and shall be made of materials suitable for all specified service conditions.

4.6.1.3 Provisions for lifting the casings and removing the centre section shall be provided.

4.6.1.4 The expander-compressor casing shall be designed with sufficient strength to contain parts which might separate in the event of uncontrolled overspeed.

4.6.2 Casing repairs

Casing repairs shall be in accordance with ISO 10439-1.

4.6.3 Material inspection of pressure containing parts

Material inspection of pressure containing parts shall be in accordance with ISO 10439-1.

4.6.4 Pressure casing connections

Pressure casing connections shall be in accordance with ISO 10439-1 and 4.6.4.

4.6.4.1 Main process connections shall be in accordance with ISO 10439-1.

4.6.4.2 Auxiliary connections shall be at least DN 15 (NPS 1/2) and in accordance with ISO 10439-1.

4.6.5 Casing support structures

NOTE 1 Expander-compressors have no coupling, therefore, there are no special requirements for casing support structures.

NOTE 2 Expander-compressor units do not require highly finished mounting surfaces.

4.6.6 External forces and moments

4.6.6.1 Expander-compressor packages shall be designed to withstand external forces and moments on each nozzle calculated in accordance with Formulae (F.1) and (F.2).

NOTE Expander-compressor shaft alignment is not affected by piping forces since they do not have a coupling.

4.6.6.2 The supplier shall furnish the allowable forces and moments for each nozzle in tabular form.

4.6.7 Variable nozzles and heat shields

4.6.7.1 Each expander shall be equipped with variable nozzles (variable inlet guide vanes).

NOTE Variable nozzles permit the efficient conversion of head into velocity throughout the design range of the unit.

4.6.7.2 Variable nozzles shall be sized, capable of flowing at least 110 % of the mass flow at any specified operating condition.

4.6.7.3 Actuating devices shall be capable of operation at all specified operating conditions, including maximum inlet pressure, maximum flow, and minimum discharge pressure.

NOTE Variable nozzles are used for flow and pressure control. Precise control of the nozzles is necessary for smooth process operation.

4.6.7.4 Variable nozzles and actuators shall be capable of closing with maximum inlet pressure at all flow conditions.

Actuators shall be equipped with an agreed force limiting device to ensure no over-forcing in closing or opening the inlet guide vanes.

NOTE Adjustable nozzles are often required to control expander discharge pressure under conditions of restricted flow on the discharge. It is necessary for nozzles to close rapidly with minimal leakage; however, variable nozzles are not tight shutoff devices.

4.6.7.5 Variable nozzles shall be designed to minimize friction.

4.6.7.6 If variable nozzles are used for toxic, flammable, or explosive process gas, the linkage passing through the casing or enclosure shall be sealed.

4.6.7.7 If required, an insulating heat shield shall be provided between the cold expander process fluids and the bearing cavity. Heat shields shall be constructed of materials with good insulation properties.

NOTE See Annex D for typical heat shield materials.

4.7 Rotating elements

4.7.1 General

4.7.1.1 Rotating elements shall be in accordance with ISO 10439-1:2015, 4.7 and 4.7.

4.7.1.2 Each impeller and shaft shall be clearly marked with a unique identification number. This number shall be in an accessible area that is not prone to maintenance damage.

4.7.2 Shaft sleeve

Unless other shaft protection is approved by the purchaser, replaceable components shall be furnished at labyrinth shaft seal locations. Sleeves, spacers, or bushings shall be made of materials that are corrosion-resistant in the specified service.

4.7.3 Shafts

4.7.3.1 Shafts shall be of one piece or permanently joined multiple piece construction, and can be hollow.

NOTE 1 Expanders can have multi-piece construction hollow shafts that are joined by methods such as friction welding per ANSI/AWS—C6.1 Recommended practices for friction welding.

NOTE 2 Because these parts are permanently joined, trapped process gas is not a problem.

4.7.3.2 All welds on the shaft shall be inspected by ultrasonic or radiographic examination. After finish machining, the welds shall be inspected by magnetic particle or liquid penetrant examination. Refer to ISO 10439-1:2015, 6.2.2 for material inspection methods and ISO 10439-1:2015, 6.2.2.1.1 for acceptance criteria.

4.7.3.3 For precipitation-hardened stainless steel shafts with maximum journal velocities (trip speed) above 95 m/s (315 ft/s), the supplier shall provide a coating or overlay on the journals to prevent wire wooling.

NOTE Chrome plating, weld overlay, High Velocity Oxygen Fuel (HVOF), High Velocity Liquid Fuel (HVLF), and graphite impregnation are some of the methods which have been used successfully to prevent wire wooling.

4.7.4 Impellers

4.7.4.1 General

Impeller shall be in accordance with ISO 10439-1:2015, 4.7.10.

4.7.4.2 Thrust balancing

4.7.4.2.1 A balance cavity, line and porting shall be provided if required to limit axial loads on the thrust bearings.

4.7.4.2.2 When an automatic or fixed thrust equalizing valve is provided as per 4.9.3.4, this valve shall be flanged and sized to handle balance drum gas leakage at twice the initial design labyrinth clearance without exceeding the load rating of the thrust bearings. If the balance line involves a purchaser's connection to his piping, then the connection sizes shall be indicated on the data sheets.

4.7.4.2.3 An automatic thrust equalizing valve shall be provided. This valve shall react to changes in thrust load as measured by thrust pressure (magnetic bearing current, etc.) to actively maintain a low thrust load on the thrust bearings by injecting to or venting from balancing chambers inside the machine. See Figure 1 for typical automatic thrust equalizing valve schematic.

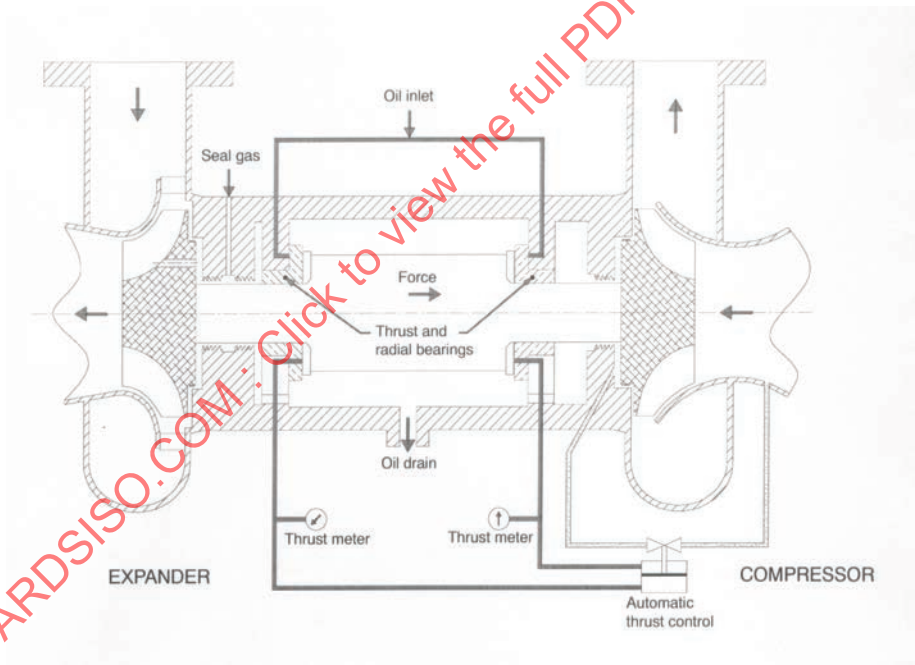

Figure 1 — Automatic thrust balancing system

4.8 Dynamics

Dynamics shall be in accordance with of ISO 10439-1:2015, 4.8.

4.8.1 Vibration balancing

4.8.1.1 The balancing method described in 4.8.1.2 to 4.8.1.5 shall apply only to single-shaft expander-compressors which require rotor disassembly and re-assembly to install. All other expander-compressors shall comply with ISO 10439-1:2015, 4.8.8.

NOTE Expander-compressors in cryogenic service are typically single-shaft rotors which require disassembly and re-assembly of the rotor to install in the machine casing. By requiring index balancing, either the compressor or expander component can be replaced individually without requiring the complete rotor to be rebalanced.

4.8.1.2 The expander wheel, compressor wheel, and the shaft shall be balanced using an index balancing procedure. All machining of components shall be completed before balancing. The wheels shall be supported by a concentric arbor during the balancing procedure. Two-plane balancing is preferred, but single-plane balancing can be used for components with a length to diameter (L/d) ratio of 0,2 or less. Each component shall be balanced so that the level of residual unbalance for each balance plane does not exceed the greatest value determined by Formulae (3) or (4) as applicable in ISO 10439-1:2015.

NOTE For information on the index balance procedure, refer to API 684.

4.8.1.3 Prior to starting the index balancing procedure for the compressor and expander wheels, the following steps shall be performed to check the integrity of the fits between the wheels and arbor.

a) Mount the wheel at an arbitrary 0 degree location on the arbor. Record the unbalance reading of the assembly.

b) Dismount and remount the wheel on the arbor in the original 0 degree position. Record the unbalance.

c) The vector reading from item b) shall be within 20 % of the vector reading from item a). If not, the arbor fit shall be checked for poor contact, dirt, or other items affecting the fit integrity.

4.8.1.4 Index balance both wheels, using an arbor, to the tolerance specified in 4.8.1.2. After this step, the wheels should be in balance and no further corrections should be required.

4.8.1.5 The shaft index balance procedure shall be performed using both wheels mounted in the following manner:

a) Mount the expander and compressor wheels on the shaft. Both wheels should be marked to an arbitrary 0 degree location on the shaft.

b) Identify appropriate balance planes on the shaft. Perform index balancing of the shaft using the wheels to the tolerance specified in 4.8.1.2.

c) Both wheels shall be treated as one part and turned together during the index balancing procedure.

4.8.1.6 * If specified, rotors shall be assembled and the balance verified. The residual unbalance for the randomly assembled components shall not exceed 10 times the maximum allowable residual unbalance as determined by Formulae (3) or (4) as applicable in ISO 10439-1:2015.

Assembled rotors that fail to meet these criteria shall be balance corrected by repeating the component index balance, not by trim balancing the assembly.

4.8.1.7 * If specified, a residual unbalance check shall be performed on assembled rotors. The residual unbalance check shall be performed after assembly balancing or assembly check-balancing is complete and before the assembled rotor is removed from the balancing machine.

NOTE Refer to ISO 10439-1:2015, Annex A for a description of the procedure for residual unbalance determination.

4.9 Bearings and bearing housings

4.9.1 General

4.9.1.1 Unless otherwise specified, hydrodynamic radial and thrust bearings shall be provided.

NOTE The typical expander-compressor has both the radial and thrust bearing built into a single assembly.

4.9.1.2 * If specified, magnetic bearings shall be supplied in accordance with ISO 10439-1:2015, Annex E.

4.9.1.3 Bearing material selection criteria shall include compatibility with the process gas.

NOTE Bearings are generally in contact with the process gas.

4.9.2 Hydrodynamic radial bearings

4.9.2.1 Sleeve or pad type bearings shall be used. The bearings shall be precision machined. Materials used shall be steel, brass, bronze, aluminium, copper alloy, or other suitable material.

4.9.2.2 Unless otherwise specified, hydrodynamic radial bearings shall be fitted with bearing metal temperature sensors, installed in accordance with API 670.

4.9.3 Hydrodynamic thrust bearings

Hydrodynamic thrust bearings shall be in accordance with ISO 10439-1:2015, 4.9.3 and 4.9.3.1 to 4.9.3.4.

4.9.3.1 Hydrodynamic thrust bearings shall be precision machined, continuous or segmented face design. Continuous face designs shall have grooving, such as spiral grooving, to allow oil distribution. Segmented face designs can be either fixed or tilting pad configuration. Materials used shall be steel, bronze, aluminium, copper alloy, or other materials suitable for the application. Hydrodynamic thrust bearings shall be arranged for continuous pressurized lubrication to each side.

NOTE A typical expander-compressor thrust bearing can be made of brass or bronze, have a tapered land or spiral groove face design, and be unbabbited.

4.9.3.2 Unless otherwise specified, thrust bearings shall be designed for equal thrust capacity in both axial directions.

4.9.3.3 Loads on hydrodynamic thrust bearings shall be limited to no more than 50 % of the bearing manufacturer's ultimate load rating at specified operating conditions.

4.9.3.4 When calculated, loads on hydrodynamic thrust bearings exceed 50 % of the ultimate capacity of the bearings, expander-compressors shall be equipped with automatic or fixed position thrust equalizing valves to reduce the bearing loads for the specified conditions to a minimum, reducing expected loads to no more than 50 % of the ultimate capacity of the bearing (see Annex C).

