

DEP SPECIFICATION

PACKAGED RECIPROCATING GAS COMPRESSORS (AMENDMENTS/SUPPLEMENTS TO ISO 13631)

DEP 31.29.40.34-Gen.

February 2012

ECCN EAR99

DESIGN AND ENGINEERING PRACTICE

DEM1



© 2012 Shell Group of companies

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, published or transmitted, in any form or by any means, without the prior written permission of the copyright owner or Shell Global Solutions International BV.

This document contains information that is classified as EAR99 and, as a consequence, can neither be exported nor re-exported to any country which is under an embargo of the U.S. government pursuant to Part 746 of the Export Administration Regulations (15 C.F.R. Parts 746) nor can be made available to any national of such country. In addition, the information in this document cannot be exported nor re-exported to an end-user or for an end-use that is prohibited by Part 744 of the Export Administration Regulations (15 C.F.R. Parts 744).

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of Shell Global Solutions International B.V. (Shell GSI) and, in some cases, of other Shell Companies.

These views are based on the experience acquired during involvement with the design, construction, operation and maintenance of processing units and facilities. Where deemed appropriate DEPs are based on, or reference international, regional, national and industry standards.

The objective is to set the standard for good design and engineering practice to be applied by Shell companies in oil and gas production, oil refining, gas handling, gasification, chemical processing, or any other such facility, and thereby to help achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to Shell companies for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual Operating Units to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs, they shall be solely responsible for such use, including the quality of their work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will typically expect them to follow those design and engineering practices that will achieve at least the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal.

The right to obtain and to use DEPs is restricted, and is typically granted by Shell GSI (and in some cases by other Shell Companies) under a Service Agreement or a License Agreement. This right is granted primarily to Shell companies and other companies receiving technical advice and services from Shell GSI or another Shell Company. Consequently, three categories of users of DEPs can be distinguished:

- 1) Operating Units having a Service Agreement with Shell GSI or another Shell Company. The use of DEPs by these Operating Units is subject in all respects to the terms and conditions of the relevant Service Agreement.
- 2) Other parties who are authorised to use DEPs subject to appropriate contractual arrangements (whether as part of a Service Agreement or otherwise).
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, Shell GSI disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof, even if it is wholly or partly caused by negligence on the part of Shell GSI or other Shell Company. The benefit of this disclaimer shall inure in all respects to Shell GSI and/or any Shell Company, or companies affiliated to these companies, that may issue DEPs or advise or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of Shell GSI, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of Shell GSI. The copyright of DEPs vests in Shell Group of companies. Users shall arrange for DEPs to be held in safe custody and Shell GSI may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

All administrative queries should be directed to the DEP Administrator in Shell GSI.

TABLE OF CONTENTS

PART I	INTRODUCTION	6
1.1	SCOPE.....	6
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	6
1.3	DEFINITIONS	6
1.4	CROSS-REFERENCES	7
1.5	SUMMARY OF MAIN CHANGES.....	7
1.6	COMMENTS ON THIS DEP	7
1.7	DUAL UNITS.....	7
PART II	GENERAL INFORMATION	8
PART III	AMENDMENTS/SUPPLEMENTS TO ISO 13631.....	9
1.	Scope	9
2.	Normative references	9
3.	Terms and definitions.....	9
3.15	standard flow.....	9
3.16	hazardous service	9
3.17	sour service.....	9
3.18	very toxic service	9
4.	Statutory requirements	9
5.	General package requirements	9
5.1	Compressor package performance curves.....	9
5.2	Package arrangement.....	10
5.3	Drawings	10
5.4	Sound pressure level	10
5.5	Electrical area classification.....	10
5.6	Package installation	10
5.7	Torsional analysis	10
5.8	Service life.....	11
5.9	Prototype equipment.....	11
5.10	Fault tolerance	11
5.11	Unit responsibility.....	11
6.	Compressor.....	12
6.1	General	12
6.2	Allowable speeds	12
6.3	Allowable discharge temperature	12
6.4	Rod loads	12
6.5	Compressor cylinders	13
6.6	Valves	14
6.7	Pistons, piston rods and piston rings.....	14
6.8	Crankcases, crankshafts, connecting rods, bearings and crossheads	14
6.9	Distance pieces.....	15
6.10	Packing cases and pressure packing	16
6.11	Compressor crankcase lubrication system	16
6.12	Compressor cylinder lubrication	17
6.13	Materials.....	17
6.14	Power transmission.....	20
7.	Capacity control.....	21
7.5	Bypass systems	