Bearings shall also be capable of meeting start-up and upset conditions.

NOTE 1 This device can be a direct operated valve, using fluid pressures taken from the thrust bearing oil film for actuation.

NOTE 2 Loading of 50 % of the ultimate load can be exceeded during start-up or upset conditions.

4.9.4 Bearing housings

4.9.4.1 Bearing housings shall be in accordance with ISO 10439-1:2015, 4.9.4 and 4.9.4.2.

4.9.4.2 Rotor support system parts (bearings, bearing housings, bearing shells, and bearing brackets) shall be separable from the mating casings.

NOTE Expander bearing housings are pressurized.

4.10 Expander-compressor shaft seals

4.10.1 Shaft seals shall comply with the requirement of ISO 10439-1:2015, 4.10 and 4.10.2 and 4.10.3.

NOTE Expander-compressors do not have shaft end seals, but the same types of seals are used for internal sealing between the process gas and the bearing housing.

4.10.2 Shaft seals shall be provided to restrict the leakage of process gas into the bearing housing over the range of specified operating conditions, including start-up and shutdown. Seals shall be suitable for specified variations in seal operating conditions that can prevail during start-up, shutdown, or settling out, and during any other special operation specified.

4.10.3 Shaft seals used in expanders can be either clearance seals or self-acting dry gas seals.

NOTE See ISO 10439-1:2015, 4.10 for information on shaft end seals.

4.11 Integral gearing

Integral gears are not applicable to expander-compressors.

4.12 Nameplates and rotation arrows

4.12.1 Nameplates and rotation arrows shall be in accordance with ISO 10439-1:2015, 4.12.

NOTE Rotation arrows are generally not provided for expander-compressors.

4.12.2 The following data shall be clearly stamped or engraved on the nameplate:

— supplier's name;

— serial number;

— size, type, and model number;

— design power;

— rated speed (rpm);

— trip speed (rpm);

— purchaser's item number or other reference;

— maximum allowable working pressure of each casing;

— maximum and minimum working temperature of each casing;

— hydrostatic test pressure of each casing;

— maximum continuous speed;

— lateral critical speeds up to and including the next critical above maximum continuous speed.

5 Accessories

5.1 Drivers

NOTE Expander-compressor units do not have separate drivers.

5.2 Couplings and guards

NOTE Expander-compressors do not have couplings and guards.

5.3 Lubrication and sealing systems

When required, a pressurized oil system shall be furnished to supply oil at suitable pressure(s) to the machine. Such systems shall be in accordance with ISO 10438 (all parts) as modified by Annex G.

5.4 Mounting plates

Mounting plates shall be in accordance with ISO 10439-1:2015, 5.4 and 5.4.1. and 5.4.2.

NOTE Soleplates are not used with expanders.

5.4.1 Unless an externally connected piece of rotating equipment such as a generator is supplied, jackscrews and other levelling devices are not required.

5.4.2 The expander-compressor shall be furnished with a baseplate in accordance with ISO 10439-1:2015, 5.4.2.

NOTE Expander-compressor units do not have couplings; therefore, sections of ISO 10439-1 that invoke requirements for alignment shims, machined surfaces, etc. are not applicable to expanders.

5.5 Controls and instrumentation

Controls and instrumentation shall be in accordance with ISO 10439-1:2015, 5.5 and 5.5.1 to 5.5.5.

5.5.1 Vibration and position monitoring

5.5.1.1 Unless otherwise specified, vibration transducers shall be supplied, installed, and calibrated in accordance with API 670.

5.5.1.2 * If specified, axial position probes shall be provided in accordance with API 670.

NOTE Expander-compressors normally use pressure from active thrust compensation system rather than axial position probes for alarm/shutdown functions.

5.5.1.3 * If specified, vibration monitors shall be supplied and calibrated in accordance with API 670.

5.5.2 Hydrodynamic bearings

5.5.2.1 *Unless otherwise specified, hydrodynamic radial bearings shall be fitted with bearing-metal temperature sensors installed in accordance with API 670. The purchaser will specify the type of detector.

5.5.2.2 *If specified, hydrodynamic thrust bearings shall be fitted with bearing-metal temperature sensors installed in accordance with API 670. The purchaser will specify the type of detector required.

5.5.2.3 * If specified, a bearing temperature monitor shall be supplied and calibrated in accordance with API 670.

5.5.3 Magnetic bearings

If magnetic thrust and radial bearings have been specified, they shall be fitted with bearing temperature sensors, installed in accordance with ISO 10439-1:2015, Annex E.

5.5.4 Overspeed shutdown system

5.5.4.1 General

5.5.4.1.1 Unless otherwise specified, an overspeed shutdown system based on a single circuit shall be provided.

The design of an expander-compressor provides an inherent degree of overspeed protection. Overspeed primarily results from an interruption of flow to the compressor or operation, primarily during start-up, with a very low compressor suction pressure. The design of the piping system, including all valves and associated controls, should ensure that compressor flow interruption or very low suction pressure does not occur. Since the system is unlikely to produce an overspeed condition, single circuit overspeed detection and trip systems are the standard.

5.5.4.1.2 * If specified, an overspeed shutdown system based on two-out-of-three voting logic shall be furnished.

5.5.4.1.3 The supplier shall design an overspeed shutdown system consisting of

a) electronic overspeed circuit [speed sensor(s) and logic device];

b) expander inlet trip valve;

c) electric solenoid valves.

NOTE Due to the wide variation in process services using expanders, it is not unusual for the expander inlet trip valve to be furnished by the purchaser.

5.5.4.2 Electronic overspeed detection circuit

5.5.4.2.1 Unless otherwise specified, an electronic overspeed detection circuit, consisting of a speed sensor(s) and logic device, shall be furnished. The design of the circuit shall include the following:

a) failure of either the sensor(s) or logic device shall initiate a shutdown;

b) all settings incorporated in the overspeed circuit shall be protected through control access;

c) it shall accept inputs from a frequency generator for verifying the trip speed setting;

d) it shall provide an output for a speed indicator.

5.5.4.2.2 Unless otherwise specified, magnetic pickups shall be supplied for speed sensing.

5.5.4.2.3 A hole or grooved surface integral with the shaft shall be provided for speed sensing. The hole or grooved surface can be used by both the overspeed system and the tachometer sensors.

5.5.4.3 Expander trip valve

5.5.4.3.1 Unless otherwise specified, the supplier will provide an expander inlet trip valve that will close when the supplier's shutdown system senses overspeed.

NOTE 1 Due to the wide variation in process services using expanders, it is not unusual for the expander inlet trip valve and solenoids to be furnished by the purchaser. The expander inlet trip valve is not the control mechanism for the expander. The trip valve is either full open or full closed (tripped). Capacity and speed control are provided by expander variable inlet nozzles, compressor minimum flow valve, or other means. The inclusion of a unit isolation valve upstream of the trip valve is typical of most installations, with provisions to depressurize the piping volume between the isolation and trip valves so that the trip valve does not have to be opened against full line pressure. The isolation valve is meant to close when the trip valve closes.

NOTE 2 See 4.6.1.4

5.5.4.3.2 The design of expander inlet trip valves shall include, but not be limited to, the following:

a) the ability to close rapidly as possible within a time as agreed;

b) actuation from a fail-safe spring loaded actuator, a gas operated actuator, or an air-operated actuator (If the design of the gas or air supply system could permit loss of gas or air pressure, then connections to provide volume bottles with capacity for two full stroke closures of the trip valve);

The torque capability of the actuator shall be sufficient to permit the valve to close with ice build-up on it. Consideration shall be given to additional sealing devices such as flexible pressure-assisted seal rings to overcome the friction of ice build-up.

c) an extended bonnet to maintain the stem packing at a non-cryogenic temperature;

d) special features to prevent ice, hydrates, and other solids from stopping valve closure.

5.5.4.3.3 If the expander inlet trip valve is furnished by the purchaser, the supplier shall review the selection and shall provide recommendations concerning the sizing, location, and closing time requirements.

5.5.4.3.4 An electric solenoid-operated valve shall be provided to initiate operation of the trip valve. Unless otherwise specified, the solenoid valve shall be de-energized to trip.

NOTE 1 Solenoids can draw significantly high currents.

NOTE 2 The purchaser can ensure that the electronic overspeed shutdown system is supplied from an uninterruptable power source.

5.5.4.3.5 When solenoids draw high currents that exceed the current rating of the relay in the overspeed shutdown system, interposing relays or other provisions shall be supplied.

5.5.5 Permanent strainer

5.5.5.1 * If specified, a permanent strainer located upstream of the trip valve in a removable spool piece, with an effective free flow area at least twice the cross-sectional area of the expander inlet trip valves shall be furnished by the supplier.

NOTE The spool piece is normally provided by the user. Differential pressure indication with a high pressure alarm switch can be provided for the strainer.

5.5.5.2 * If specified, the spool piece and differential pressure instrumentation for the permanent strainer shall be provided.

5.5.5.3 The supplier's design shall include provision for a local manual trip mechanism located near the expander inlet trip valve. Actuation of the manual trip mechanism shall close the trip valve and the variable inlet nozzles.

5.5.5.4 * If specified, the supplier shall furnish the local manual trip mechanism.

5.6 Piping and appurtenances

5.6.1 Piping and appurtenances furnished shall be in accordance with ISO 10439-1:2015, 5.6 and 5.6.2.

5.6.2 The supplier shall furnish all piping systems, including mounted appurtenances, located within the confines of the baseplate. The piping shall terminate with flanged connections at the edge of the

baseplate. The purchaser will furnish only interconnection piping between equipment groupings and off-base facilities.

5.7 Special tools

Special tools shall be furnished in accordance with ISO 10439-1:2015, 5.7.

6 Inspection, testing, and preparation for shipment

6.1 General

6.1.1 Inspection, testing, and preparation for shipment shall be in accordance with ISO 10439-1:2015, Clause 6 and 6.1 to 6.4.

6.1.2 General requirements for 6.1 to 6.4 shall be in accordance with ISO 10439-1:2015, 6.1. Also refer to Annex E for the inspector's checklist.

6.2 Inspection

Requirements for inspection shall be in accordance with ISO 10439-1.

6.3 Testing

6.3.1 General

6.3.1.1 In addition to ISO 10439-1:2015, 6.3, the expander-compressor(s) shall be tested in accordance with 6.3.3 and 6.3.4. Other optional tests that might be specified are described in 6.3.5.

6.3.1.2 Immediately upon completion of each witnessed mechanical or performance test, copies of the log data recorded during the test shall be given to the witnesses.

6.3.2 Wheel shaker test

6.3.2.1 For any new design which has not been previously built and tested, a shaker test shall be performed. The purpose of this test is to verify that the fundamental natural frequency of the blades and disk are in agreement with the range of predicted values calculated during the design phase. The measured frequency shall be within ±5 % of the calculated frequency under wheel shaker test conditions.

6.3.2.2 If this test does not validate the calculated values, the actual natural frequency shall be assessed against the operating speed range and expected stresses and the need for corrective action mutually agreed between the supplier and the purchaser.

6.3.2.3 If it is necessary to modify the wheel to adjust this natural frequency, the modified wheel shall be retested to confirm that the modification was successful.

6.3.3 Mechanical running test

6.3.3.1 The requirements of 6.3.3.1.1 to 6.3.3.1.5 shall be met before the mechanical running test is performed.

6.3.3.1.1 Unless otherwise agreed, the contract shaft seals and bearings shall be used in the machine for the mechanical running test.

NOTE Test expander wheel seals might be required due to the temperature differences between operating conditions and test conditions.

6.3.3.1.2 A test compressor wheel that closely matches the weight, centre of gravity, and moment of inertia of the actual wheel can be used.

NOTE A test wheel is typically used when the mechanical test would result in temperatures in the compressor which could cause damage to the actual wheel, or the expander cannot produce sufficient power on the test stand to achieve the desired speeds. The test wheel generates less heat and absorbs less power, thereby, eliminating this problem.

6.3.3.1.3 When oil lubricated bearings and/or seals are supplied, all oil pressures, viscosities, and temperatures shall be within the range of operating values recommended in the supplier's operating instructions for the specific unit being tested. Oil flow rates shall be measured.

6.3.3.1.4 Oil system components downstream of the filters shall meet the cleanliness requirements of ISO 10438 (all parts) before any test is started.

6.3.3.1.5 If magnetic bearings are used, the cooling air to the bearing cavity shall be established, levitation and turning of the magnetic bearings shall be checked per the manufacturer's instructions, and the magnetic bearing control package shall be exercised.

6.3.3.2 The mechanical running test of the equipment shall be conducted as specified in 6.3.3.2.1 to 6.3.3.2.4.

6.3.3.2.1 The equipment shall be operated at speed increments from zero to the maximum continuous speed until bearing temperatures, lube-oil temperatures (if applicable), and shaft vibrations have stabilized.

NOTE The supplier decides on the need for no dwell zones for blade resonances, critical speeds, and other natural frequencies

6.3.3.2.2 The equipment shall be run for 4 h continuous operation at maximum continuous speed.

6.3.3.2.3 The speed shall be increased to trip speed and the equipment shall be run for a minimum of 15 min.

6.3.3.2.4 The unit shall be tripped and allowed to coast to a stop.

6.3.3.3 During the mechanical running test, the requirements of 6.3.3.3.1 to 6.3.3.3.6 shall be met.

6.3.3.3.1 During the mechanical running test, the mechanical operation of all equipment being tested and the operation of the test instrumentation shall be satisfactory. The measured unfiltered vibration shall not exceed the limits of ISO 10439-1:2015, 4.8.8.8 and shall be recorded throughout the operating speed range. Any other test acceptance criteria shall be mutually agreed and stated in the test agenda.

6.3.3.3.2 While the equipment is operating at maximum continuous speed, or other speed and/or load that might have been specified in the test agenda, vibration data shall be acquired to determine amplitudes at frequencies other than synchronous. As a minimum, this data shall cover a frequency range from 0,25 times to 8 times the maximum continuous speed. If the amplitude of any discrete, nonsynchronous vibration exceeds 20 % of the allowable vibration as defined in ISO 10439-1:2015, 4.8.8.8 or 6,5 µm (0,25 mil), whichever is greater; the purchaser and the supplier shall mutually agree on requirements for any additional testing and on the equipment's acceptability.

6.3.3.3.3 The mechanical running test shall verify that lateral critical speeds conform to the requirements of ISO 10439-1:2015, 4.8.29. Any non-critically damped critical speed below the trip speed shall be determined during the mechanical running test and stamped on the nameplate followed by the word "test."

6.3.3.3.4 Shop verification of the unbalanced response analysis is not required.

6.3.3.3.5 * If specified, all real-time vibration data as agreed by the purchaser and supplier shall be recorded and a copy provided to the purchaser.

6.3.3.3.6 When spare mechanical centre sections including bearing housings are ordered to permit concurrent manufacture, each spare mechanical centre section shall also be given a mechanical running test in accordance with the requirements of this International Standard.

6.3.3.4 * For spare rotors and, if specified for main rotors, the requirements of 6.3.3.4.1 to 6.3.3.4.4 shall be met after the mechanical running test is completed.

Removal of bearings and seals can require disassembly of the machine. The merits of bearing and seal inspection of expander-compressor by dismantling, inspecting, and reassembling the machine, should be evaluated against the benefits of shipping a unit with proven mechanical assembly and casing joint integrity.

6.3.3.4.1 Hydrodynamic bearings shall be removed, inspected, and reassembled after the mechanical running test is completed.

6.3.3.4.2 * If specified, shaft seals shall be removed for inspection following a successful running test.

NOTE Removal and inspection of some seal types (such as cartridges) can require that the seal be returned to the seal manufacturer's facility.

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

6.3.3.4.4 If minor scuffs and scratches occur on bearings or process gas seal surfaces, minor cosmetic repairs of these parts is not a cause for rerunning the test.

6.3.4 Assembled machine gas leakage test

6.3.4.1 After the mechanical running test is completed, each completely assembled machine casing intended for toxic or flammable gas service shall be tested for gas leakage. The assembled casing shall be pressurized to the lowest of the expander or compressor casing maximum allowable working pressure, held at this pressure for a minimum of 30 min and subjected to a soap-bubble test to check for gas leaks. The test shall be considered satisfactory when no casing or casing joint leaks are observed.

NOTE These tests are intended to verify the integrity of the casing joints.

6.3.4.2 If a post-test inspection of machine internals is required (see 6.3.3.4), these tests shall be performed after machine reassembly following a satisfactory inspection.

6.3.5 Optional tests

Refer to ISO 10439-1:2015, 6.3.9 for optional tests.

6.3.5.1 Performance test

6.3.5.1.1 The expander shall be performance tested at the U/C ratio corresponding to the certified point, where:

U is the expander wheel tip speed;

C is the velocity equivalent to the enthalpy drop across the machine.

Sufficient points shall be taken to either side of the peak to establish the expander efficiency parabolic curve. The measured efficiency shall be at least 98 % of the predicted value. There is no applicable industry standard test code for expanders. It might be necessary to perform corrections to the data such as when certified point Q/N and U/C cannot be met simultaneously during the test.

NOTE The expander U/C ratio is the single most important parameter affecting the machine performance. The typical expander is designed to peak at a U/C ratio (a dimensionless number) of 0,7.

6.3.5.1.2 The compressor shall be performance tested at the Q/N ratio corresponding to the certified point, where:

Q is the compressor inlet volume flow;

N is the normal speed of the machine.

A minimum of five points shall be taken to either side to establish a curve of the compressor head and efficiency versus flow. The surge point shall be established and the observed surge point indicated on the performance test head curve. Other than this, the performance test shall be in accordance with ASME PTC10-1997 or ISO 5389. The compressor shall deliver at least 98 % of the normal head at the normal capacity at the speed derived through power balance from the measured expander efficiency. The compressor power at the normal condition shall not be more than 106 % of that available from the expander, nor shall it be less than 96 % of that available from the expander.

NOTE Refer to the applicable test code for general instructions. ASME PTC 10–1997 does not apply to some low-pressure ratio compressors. Refer to 1.2.2 of PTC 10–1997 for the selection of the appropriate test code to be used.

6.3.5.1.3 These tolerances shall be inclusive of all test tolerances.

NOTE Both of the performance test codes referred to have provision for calculating inaccuracy based on instrumentation and procedures. These test inaccuracies are already included in the above tolerance and, therefore, are not to be further additive.

6.3.5.1.4 The performance test shall be conducted using only one contract mechanical centre section.

6.4 Preparation for shipment

6.4.1 Preparation for shipment shall be in accordance with ISO 10439-1:2015, 6.4 and 6.4.2.

6.4.2 When a spare mechanical centre section is purchased, it shall be prepared for unheated indoor storage for a period of at least five years.

NOTE This can require inspection or other activities by the purchaser.

7 Supplier's data

7.1 General

7.1.1 Supplier data shall be provided in accordance with ISO 10439-1:2015, Clause 7 and 7.1 to 7.3.

7.1.2 The information to be furnished by the supplier is specified in Annex B and ISO 10439-1:2015, Clause 7. The supplier shall complete and forward the VDDR form in Annex B to the address or addresses noted in the inquiry or order. This form shall detail the schedule for transmission of drawings and data as agreed at the time of the order as well as the number and type of copies required by the purchaser.

7.2 Proposals

7.2.1 Technical data

Technical data shall be in accordance with ISO 10439-1:2015, 7.2.3 and 7.2.1.1.

7.2.1.1 Curves

7.2.1.1.1 Performance curves shall be submitted for each compressor and expander. These curves shall encompass the map of operations, with any limitations indicated thereon. All curves shall be marked "PREDICTED".

7.2.1.1.2 Predicted curves provided for expander-compressors shall include the following:

a) expander power versus flow;

b) compressor power versus flow;

c) compressor head and pressure ratio versus flow for at least four speed lines from 70 % to 110 % of normal speed;

d) compressor surge line;

e) expander *U*/*C* versus efficiency.

7.3 Contract data

Contract data shall be in accordance with ISO 10439-1:2015, 7.3 and 7.3.1 and 7.3.2.

7.3.1 General

7.3.2 Curves and data sheets

7.3.2.1 Curves shall be provided in accordance with ISO 10439-1:2015, 7.3.2.1 and 7.3.2.2.

7.3.2.2 If a performance test is specified, the supplier shall provide test data and curves when the test has been completed. Curves for the as-tested performance shall include the data shown in 7.2.1.1.2. All curves shall be marked "AS TESTED".

Annex A
(normative)

Datasheets

The datasheets are also available in electronic format via http://standards.iso.org/iso/.

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APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ○ AS BUILT
FOR _____ UNIT _____
SITE _____
SERVICE _____ MODEL:
MANUFACTURER _____ SERIAL NO. _____
APPLICABLE STANDARD: ○ US ○ ISO
NOTE: INFORMATION TO BE COMPLETED BY: ○ PURCHASER ☐ MANUFACTURER ▽ PURCHASER OR MANUFACTURER

OPERATING CONDITIONS

(ALL DATA ON PER UNIT BASIS)

	NORMAL CASE		CASE A		CASE B	
	EXP	COMP	EXP	COMP	EXP	COMP
INLET CONDITIONS:						
○ (m³/h) (1.013 barA & 0°C DRY)						
○ WEIGHT FLOW, (kg/h) (EXP: WET / DRY; COMP: WET / DRY)						
○ PRESSURE (barA)						
○ TEMPERATURE (°C)						
○ MOLECULAR WEIGHT						
○ _____						
○ _____						
DISCHARGE CONDITIONS:						
☐ PRESSURE (barA)						
☐ TEMPERATURE (°C)						
☐ WEIGHT PERCENT LIQUID (%)						
☐ GAS HORSEPOWER (kW)						
☐ SPEED (rpm)						
☐ ADIABATIC / POLYTROPIC EFFICIENCY (Exp / Comp, %)						
○ _____						
○ _____						
○ GUARANTEE CASE (check one case)						

VARIABLE INLET GUIDE VANE PROCESS CONTROL SIGNAL SOURCE:
TYPE: ○ ELECTRONIC RANGE: _____ mA
○ PNEUMATIC _____ (barG)

GAS ANALYSIS: ○ MOL % ○ WT %		NORMAL		CASE A		CASE B		SEAL	REMARKS:
		EXP	COMP	EXP	COMP	EXP	COMP	GAS	
	MW								
HELIUM	4.000								
HYDROGEN	2.016								
NITROGEN	28.016								
WATER VAPOR	18.016								
CARBON DIOXIDE	44.010								
HYDROGEN SULFIDE	34.076								
METHANE	16.042								
ETHYLENE	28.052								
ETHANE	30.068								
PROPYLENE	42.078								
PROPANE	44.094								
I-BUTANE	58.120								
n-BUTANE	58.120								
I-PENTANE	72.146								
n-PENTANE	72.146								
HEXANE PLUS									
TOTAL									
AVG. MOL. WT.									

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CONSTRUCTION FEATURES

☐ **SPEEDS:**
MAX. CONT. _____ RPM TRIP _____ RPM
TIP SPEEDS: EXPANDER _____ (m/s) @ MCS
COMPRESSOR _____ (m/s) @ MCS

LATERAL CRITICAL SPEEDS (DAMPED)
☐ FIRST CRITICAL _____ RPM BENDING MODE
○ UNDAMPED CRITICAL SPEED MAP
○ COMPLETE ROTORDYNAMIC ANALYSIS (API 617 TYPE)

CASINGS:
☐ MODEL _____

	EXP	BRG HSG	COMP
☐ CASING SPLIT			
☐ MATERIAL			
☐ ASTM A-351 CF8			
☐ ASTM A-352 LC3			
☐ ASTM A-352 LCC			
☐ ASTM A-216 WCB			
☐ _____			
○ DESIGN PRES (barG)			
○ MAX DESIGN TEMP, (°C)			
○ MIN. DESIGN TEMP (°C)			
○ VISUAL INSPECTION			
○ CHARPY TESTING			
○ MAGNETIC PARTICLE			
○ LIQUID PENETRANT			
○ CRITICAL AREA X-RAY			
_____			
_____			
☐ HYDROTEST PRESS	☐ 1.5 X DESIGN	☐ _____	
○ CASING LEAK TEST	☐ 1.1 X DESIGN	☐ _____	

○ 100% NITROGEN
○ NITROGEN / HELIUM MIX (90 / 10)
○ 100% HELIUM

NOTE: LEAK TEST PERFORMED FOLLOWING HYDROTEST USING SOAP BUBBLE METHOD

IMPELLERS:

	EXP	COMP
☐ DIAMETER (IN.)		
☐ TYPE (OPEN, ENCLOSED)		
☐ TYPE FABRICATION		
☐ EXPANDER WHEEL MATERIAL		
☐ YIELD STRENGTH (bar)	MAX _____ MIN _____ (TYP)	
☐ HARDNESS:	_____ BNH / R_C (TYP)	
☐ COMPRESSOR WHEEL MATERIAL		
☐ YIELD STRENGTH (bar)	MAX _____ MIN _____ (TYP)	
☐ HARDNESS:	_____ BNH / R_C (TYP)	

SHAFT:
☐ MATERIAL _____
SHAFT END: ☐ TAPERED ☐ CYLINDRICAL
☐ YIELD STRENGTH (bar) _____
☐ SHAFT HARDNESS (BNH)(Rc) _____

☐ **SHAFT SEALS:**
☐ SINGLE PORT BUFFERED LABYRINTH
☐ DOUBLE PORT BUFFERED LABYRINTH
☐ TRIPLE PORT BUFFERED LABYRINTH
BLEED PRESSURE: _____ (barG)
☐ DRY GAS SEAL: _____
○ TYPE BUFFER GAS _____
○ BUFFER GAS SUPPLY PRESSURE _____ (barG)
☐ OTHER _____

SEAL GAS REQUIREMENTS :
☐ TYPE: _____
☐ MIN. SUPPLY PRESS. _____ (barG)
☐ MAX SUPPLY PRESS. _____ (°C)
☐ MIN SUPPLY TEMP. _____ (°C)
☐ MAX SUPPLY TEMP. _____ (°C)
☐ NORMAL FLOW _____ (m^3/h) _____ (bar) ΔP
☐ MAX FLOW _____ (m^3/h) _____ (bar) ΔP

NOTE: PURCHASER TO SUPPLY SEAL GAS COMPOSITION ON SHEET 1.

CASING CONNECTIONS:

CONNECTION	☐ SIZE NPS / RATING	☐ FACING	☐ POSITION	☐ FLANGED OR STUDDED	○ MATING FLG & GASKET BY VENDOR	☐ GAS VELOCITY (m/s)
EXPANDER INLET						
EXPANDER DISCHARGE						
COMPRESSOR INLET						
COMPRESSOR DISCHARGE						

☐ **OTHER CONNECTIONS**

SERVICE:	NO.	SIZE	TYPE
LUBE-OIL INLET			
LUBE OIL OUTLET			
SEAL GAS INLET			
SEAL GAS OUTLET			
CASING DRAINS, EXP / COMP			
INTERMEDIATE BLEED			

SERVICE:	NO.	SIZE	TYPE
THRUST PRESSURES			
WHEEL PRESSURES, EX / COM			
BEARING HOUSING PRES			

CASING DRAINS:
○ PLUGGED ○ FLANGED AND VALVED
○ FLANGED ○ FLANGED, VALVED, AND MANIFOLDED

○ **ALLOWABLE PIPING FORCES AND MOMENTS:**
○ 1.85 X NEMA SM23
○ 3 X NEMA SM23
○ OTHER: _____

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CONSTRUCTION FEATURES (CONTINUED)

BEARINGS:

RADIAL:

☐ TYPE:
- ☐ SLEEVE BEARING
- ☐ TILTING PAD BEARING
- ☐ ACTIVE MAGNETIC BEARING
- ☐ OTHER _____

☐ MATERIAL:
- ☐ ALUMINUM (BABBITTED)
- ☐ BRASS / BRONZE(BABBITTED)
- ☐ CARBON STEEL (BABBITTED)
- ☐ OTHER _____

☐ SHAFT DIA. (mm) _____

☐ MANUFACTURER _____

BEARING TEMPERATURE DEVICES:

○ **TYPE**
- ○ THERMOCOUPLES TYPE: _____
- ○ RESISTANCE TEMP DETECTORS
  - ○ RESISTANCE MAT'L _____ ○ _____ OHMS

○ **LOCATION / QTY**
- ☐ SINGLE DUAL ELEMENT (MAIN & SPARE) ____ PER BRG

○ **TEMPERATURE PROTECTION LOGIC DEVICE:**
- ○ TEMPERATURE MONITOR ○ DCS
- ○ PLC ○ OTHER _____
- ○ LOGIC DEVICE SUPPLIED BY: ○ VENDOR PURCH
- ○ LOCATION OF TEMPERATURE PROTECTION LOGIC DEVICE:
- ○ LOCAL CONTROL PANEL ○ REMOTE CONTROL PANEL
- ○ MAIN CONTROL ROOM ○ OTHER _____

○ **BEARING TEMPERATURE DISPLAY TYPE:**
- ○ TEMPERATURE MONITOR ☐ MODEL _____
- ○ ALPHANUMERIC DISPLAY
- ○ MMI / VDU
- ○ PURCHASER
- ○ OTHER _____

○ DISPLAY DEVICE PROVIDED BY: ○ VENDOR ○ PURCH
- ○ LOCATION OF TEMPERATURE DISPLAY DEVICE:
- ○ LOCAL CONTROL PANEL ○ REMOTE CONTROL PANEL
- ○ MAIN CONTROL ROOM ○ OTHER _____

SPEED PROBES:

○ **TYPE:** ○ ELECTROMAGNETIC ○ EDDY CURRENT

○ **QUANTITY** _____

○ **MACHINE PROTECTION LOGIC DEVICE:**
- ○ SWITCH ○ SPEED MONITOR ○ _____

○ **LOCATION OF SPEED DISPLAY:**
- ○ LOCAL PANEL ○ REMOTE DISPLAY

THRUST:

☐ TYPE:
- ☐ TAPERED LAND THRUST BEARING
- ☐ TILTING PAD THRUST BEARING
- ☐ ACTIVE MAGNETIC THRUST BEARING
- ☐ OTHER _____

☐ MANUFACTURER _____

LUBRICATION: ☐ FLOODED ☐ DIRECTED ☐ N/A

THRUST COLLAR / DISK: ☐ INTEGRAL ☐ SEPARATE

VIBRATION DETECTORS:

TYPE: ☐ EDDY CURRENT ☐ INDUCTIVE ☐ _____
- ○ MFR _____
- ☐ MODEL _____

○ **LOCATION AND QUANTITY:**
- ○ NO. PER JOURNAL BEARING _____ TOTAL NO. _____
- ○ IF REQ'D, OSCILLATOR-DEMODULATORS SUPPLIED BY:
  - ○ VENDOR ○ MODEL _____
  - ○ PURCHASER ○ MODEL _____

○ **MACHINE VIBRATION PROTECTION LOGIC DEVICE:**
- ○ VIBRATION MONITOR ○ DCS
- ○ PLC ○ OTHER _____
- ○ LOGIC DEVICE PROVIDED BY: ○ VENDOR ○ PURCH
- ○ LOCATION OF VIBRATION PROTECTION LOGIC DEVICE:
- ○ LOCAL CONTROL PANEL ○ REMOTE CONTROL PANEL
- ○ MAIN CONTROL ROOM ○ _____

○ **VIBRATION AMPLITUDE DISPLAY**
- ○ VIBRATION MONITOR ☐ MODEL _____
- ○ ALPHANUMERIC DISPLAY
- ○ MMI / VDU
- ○ OTHER _____
- ○ DISPLAY DEVICE PROVIDED BY: ○ VENDOR ○ PURCH
- ○ LOCATION OF DISPLAY DEVICE:
- ○ LOCAL CONTROL PANEL ○ REMOTE CONTROL PANEL
- ○ MAIN CONTROL ROOM ○ _____

○ KEY PHASOR ○ YES ○ NO

MAGNETIC BEARING CONTROL CABINET, IF REQUIRED

○ UPS SUPPLIED BY: ○ VENDOR ○ PURCHASER

○ **LOCATION OF CONTROL CABINET:**
- ○ LOCAL PANEL ○ REMOTE PANEL
- ○ MAIN CONTROL ROOM ○ _____

○ CABLE LENGTH FROM MACHINE SKID TO CONTROL CABINET: _____ (m)

○ **POWER AND SIGNAL CABLES:**
- ○ SUPPLIED BY PURCHASER ○ SUPPLIED BY VENDOR

○ **COMUNICATION PROTOCOL**
- ○ MODBUS ○ OTHER: _____

☐ POWER CONSUMPTION: (kW)

REMARKS: _____

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ACCESSORIES

EXPANDER INLET TRIP VALVE:

- TYPE:
  - BUTTERFLY VALVE SIZE: _____ RATING: _____ ALLOWABLE PRESSURE DROP: _____ (bar)
  - OTHER: _____
- DESIGN PRESSURE: _____ (barG) DESIGN TEMPERATURE (MIN / MAX) _____ / _____ (°C)
- MATERIAL:
  - STAINLESS STEEL LOW TEMP CARBON STEEL CARBON STEEL _____
- TRIP VALVE SUPPLIED BY: VENDOR PURCHASER

INLET SCREENS AND PIPE SPOOLS:

INLET SCREENS:	EXP	COMP
TYPE: (CONE, BASKET, OTHER)		
SIZE (DIA.) (mm)		
MESH SIZE		
PRESSURE DROP (bar)		
MATERIAL:		
STAINLESS STEEL	○	○
OTHER _____	○	○

INLET SCREENS SUPPLIED BY: VENDOR PURCHASER

INLET SPOOLS FOR INLET SCREENS:	EXP	COMP
SIZE		
RATING		
FACING		
DESIGN PRESSURE: (barG)		
DESIGN TEMPERATURE (MIN/MAX) (°C)		
DESIGN TEMPERATURE (MIN/MAX) (°C)		
MATERIAL:		
STAINLESS STEEL	○	○
LOW TEMP CARBON STEEL	○	○
CARBON STEEL	○	○
OTHER:		
SPOOL CONSTRUCTION:		
SLIP-ON / SOCKETWELD	○	○
SOCKETWELD	○	○
WELDNECK / BUTTWELD	○	○

PIPE SPECIFICATION: _____

COMPRESSOR ANTI-SURGE SYSTEM FURNISHED BY PURCHASER SUPPLIER

- CONTROLLER: PID CONTROLLER OTHER: _____
- RECYCLE VALVE BY SUPPLIER SIZING ONLY
  - TYPE: _____ MTL: _____ NOISE LIMIT: VENDOR STD SPECIAL: _____
  - DESIGN PRESSURE: _____ (barG) DESIGN TEMPERATURE (MIN/MAX) _____ / _____ (°C)
  - PRESSURE UPSTREAM: _____ (barG) DOWNSTREAM Δ P _____ (barG)
  - ☐ Δ P VALVE _____ STROKE TIME OPEN - CLOSE _____ (sec) _____
- INLET FLOW DEVICE TYPE: _____ BY: _____
- COMP. INLET FLOW TRANSMITTER COMP. DIFF. PRESSURE TRANSMITTER
- PIPING: BY PURCHASER BY SUPPLIER

REMARKS: _____

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SITE DATA

- ○ ELEVATION _____ (m) BAROMETER _____ (barA)
- ○ RANGE OF AMBIENT TEMPS:
  - NORMAL _____ (°C)
  - MAXIMUM _____ (°C)
  - MINIMUM _____ (°C)

LOCATION:

- ○ INDOOR ○ OUTDOOR ○ GRADE
- ○ HEATED ○ UNDER ROOF ○ MEZZANINE
- ○ UNHEATED ○ PARTIAL SIDES ○ _____

UNUSUAL CONDITIONS: ○ DUST ○ FUMES

- ○ WINTERIZATION REQ'D. ○ TROPICALIZATION REQ'D.
- ○ OTHER _____

INSTRUMENT AND CONTROLS

STANDARD ○ NEMA ○ IEC

	INDOOR	OUTDOOR
CONTROL ENCLOSURE		
TERMINAL BOX		

SHOP INSPECTION AND TESTS:

	REQ'D	OBSRV	WTNS
CLEANLINESS	○	○	○
HYDROSTATIC	○	○	○
LOW SPEED BALANCE (ISO 1940 G2.5)	○	○	○
IMPELLER OVERSPEED (115% OF MCS)	○	○	○
IMPELLER RESONANCE TEST	○	○	○
MECHANICAL RUN	○	○	○
○ MAIN ○ SPARE			
○ CONTRACT PROBES ○ SHOP PROBES			
VARY LUBE & SEAL OIL PRESSURES AND TEMPERATURES	○	○	○
POLAR FORM VIB DATA	○	○	○
TAPE RECORD VIB DATA	○	○	○
TAPE DATA TO PURCHASER	○	○	○
PERFORMANCE TEST (AIR)	○	○	○
COMPLETE UNIT TEST	○	○	○
HE/N2 CASING LEAK TEST	○	○	○
SOUND LEVEL TEST	○	○	○
FULL POWER TEST	○	○	○
	○	○	○
	○	○	○

PAINTING:

- ○ VENDOR STANDARD
- ○ OTHER _____

SHIPPING PREPARATION:

- ○ DOMESTIC PACKING
- ○ EXPORT PACKING (MIL-P 116J METHOD II)
- ○ SPECIAL: _____

SPARE ROTATING ASSEMBLY:

- ○ WOODEN SHIPPING CONTAINER
- ○ METAL STORAGE CONTAINER
  - ○ N2 PURGE ○ OTHER:

APPLICABLE SPECIFICATIONS:

- ○ VENDOR STANDARD
- ○ API 617, 7TH EDITION
- ○ OTHER: _____

NOISE SPECIFICATIONS:

- ○ VENDOR STANDARD
- ○ PURCHASER SPECIFICATION
- ○ SEE SPECIFICATION _____

ACOUSTIC COVERING: ○ YES ○ NO

○ ELEC. AREA CLASS. (Part 1-4.4.1.6) ○ NEC ○ IEC

EQUIPMENT

CLASS _____ GROUP _____ DIV. _____

ZONE _____ GROUP _____ TEMP CLASS _____

CONTROL PANNELS

CLASS _____ GROUP _____ DIV. _____

ZONE _____ GROUP _____ TEMP CLASS _____

○ **UTILITY CONDITIONS:**

INSTRUMENT AIR FOR GUIDE VANE ACTUATOR:

MAX PRESS _____ (barG) MIN PRESS _____ (barG)

MISCELLANEOUS:

☐ RECOMMENDED STRAIGHT RUN OF PIPE DIAMETERS

- AT EXPANDER DISCHARGE: _____
- AT COMPRESSOR INLET: _____

○ VENDOR TO REVIEW & COMMENT ON PURCHASER'S PIPING & FOUNDATION

○ VENDOR TO REVIEW & COMMENT ON PURCHASER'S CONTROL SYSTEMS

○ _____

○ _____

○ _____

☐ **WEIGHTS** (kg)

- EXP / COMP UNIT _____ (kg)
- MAINTENANCE (SPARE ROTATING ASSY) _____ (kg)
- TOTAL MACHINERY SKID WEIGHT: _____ (kg)
- TOTAL SUPPORT SYSTEM SKID WT. (IF SEPARATE): _____ (kg)

☐ **SPACE REQUIREMENTS** (m)

- MACHINERY SKID: L _____ W _____ H _____
- SUPPORT SYSTEM SKID: L _____ W _____ H _____

SPECIAL TOOL PACKAGING

- ○ METAL STORAGE CONTAINER
- ○ OTHER: _____

DELIVERY:

- ○ FCA FACTORY
- ○ FOB SITE (DOMESTIC ONLY)
- ○ OTHER: _____

REMARKS: _____

Annex B
(informative)

Vendor (Supplier) data and drawing requirements (VDDR)

B.1 VDDR for centrifugal and axial compressors

The vendor (supplier) data and drawing requirements (VDDR) for centrifugal and axial compressors are also available in electronic format via http://standards.iso.org/iso/. The text for details of the description is given in B.2.

EXPANDER-COMPRESSOR SUPPLIER DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No.
	Purchase order No.	Date
	Requisition No.	Date
	Inquiry No.	Date
	Revision ..... by	Manufacturer
	For	Unit
	Site	Service

Proposal a – Bidder shall furnish number of paper copies /number of electronic copies of data as indicated

Review – Supplier shall furnish number of paper copies /number of electronic copies of data as indicated

Final – Supplier shall furnish number of paper copies /number of electronic copies of data as indicated

			Description (see text)	**Distribution record**				
				Review due from supplier b c	Review received from supplier	Review returned to supplier	Final due from supplier c	Final received from supplier
/	/	/	1. Certified dimensional outline drawing and list of connections					
/	/	/	2. Cross-sectional drawings and part numbers					
/	/	/	3. Rotor assembly drawings and part numbers					
/	/	/	4. Thrust-bearing assembly drawings and part numbers					
/	/	/	5. Journal-bearing assembly drawings and bill of materials					
/	/	/	6. Coupling assembly drawings and bill of materials					
/	/	/	7. Lube-oil schematic and bill of materials					
/	/	/	8. Lube-oil arrangement drawing and list of connections					
/	/	/	9. Lube-oil component drawings and data					
/	/	/	10. Seal system schematic and bill of material					
/	/	/	11. Seal system arrangement drawing and list of connections					
/	/	/	12. Seal system component drawings and data					
/	/	/	13. Seal assembly drawing and part numbers					
/	/	/	14. Electrical and instrumentation schematics and bill of materials					
/	/	/	15. Electrical and instrumentation arrangement of drawing and list of connections					
/	/	/	16. Buffer gas system schematic and bill of material					
/	/	/	17. Buffer gas system arrangement drawing and list of connections					
/	/	/	18. Buffer gas system component drawing and data					
/	/	/	19. Data sheets (proposal/as-built)					

a Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

b Purchase may indicate in the column the desired time frame for submission of data.

c Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

EXPANDER-COMPRESSOR SUPPLIER DRAWING AND DATA REQUIREMENTS	Job No.	Item No.
	Purchase order No.	Date
	Requisition No.	Date
	Inquiry No.	Date
	Revision …….. by	Manufacturer
	For	Unit
	Site	Service

Proposal a – Bidder shall furnish number of paper copies /number of electronic copies of data as indicated

Review – Supplier shall furnish number of paper copies /number of electronic copies of data as indicated

Final – Supplier shall furnish number of paper copies /number of electronic copies of data as indicated

			Description (see text)	**Distribution record**				
				Review due from supplier b c	Review received from supplier	Review returned to supplier	Final due from supplier c	Final received from supplier
/	/	/	20. Allowable external forces and moments for each nozzle in tabular form (with proposal)					
/	/	/	21. Predicted noise sound level (proposal)					
/	/	/	22. Metallurgy of major components (in proposal)					
/	/	/	23. Lateral analysis report					
/	/	/	24. Torsional analysis report					
/	/	/	25. Vibration analysis report					
/	/	/	26. Performance curves for each compressor and expander					
/	/	/	27. Impeller overspeed test report					
/	/	/	28. Mechanical running test report					
/	/	/	29. Coupling selection and rating					
/	/	/	30. List of recommended spare parts					
/	/	/	31. List of special tools					
/	/	/	32. Preparation for storage at job site before installation					
/	/	/	33. Weather protection and winterization required at job site					
/	/	/	34. Tabulation of all utilities					
/	/	/	35. List of similar machines					
/	/	/	36. Operating restrictions to protect equipment during start-up operation and shutdown					
/	/	/	37. List of components requiring purchaser's approval					
/	/	/	38. Summary of materials and hardness of materials exposed to H2S					

a Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

b Purchase may indicate in the column the desired time frame for submission of data.

c Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

EXPANDER-COMPRESSOR SUPPLIER DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No.
	Purchase order No.	Date
	Requisition No.	Date
	Inquiry No.	Date
	Revision …….. by	Manufacturer
	For	Unit
	Site	Service

Proposal a – Bidder shall furnish number of paper copies /number of electronic copies of data as indicated

Review – Supplier shall furnish number of paper copies /number of electronic copies of data as indicated

Final – Supplier shall furnish number of paper copies /number of electronic copies of data as indicated

			Description (see text)	**Distribution record**				
				Review due from supplier [b] [c]	Review received from supplier	Review returned to supplier	Final due from supplier [c]	Final received from supplier
/	/	/	39. Seal leakage rates					
/	/	/	40. Interstage cooler system data					
/	/	/	41. Drawings, details and description of instrumentation and controls					
/	/	/	42. Minimum length of straight pipe required at machine inlet or side inlets					
/	/	/	43. Maximum and minimum allowable seal pressure for each compressor					
/	/	/	44. Statement of manufacturer's testing capabilities					
/	/	/	45. Performance test data and curves					
/	/	/	46. Back-to-back impeller machine supplier to provide thrust-bearing loads versus differential pressure curve					
/	/	/	47. Balance piston leakage rates					
/	/	/	48. When specified, supplier shall supply curves of balance piston line differential pressure versus thrust load					
/	/	/	49. Production/delivery schedule					
/	/	/	50. Testing procedures					
/	/	/	51. Progress reports					
/	/	/	52. Installation manual					
/	/	/	53. Operating and maintenance manual					
/	/	/	54. Technical data manual					
/	/	/						
/	/	/						
/	/	/						

[a] Proposal drawings and data do not have to be certified. Typical data shall be clearly identified as such.

[b] Purchase may indicate in the column the desired time frame for submission of data.

[c] Bidder shall complete these two columns to reflect the actual distribution schedule and include this form with the proposal.

EXPANDER-COMPRESSOR SUPPLIER DRAWING AND DATA REQUIREMENTS		
	Job No.	Item No.
	Purchase order No.	Date
	Requisition No.	Date
	Inquiry No.	Date
	Revision ..... by	Manufacturer
	For	Unit
	Site	Service

Notes:

1. Where necessary to meet the scheduled shipping date, the supplier shall proceed with manufacture upon receipt of the order and without awaiting the purchaser's approval of drawings.
2. The supplier shall send all drawings and data to the following:

_____

_____

_____

3. All drawings and data shall show project, purchase order, and item numbers as well as plant location and unit. One set of the drawings and instructions necessary for field installation, in addition to the copies specified above, shall be forwarded with shipment.
4. See the descriptions of required items that follow.
5. All of the information indicated on the distribution schedule shall be received before final payment is made.
6. If typical drawings, schematics, bills of material are used for proposals, they shall be marked-up to show the expected weight and dimensions to reflect the actual equipment and scope proposed.

Nomenclature:

S number of weeks before shipment.

F number of weeks after firm order.

D number of weeks after receipt of approved drawings.

Supplier _____

Date _____ Supplier Reference _____

Signature _____

(Signature acknowledges receipt of all instructions)

B.2 Descriptions

1) certified dimensional outline drawing and list of connections including the following:
   i) the size, rating, and location of all customer connections;
   ii) approximate overall and handling weights;
   iii) overall dimensions and maintenance and dismantling clearances;
   iv) shaft centering height;
   v) dimensions of base plate (if furnished) for train or skid mounted package, complete with diameters, number and locations of bolt holes, and thicknesses of sections through which the bolts shall pass;
   vi) grounding details;
   vii) forces and moments allowed for suction and discharge nozzles;
   viii) centre of gravity and lifting points;
   ix) shaft end separation and alignment data;
   x) direction of rotation;
   xi) winterization, tropicalization, and/or noise attenuation details, when required;
   xii) sketches to show lifting of assembled machine and major components and auxiliaries.
2) cross-sectional drawings and part numbers of major equipment
3) rotor assembly drawings and part numbers
4) thrust-bearing assembly drawings and part numbers
5) journal-bearing assembly drawings and bill of materials
6) coupling assembly drawing and bill of materials
7) lube-oil schematic and bill of material including the following:
   i) oil flows, temperatures, and pressure at each point;
   ii) control alarm shutdown settings for pressure and temperature;
   iii) total heat loads;
   iv) utility requirements including electrical, water, air and steam;
   v) pipe, valve, and orifice sizes;
   vi) instrumentation, safety devices, control schemes, and wiring diagrams.
8) lube-oil arrangement drawing and list of connections
9) lube-oil component drawings and data including the following:
   i) pumps and drivers;
   ii) coolers, filter, and reservoir;

iii) instrumentation.

10) seal system schematic and bill of material including the following:
    i) flows oil or gas, temperatures, and pressures at each point;
    ii) control, alarm and shutdown settings for pressure and temperatures;
    iii) total heat load for coolers, if required;
    iv) utility requirements, including electrical, water, air, and steam;
    v) pipe, valve, and orifice sizes;
    vi) instrumentation, safety devises, control schemes, and wiring diagrams;
    vii) filtration requirements;
    viii) height of overhead tank above centreline of machine.
11) seal system arrangement drawing and list of connections
12) seal system components drawing and data, including the following:
    i) pumps and drivers;
    ii) coolers, filter, and reservoirs;
    iii) instrumentation.
13) seal assembly drawing and part numbers
14) electrical and instrumentation schematics and bill of materials
15) electrical and instrumentation arrangement drawing and list of connections:
    i) vibration warning and shutdown limits;
    ii) bearing temperature warning and shutdown limits;
    iii) lube-oil temperature warning and shutdown limits;
    iv) lube-oil pressure warning and shutdown limits;
    v) lube-oil level warning and shutdown limits;
    vi) machine discharge pressure and temperature warning and shutdown limits;
    vii) seal, pressure, temperature, flow warning, and shutdown limits.
16) electrical and instrumentation arrangement drawing and list of connections
17) buffer gas system schematic and bill of material
18) buffer gas system arrangement drawing and list of connections
19) buffer gas system component drawings and data, including the following:
    i) control devices;
    ii) pressure and filtration requirements.
20) data sheets provided with proposal as-built
21) The supplier shall furnish the allowable forces and moments for each nozzle in tabular form with the proposal.

22) predicted noise level, sound pressure, and sound power level

23) metallurgy of major components identified with ASTM, AISI, ASME, or SAE numbers stated in proposal

24) Lateral analysis report when specified shall also include a stability analysis.

25) torsional analysis report

26) vibration analysis conducted on machines that require disassembly after balancing to allow machine assembly

    The supplier shall also provide historic unbalance data for the machine size and type.

27) Performance data and curves shall be submitted to the purchaser with proposal.

28) Dimensions taken from each impeller before and after overspeed testing shall be submitted for review.

29) mechanical running test report to include the following:

    i) unfiltered vibration;

    ii) plots showing synchronous vibration and phone angle, filtered and unfiltered;

    iii) when specified, data shall be furnished in polar form;

    iv) when specified, tape recordings shall be made of all real time vibration data;

    v) electrical and mechanical run-out at each probe.

    Immediately upon completion of each witnessed mechanical or performance test, copies of the log and data recorded during the test shall be given to the witnesses.

30) coupling selection and rating

31) list of spare parts recommended for start-up and normal maintenance purposes

32) list of the special tools furnished for maintenance

33) The supplier shall provide the purchaser with instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and prior to start-up.

34) a description of any special weather protection required for start-up, operation, and period of idleness under the site conditions specified on the data sheets

35) a complete list of utility requirements: quantity, filtration, and supply pressure of the following:

    i) steam;

    ii) water;

    iii) electricity;

    iv) air;

    v) gas;

    vi) lube oil and seal oil (quantity and supply pressure);

    vii) heat loads;

    viii) power ratings and operating power requirements for auxiliary drivers.

36) a list of machines similar to the proposed machines that have been installed and operating under conditions analogous to those specified in the inquiry

37) any start-up, shutdown, or operating restrictions required to protect the integrity of the equipment, including any unacceptable speeds due to natural frequencies

38) a list of any components that can be construed as being of alternative design, requiring purchaser's acceptance

39) a summary of the materials of construction for the compressor, including hardness for materials exposed to H_2S

40) the maximum seal gas rates (injection or eduction) and rated or expected inner seal-oil leakage rates, if applicable

    When self-acting dry gas seals are supplied, expected seal gas consumption, minimum seal gas supply flow, and primary vent flow should be given at maximum sealing pressure and at conditions over the operating envelope of the machine.

41) When interstage coolers are furnished, the supplier shall provide the following:

    i) drawing showing cooling system details;

    ii) data for purchasers heat and material balances;

    iii) details of provisions for separating and withdrawing condensate;

    iv) supplier's recommendations regarding provision for support and piping expansion.

42) drawings, details, and descriptions of the operations of instrumentation and controls as well as the makes, materials, and type of auxiliary equipment

    The supplier shall also include a complete description of the alarm and shutdown facilities to be provided.

43) the minimum length of straight pipe required for proper flow characteristics at the inlet and at any side inlet connection

44) maximum and minimum allowable seal pressure for each compressor

45) a statement of the manufacturer's capability regarding testing (including performance testing) of the compressor and any other specified items on the train

    Details of each optional test specified shall be included.

46) Predicted performance curves shall be provided for compressor and expander including the following:

    i) expander power versus flow;

    ii) compressor power versus flow;

    iii) compressor head and ratio, four speed lines from 70 % to 110 % of normal speed lines;

    iv) expander v/c versus efficiency.

    If a performance test is specified as tested, then curves and data shall be provided.

47) For compressors that have a back-to-back impeller arrangement, the supplier shall furnish a curve showing the expected loading on the active or inactive side of the thrust bearing versus any combination of differential pressures across the low pressure and high pressure sections of the casing.

48) The supplier shall supply balance piston leakage based on design clearances and twice design clearances for the rated conditions.

49) When specified, the supplier shall supply curves of balance piston line differential pressure versus thrust load.

50) The supplier shall provide production and delivery schedules.

51) The supplier shall submit detailed procedures including acceptance criteria for the mechanical running test and all optional tests, at least six weeks prior to the first running test.

52) The supplier shall submit progress reports.

53) All information required for the proper installation of the equipment shall be compiled in a manual that shall be issued no later than the time of final certified drawings.

54) A manual containing all required operating and maintenance instructions shall be supplied not later than two weeks after all specified test shall have been successfully completed.

55) The supplier shall provide a "technical data manual within 30 days of completion" of shop testing including the following:

    i) necessary certification of materials;

    ii) purchase specification for all items on the bill of materials;

    iii) test data to verify requirements of specifications have been met;

    iv) heat treat records;

    v) results of quality test and inspections;

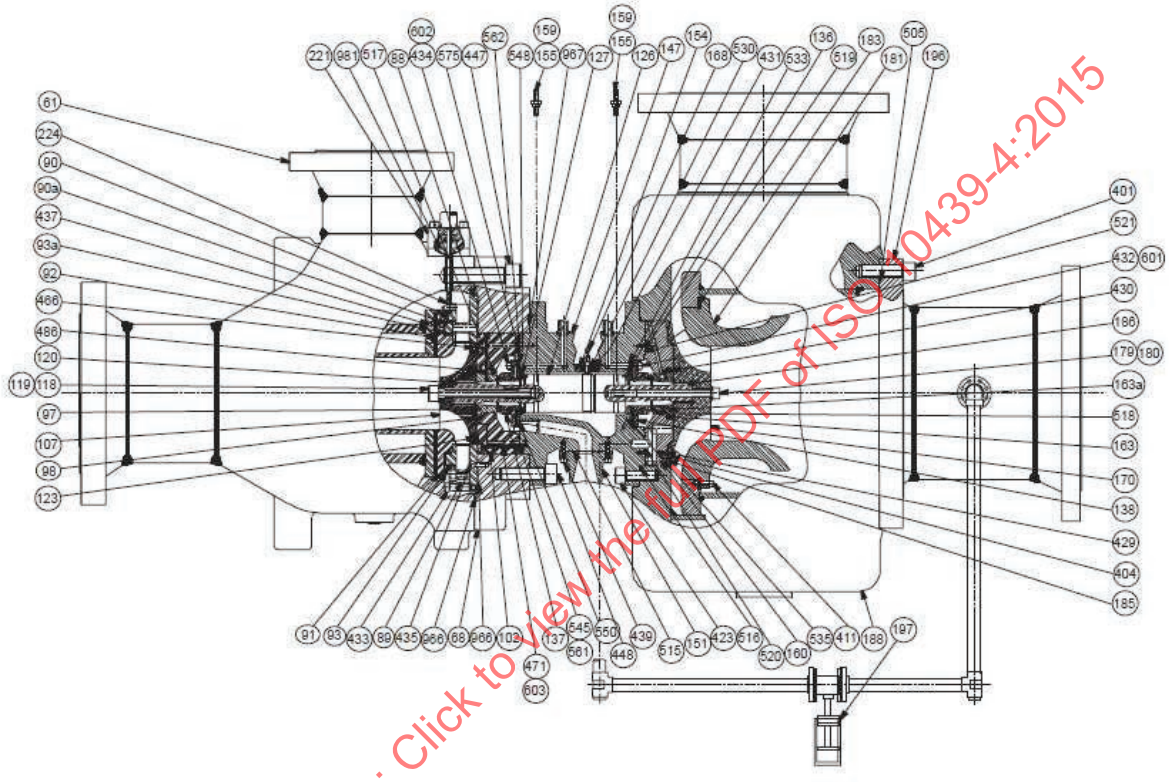
    vi) mechanical running test data log;

    vii) final assembly maintenance and running clearances.

    The supplier is also required to keep this data available for examination by the purchaser, upon request, for at least five years.

Annex C
(informative)

Nomenclature



Key

61	expander case
68	labyrinth seal housing
88	nozzle cover
89	nozzle segment and cam roller
90	nozzle adjusting ring
90a	nozzle clamping ring
91	nozzle fixed ring
92	shim-nozzle fixed ring
93	piston ring
93a	seal ring
97	heat barrier wall insert
98	shim-heat barrier wall insert
102	heat barrier wall
107	expander wheel
118, 119	retaining screw and retaining washer
120	shaft key (expander)
123	expander wheel back seal
126	shaft
151	bearing housing drain
154	tachometer pick-up insert
155, 159	vibration pick-up and lock nut
160	compressor seal
163	compressor seal insert
163a	tachometer pick-up
170	compressor wheel
179, 180	retaining screw and retaining washer
181	compressor follower
183	shim-compressor follower
185	compressor wheel back seal
186	shaft key (compressor)
188	compressor case
196	compressor inlet spacer
197	auto thrust balance assembly
221	actuator mount assembly
224	nozzle actuator rod
401 to 486	screw

127	bearing thrust washer (expander)	505 to 575	o-ring
136	bearing thrust washer (compressor)	601 to 603	washer
137	bearing-drive	966 to 981	raco seal
138	bearing-load		
147	bearing housing		

Figure C.1 — Typical expander–compressor showing nomenclature of key parts

Annex D
(informative)

Typical materials

The materials listed in this annex are considered equivalent as far as suitability for service. This does not imply that they are exactly equivalent. There can be significant differences in testing and other material requirements. The list of typical materials is also available in electronic format via http://standards.iso.org/iso/.

Annex D Typical material specifications for major components					
Component	Materials[a]	Specification [b]	Equivalent JIS Material	Equivalent EN Material	
Casing					
Cast	Cast iron	ASTM A 278, Class 30	JIS G5501 FC200	EN 1561 EN-GJL-250	EN-JL1040
		ASTM A 278, Class 40	JIS G5501 FC300	EN 1561 EN-GJL-300	EN-JL1050
	Austenitic cast iron	ASTM A 436, Type 2	JIS G5510 FCA-NiCr202	NA	
		ASTM A 571, Type D-2M Class 1 & 2	JIS G5510 FCDA-Ni22	NA	
	Ductile iron	ASTM A 395	JIS G5502	EN 1563 EN-GJS-400-18U-RT	EN-JS1059
	Cast steel	ASTM A 216, Grade WCB [d]	JIS G5102 SCW450	EN 10213 GP240GH ISO 4991 G240 similar reference DIN 1681 GS-38	1.0619 1.0420
		ASTM A 216, Grade WCC			
		ASTM A 352, Grade LCB	JIS G5152 SCPL1	GC24E	1.1156
		ASTM A 352, Grade LC2	JIS G5152 SCPL21	EN 10213 G9Ni10	1.5636
		ASTM A 352, Grade LC3	JIS G5152 SCPL31	EN 10213 G9Ni14	1.5638
		ASTM A 352, Grade LC4	similar reference JIS G5152 SCPL31	similar reference EN 10213 G9Ni14	1.5638
		ASTM A 352, Grade LCC	similar reference JIS G5152 SCPL1	EN 10213 G17Mn5 EN 10213 G20Mn5 similar reference SEW 685 G26CrMo4	1.1131 1.6220 1.7221
		ASTM A 217	JIS G5151	EN 10213	
	Cast stainless steel	A 351, Grade CF3M,	CF3M: JIS G5121 SCS16A CF8: JIS G5121 SCS13A CF8M: JIS G5121 SCS14A	CF3M: EN 10213 GX2CrNiMo19-11-2	1.4409
		CF8 or CF8M		CF8: EN 10213 GX5CrNi19-10 or SEW 685 GX6CrNi18-10 CF8M: EN 10213 GX5CrNiMo19-11-2	1.4308 1.6902 1.4408
		ASTM A351, Grade CF8A			
		ASTM A 351, Grade CF3MA or CF8MA	JIS G5121 SCS19A	CF3MA: EN 10213 GX2CrNiMo19-11-2 CF8MA: EN 10213 GX5CrNiMo19-11-2	1.4409 1.4408
		ASTM A 487 Grade CA6NM Class A and B		EN 10213 GX4CrNi13-4	1.4317
		ASTM A 757 Grade E3N		EN 10213 GX3CrNi13-4	1.6982
		ASTM A 757 Grade D1Q1		SEW 685 G15CrMo9-10	1.7377
	Cast aluminum	ASTM A 356 or A 357	JIS G5151	NA	
		ASTM B26M 356	JIS H5202 AC4C	EN1706 AC-42000 (Al-Si 7Mg)	
	Cast titanium	ASTM B 367, Grade C3 or C4	C3: JIS H4600 2 C4: NA	NA	
Casing Fabricated	Steel	ASTM A 285, Grade C	JIS G3118 SGV450		
		ASTM A 516, Grade 55, 60, 65, 70	55: JIS G3118 SGV410 60: JIS G3118 SGV410 65: JIS G3118 SGV450 70: JIS G3118 SGV480	55: EN 10028-2 P235GH 60: EN 10028-2 P265GH 65: EN 10028-2 P355GH EN 10025 S355J2+N 70: EN 10028-2 P355GH	1.0345 1.0425 1.0473 1.0577 1.0473
		ASTM A 203, Grade A or B	A: JIS G3127 SL2N255 B: NA	12Ni9	1.5635
		ASTM A 203, Grade D or E	D: JIS G3127 SL3N255 E: JIS G3127 SL3N275	EN 10028-4 12Ni14	1.5637
		ASTM A 537, Class 1 or 2	1: JIS G3115 SPV355 2: JIS G3115 SPV450	EN 10028-6 P355QH EN 10028-6 P460QH	1.8867 1.8871
		ASTM A 353	JIS G3127 SL9N520	EN 10028-3 X8Ni9	1.5662
		ASTM A 553, Type I	JIS G3127 SL9N590	EN 10028-3 X8Ni9	1.5662
		ASTM A 553, Type II	JIS G3127 SL9N590	EN 10028-3 X8Ni9	1.5662
		ASTM A 266, Class 1 or 4	JIS G3202 SFVC1	EN 10222-4 P355NH	1.0565
		ASTM A 336, Class F1	JIS G3202 SFVA F1	EN 10222-2 16Mo3	1.5415
		ASTM A 414	JIS G3116	EN 10120	
		ASTM A 508, Class 5a [now: Grade 5 Class	JIS G3204 SFVQ3	20NiCrMo14-6	1.6742
		ASTM A 350, Grade LF2	JIS G3205 SFL2	EN 10222-3 12Ni14	1.5637
		ASTM A 350, Grade LF3	JIS G3205 SFL3	EN 10222-3 12Ni14	1.5637
		ASTM A266 CL.1	JIS G3202 SFVC1		
		ASTM A662 Grade B		EN 10028-4 P355N EN 10028-4 P355NL2	1.0562 1.1106
		ASTM A 765 Grade IV		EN 10222-4 P355QH1	1.0571
		ASTM A 350 Grade LF6 Class 1		DIN 17103 TStE 355	1.0566

Component	Materials[a]	Specification[b]	Equivalent JIS Material	Equivalent EN Material	
	Stainless steel	ASTM A 240, Type 304, 304L, 316, 316 L or	304: JIS G4304 SUS304, JIS G4305 SUS304 304L: JIS G4304 SUS304L, JIS G4305 SUS304L 316: JIS G4304 SUS316, JIS G4305 SUS316 316L: JIS G4304 SUS316L, JIS G4305 SUS316L 321:JIS G4304 SUS321, JIS G4305 SUS321	304: EN 10028-7 X5CrNi18-10 304L: EN 10028-7 X2CrNi18-9 316: EN 10028-7 X5CrNiMo17-12-2 316L: EN 10028-7 X2CrNiMo17-12-2 or EN 10028-7 X5CrNiMoTi17-12-2 321: EN 10028-7 X5CrNiTi18-10	1.4301 1.4307 1.4401 1.4404 1.4571 1.4541
		321			
		ASTM A 182, Grade F304, F304L, F316 or	F304: JIS G3214 SUS F304 F304L: JIS G3214 SUS F304L F316: JIS G3214 SUS F316 F321: JIS G3214 SUS F321	F304: EN 10222-5 X5CrNi18-10 F304L: EN 10222-5 X2CrNi18-9 F316: EN 10222-5 X5CrNiMo17-12-2 or EN 10222-5 X5CrNiMoTi17-12-2 F321: EN 10222-5 X5CrNiTi18-10	1.4301 1.4307 1.4401 1.4571 1.4541
		F321			
		ASTM A 182, Grade F 6NM		EN 10222-5 X3CrNiMo13-4	1.4313
		AISI 304L	JIS G3214 SUS 304L		
Casing Fabricated	Aluminum	ASTM B 209, Alloy 6061 or 7075	6061: JIS H4000 6061 7075: JIS H4000 7075		
		ASTM B 211, Alloy 6061 or 7075	6061: JIS H4040 6061 7075: JIS H4040 7075		
		ASTM B 247, Alloy 6061 or 7075	6061: JIS H4140 6061 7075: JIS H4140 7050		
		AMS 4108, Alloy 7050	JIS H4140 7050		
Diaphragms, guide vanes and inner casings	Cast iron	ASTM A 48 or A 278, Class 30	JIS G5501 FC250	EN 1561 EN-GJL-250	EN-JL1040
	Ductile iron	ASTM A 536	JIS G5502	EN 1563 EN-GJS-400-15U	EN-JS1072
	Cast iron	ASTM A 216, Grade WCB	JIS G5102 SCW450	EN 10213 GP240GH ISO 4991 G240 similar reference DIN 1681 GS-38	1.0619 1.0420
	Steel	ASTM A 283, A 284, A 285, A 516 or	JIS G3101 SS400	EN 10025 S235JR EN 10025 S355J2+N	1.0038 1.0577
		A 543			
		ASTM A 36	JIS G3101 SS400	EN 10025 S235JR	1.0038
	Stainless steel	ASTM A 743/744 or A 351, Grade CA15,	JIS G5121 SCS13A, JIS G5121 SCS19A	CF8: EN 10213 GX5CrNi19-10 or SEW 685 GX6CrNi18-10 CF8M: EN 10213 GX5CrNiMo19-11-2	1.4308 1.6902 1.4408
		CF3, CF3M, CF8 or CF8M			
		ASTM A 240, Type 410	JIS G4304 SUS410, JIS G4305 SUS410	EN 10088-2 X12Cr13	1.4006
		ASTM A 276, Type 410	JIS G4303 SUS410	EN 10088-3 X12Cr13	1.4006
		AISI304	JIS G4304 SUS304		
		AISI304L	JIS G3214 SUSF304L	similar reference EN 10250 X6CrNiTi18-10	1.4541
		ASTM A 182, Grade F321, F316Ti		F316 Ti: EN 10250 X6CrNiMoTi17-12-2 F321: EN 10250 X6CrNiTi18-10	1.4571 1.4541
		ASTM A662 Grade B		EN 10028-4 P355N EN 10028-4 P355NL2	1.0562 1.1106
		ASTM A 350 Grade LF6 Class 1		DIN 17103 TStE 355	1.0566
		ASTM A 182, Grade F 6NM		EN 10250 X3CrNiMo13-4	1.4313
		ASTM A 487 Grade CA6NM Class A and B		EN 10213 GX4CrNi13-4	1.4317
		ASTM A 757 Grade E3N		EN 10213 GX3CrNi13-4	1.6982
	Aluminum	ASTM B 26, Alloy 355 or C355	JIS H5202 AC4D	n.a.	
Shaft	Steel	ASTM A 470, Class 1	similar reference JIS G3201 SF540A		
		ASTM A 470, Class 7	similar reference JIS G3204 SFVQ3 （WH社 10325UA-UE）	SEW 555 26NiCrMoV11-5 SEW 555 26NiCrMoV14-5	1.6948 1.6957
		AISI 4340	JIS G4053 SNCM439	EN 10083-3 30CrNiMo8	1.6580
		AISI 4140	JIS G4053 SCM440	EN 10083-3 42CrMo4	1.7225
		AISI Types 1040-1050 [c]	JIS G4051 S40C	EN 10083-2 C45E	1.1191
		AISI Types 4140-4150 [c]	JIS G4053 SCM440	EN 10083-3 42CrMo4	1.7225
		AISI Type 2320 [c]	NA		
		AISI 2330	NA		
		ASTM A 522, Type 1	JIS G3127 SL9N520	EN 10222-3 X8Ni9	1.5662
		ASTM 4340-4345	ASTM maybe replaced to AISI. JIS G4053 SNCM439	EN 10083-3 30CrNiMo8 ISO 4957 55NiCrMoV7	1.6580 1.2714

Component	Materials[a]	Specification [b]	Equivalent JIS Material	Equivalent EN Material	
	Stainless steel	ASTM A 336, Grade F6	G3214 SUS F410-C	EN 10088-3 X12Cr13	1.4006
		ASTM A 473, Type 410	JIS G3214 SUS F410	EN 10088-3 X12Cr13	1.4006
		ASTM A 182, Grade F 6NM		EN 10250 X3CrNiMo13-4	1.4313
	Precipitation hardening stainless steel	ASTM A 705, Types 630 or XM-12	JIS G3214 SUS F630	EN 10250 X5CrNiCuNb16-4	1.4542
		ASTM A 564, Type 630 or XM-12	JIS G4303 SUS630	EN 10250 X5CrNiCuNb16-4	1.4542
Impellers	Aluminum	ASTM B 26, Alloy C355	JIS H5202 AC4C		
Cast	Precipitation hardening stainless steel	ASTM A 747, Type CB7CU-1 or CB7CU-2	G5121 SCS 24		
	Steel	ASTM A 148	JIS G5111		
		ASTM A 487 Gs 4Q	JIS G5111 SCMnCrM2		
	Stainless steel	ASTM A 743/744 or A 351, Grade CA15	JIS G5121 SCS1		
		or CA6NM			
		ASTM A 743/744 or A 351, Grade CF3, CF3M,	CF3: JIS G5121 SCS19A CF3M: JIS G5121 SCS16A CF8: JIS G5121 SCS13A CF8M: JIS G5121 SCS14A		
		CF8 or CF8M			
	Aluminum	ASTM A 356 or A 357	JIS G5151		
	Titanium	ASTM B 367, Grade C3 or C4	C3: JIS H4600 2 C4: NA		
		ASTM A 367, Grade C5	A 367 maybe replaced to B 367. JIS H4600 3種。		
Fabricated (covers,	Aluminum	ASTM B 209, Alloy 6061 or 7075	6061: JIS H4000 6061 7075: JIS H4000 7075		
hubs, blades)					
		ASTM B 211, Alloy 6061 or 7075	6061: JIS H4040 6061 7075: JIS H4040 7075		
		ASTM B 221, Alloy 6061 or 7075	6061: JIS H4040 6061 7075: JIS H4040 7075		
		ASTM B 247, Alloy 2618,	2618: JIS H4140 2618 6061: JIS H4140 6061 7075: JIS H4140 7050		
		6061 or 7075			
		AMS 4108, Alloy 7050	JIS H4140 7050		
		7175			WL 3.4334
Impellers	Steel	AISI Types 4130-4140 [c]	JIS G4053 SCM430	EN 10083-3 42CrMo4	1.7225
Fabricated					
		AISI Types 4320-4345 [c]	JIS G4053 SNCM431	EN 10083-3 30CrNiMo8	1.6580
		ASTM A 470, Class 8		14CrMoV6-9	1.7735
		AISI Type 3140 [c]	similar reference JIS G4102 SNC236		
		ASTM A 543	JIS G3101 SS400		
		ASTM A 522, Type Ⅰ	JIS G3127 SL9N520	EN 10222-3 X8Ni9	1.5662
		ASTM A 522, Type Ⅱ	JIS G3127 SL9N520	EN 10222-3 X8Ni9	1.5662
		ASTM A 353	JIS G3127 SL9N520	EN 10222-3 X8Ni9	1.5662
		AISI Type 403 [c]	JIS G3214 SUS F403	EN 10088-3 X6Cr13	1.4000
		ASTM A 473, Type 410	JIS G3214 SUS F410	EN 10088-3 X12Cr13	1.4006
		ASTM A 240, Type 304, 304L, 316	304: JIS G4304 SUS304, JIS G4305 SUS304 304L: JIS G4304 SUS304L, JIS G4305 SUS304L 316: JIS G4304 SUS316, JIS G4305 SUS316	304: EN 10028-7 X5CrNi18-10 304L: EN 10028-7 X2CrNi18-9 316: EN 10028-7 X5CrNiMo17-12-2 316L: EN 10028-7 X2CrNiMo17-12-2	1.4301 1.4307 1.4401 1.4404
		ASTM A 473, Type 304, 304L, 316, or 316L	304: JIS G3214 SUS F304 304L: JIS G3214 SUS F304L 316: JIS G3214 SUS F316 316L: JIS G3214 SUS F316L	F304: EN 10222-5 X5CrNi18-10 F304L: EN 10222-5 X2CrNi18-9 F316: EN 10222-5 X5CrNiMo17-12-2 F316L: EN 10222-5 X2CrNiMo17-12-2	1.4301 1.4307 1.4401 1.4404
		UNS S42400	NA	EN 10250 X3CrNiMo13-4	1.4313
		AISI 410	JIS G4303 SUS410 -MOD	NA	
		ASTM A 638 Grade 660 Type 2 (A286)		EN 10302 X6NiCrTiMoVB25-15-2	1.4980
	Precipitation hardening stainless steel	ASTM A 705, Type 630 or XM-12	JIS G3214 SUS F630	EN 10250 X5CrNiCuNb16-4	1.4542
		AISI S17400	JIS G4303 SUS630		
		ASTM A 693, Type 630 or XM-12	JIS G4304 SUS630, JIS G4305 SUS630	EN 10088-2 X5CrNiCuNb16-4	1.4542
	Ni-Cu	SAE AMS 4646	NA		
		ASTM B 127	JIS H4551		
		QQ-N-286	JIS H4551 NW5500		
		ASTM B 865 UNS N05500		DIN 17743 NiCu30Al ISO 9725 NiCu30Al3Ti	2.4375 NW5500
	Titanium	ASTM B 381 Grade F5		DIN 17864 TiAl6V4	3.7165

Component	Materials[a]	Specification[b]	Equivalent JIS Material	Equivalent EN Material	
Labyrinths					
Impeller interstage	Aluminum	ASTM B 26, Alloy 443, 335, 850,	JIS H5202	EN 586	
shaft seal and		A850 or B850			
balance piston		6061-T6 or 1100	6061: JIS H4000 6061 1100: JIS H4000 1100		
		ASTM B 209 Grade 5083		EN 586 EN-AW-5083 [Al Mg4.5Mn0.7]	AW5083
		7175			WL 3.4334
	Babbit	ASTM B 23	JIS H5401		
	Brass	ASTM B 16 or B 21	JIS H3250	EN 12420	
		ASTM B 36	JIS H3100	EN 1652	
		ASTM B 171	JIS H3100	EN 1652	
		ASTM B 564 UNS N04400		DIN 17743 NiCu30Fe ISO 9725 NiCu30	2.4360 NW4400
	Bronze			Cu Sn 10/12	
	Stainless steel	AISI Type 403, 410, 416,	403: JIS G3214 SUS F403 410: JIS G3214 SUS F410 416: JIS G3214 SUS F416	EN 10088-3 X6Cr13 EN 10088-3 X12Cr13 additional: X19CrMo12-1	1.4000 1.4006 1.4921
		420		EN 10088-3 X20Cr13	1.4021
		303, 304, or 316	403: JIS G3214 SUS F303 410: JIS G3214 SUS F304 416: JIS G3214 SUS F316	EN 10088-3 X6CrNiTi18-10 EN 10088-3 X6CrNiMoTi17-12-2	1.4541 1.4571
		304, 304L,316			1.4301 1.4306 1.4401
	Cr-Ni-Fe-Mo-Cu-Cb	ASTM B 462	JIS H4551 NW6007	EN 10088-3 X1NiCrMoCuN25-20-7	1.4529
	Stainless steel honeycomb	ASTM A 240, Type 304, 304L, 316 or 316L	304: JIS G4304 SUS304, JIS G4305 SUS304 304L: JIS G4304 SUS304L, JIS G4305 SUS304L 316: JIS G4304 SUS316, JIS G4305 SUS316 316L: JIS G4304 SUS316L, JIS G4305 SUS316L	304: EN 10028-7 X5CrNi18-10 304L: EN 10028-7 X2CrNi18-9 316: EN 10028-7 X5CrNiMo17-12-2 316L: EN 10028-7 X2CrNiMo17-12-2	1.4301 1.4307 1 4401 1 4404
	Ni-Cu alloy	ASTM B 164	JIS H4553	DIN 17743 NiCu30Fe ISO 9725 NiCu30	2.4360 NW4400
	Nonmetallic TFE [e]				
	Nonmetallic TFE [e]				
	carbon-filled				
	Nonmetallic TFE [e]				
	mica-filled				
	Lead	ASTM B 29	H2105	NA	
	Nickel-graphite				
	Phenolic resin	Micarta, NEMA, Grade LE	NA		
	impregnated materials				
		Micarta, NEMA, Grade G10 or G9	NA		
Balance piston	Steel(new)	ASTM A 470, Class 1	similar reference JIS G3201 SF540A		
		ASTM A 470, Class 7	similar reference JIS G3204 SFVQ3	SEW 555 26NiCrMoV11-5 SEW 555 26NiCrMoV14-5	1.6948 1.6957
		AISI Types, 1040-1050 [c]	JIS G4051 S40C	EN 10083-2 C45E	1.1191
		AISI Types, 4130-4145 [c]	JIS G4053 SCM440	EN 10083-3 42CrMo4	1.7225
		AISI Types, 4330, 4345 [c]	JIS G4053 SNCM431	EN 10083-3 30CrNiMo8	1.6580
		AISI Type, 2320 [c]	NA		
		ASTM A 522, Type I	JIS G3127 SL9N520	EN 10222-3 X8Ni9	1.5662
	Stainless steel(new)	ASTM A 336, Grade F6	G3214 SUS F410-C		
		ASTM A 473, Type 410	JIS G3214 SUS F410	EN 10088-3 X12Cr13	1.4006
		AISI Type 403 or 410 [c]	403: JIS G3214 SUS F403 410: JIS G3214 SUS F410	EN 10088-3 X6Cr13 EN 10088-3 X12Cr13	1.4000 1.4006
	Precipitation hardening stainless steel	ASTM A 705, Type 630 or XM-12	JIS G3214 SUS F630	EN 10250 X5CrNiCuNb16-4	1.4542
		ASTM A 470, Class 8		14CrMoV6-9	1.7735
		UNS S42400	NA	EN 10250 X3CrNiMo13-4	1.4313
		ASTM A 638 Grade 660 Type 2 (A286)		EN 10302 X6NiCrTiMoVB25-15-2	1.4980
	Ni-Cu alloy	ASTM B 865 UNS N05500		DIN 17743 NiCu30Al ISO 9725 NiCu30Al3Ti	2.4375 NW5500
		SAE ANS 4676	NA		

Component	Materials[a]	Specification[b]	Equivalent JIS Material	Equivalent EN Material	
Shaft sleeves	Steel	AISI Types, 4130-4150 [c]	JIS G4053 SCM440	EN 10083-3 42CrMo4	1.7225
		AISI Types, 4320, 4345 [c]	JIS G4053 SNCM431	EN 10083-3 30CrNiMo8	1.6580
		AISI 4330	JIS G4053 SNCM431		
		ASTM A 470, Class 7	similar reference JIS G3201 SF540A	SEW 555 26NiCrMoV11-5 SEW 555 26NiCrMoV14-5	1.6948 1.6957
		ASTM A 522, Type I	JIS G3127 SL9N520	EN 10222-3 X8Ni9	1.5662
		ASTM A 106	JIS G3456	EN 10216	
		ASTM A 350	JIS G3205	EN 10250	
		ASTM A 350, Grade LF-3	JIS G3205 SFL3	EN 10250 12Ni14	1.5637
	Stainless steel	AISI Types 403 or 410 [c]	403: JIS G3214 SUS F403 410: JIS G3214 SUS F410	EN 10088-3 X6Cr13 EN 10088-3 X12Cr13	1.4000 1.4006
	Ni-Cu alloy	ASTM B 164 or SAE AMS 4676	JIS H4553		
	Ni-Mo-Cr alloy	ASTM B574, Alloy N10276	JIS H4551 NW0276	DIN 17744 NiMo16Cr15W ISO 9725 NiMo16Cr15Fe6W4	2.4819 NW0276
		ASTM A 494, Grade CW-12M-1	similar reference JIS H5701 NMCrC		
	Precipitation hardening stainless steel	A 705 Type 630 or XM-12	JIS G3214 SUS F630	EN 10250 X5CrNiCuNb16-4	1.4542

NOTE 1 AISI and UNS designations are only a description of chemical analyses of types of steels; they are not procurement specification.
NOTE 2 See nomenclature in cross-sections of either the centrifugal or axial compressor for part names in Annex C or ISO 10439-2:2015, Annex C.
[a] The materials shown in this table are those commonly used by compressor manufacturers, but the list is not all inclusive. Other suitable materials may exist and may be used as indicated by specific design considerations.
[b] Descriptions of AISI Types (cross-referenced to UNS) can be found in SAE HS1086. Descriptions of UNS Types can can also be found in ASTM DS 56J.
[c] The temperature limits shown in this table are those commonly observed by compressor manufacturers and are not necessarily the same as any
[d] Normalized or normalized and tempered.
[e] TFE = tetrafluoroethylene.

Annex E
(informative)

Inspector's checklist

The inspector's checklist provides a cross-reference of the applicable item to be inspected with the clause in ISO 10439. It provides for a tabular format to document the items inspected, the date they were inspected, the person(s) inspecting, and the current status. The inspector's checklist is also available in electronic format via http://standards.iso.org/iso/.

Item	ISO 10439		Date inspected	Inspected by	Status
	Paragraph	Part			
4.5 MATERIALS					
Coating applied prior to acceptance balance	4.5.1.15	1			
PMI	4.5.1.16.1	1			
Impact testing	4.5.1.17.5	1			
Castings - material specification compliance	4.5.2.1	1			
Castings - purchaser approval of repairs	4.5.2.3.3	1			
Castings - ductile (Nodular) iron	4.5.2.5	1			
Forgings - repairs	4.5.3.2	1			
Welding - non-pressure components	4.5.4.1	1			
Welding - pressure containing and rotating parts	4.5.4.2	1			
4.6 CASINGS					
Jackscrews, dowels, and special tools	4.6.1.4	1			
Provisions for lifting casings	4.6.1.3	4			
Depth of threaded holes	4.6.1.5	1			
Studs instead of cap screws	4.6.1.7.2	1			
Adequate clearance at bolts	4.6.1.7.3	1			
Bolting materials	4.6.1.7.6	1			
Welding	4.6.1.8	1			
Casing repair - minimum level of inspection and purchaser review	4.6.2.1	1			
Casing repair - major repairs	4.6.2.2	1			
Casing repair - material standards	4.6.2.3	1			
Pressure casings - plate edges	4.6.2.4.1	1			
Pressure casings - MPT or LPT	4.6.2.4.2	1			
Pressure casings - weld QC	4.6.2.4.3	1			
Pressure casings - full penetration welds	4.6.2.4.4	1			
Casings - heat treatment	4.6.2.4.5	1			
Pressure containing weld inspection	4.6.2.4.6	1			
Materials inspection standards	4.6.3.2	1			
Cast steel casings - acceptability of defects	4.6.3.3	1			
Pressure casing connection size	4.6.4.1.3	1			
Casing connections - welding before hydrotest	4.6.4.1.5	1			
Main process connection orientation	4.6.4.2.1	1			
Flanges	4.6.4.2.2	1			
Cast iron flanges	4.6.4.2.6	1			
Concentricity of bolt circle and bore	4.6.4.2.12	1			
Steel flange facing finish	4.6.4.2.13	1			
Machined and studded connections	4.6.4.2.14	1			
Flanges parallel within 0,5 degrees	4.6.4.2.15	1			
Auxiliary connections - minimum size	4.6.4.2	4			
Auxiliary connections - flanges	4.6.4.3.2	1			
Auxiliary connections - allowable types	4.6.4.3.3	1			
Auxiliary connections - pipe nipples	4.6.4.3.4	1			
Auxiliary connections - socket weld gap	4.6.4.3.6	1			
Auxiliary connections - lube or seal service	4.6.4.3.7	1			
Threaded openings for tapered pipe threads	4.6.4.3.8.1	1			
Tapered pipe threads	4.6.4.3.8.2	1			
Seal welding tapered pipe threads	4.6.4.3.8.3	1			
Pipe nipples for threaded openings	4.6.4.3.8.4	1			
Plugs for threaded openings	4.6.4.3.8.5	1			
Machine mounting surfaces	4.6.5.1	1			
4.7 ROTATING ELEMENTS					
Shaft ends for couplings	4.7.1	1			
Impeller and shaft marking	4.7.1.2	4			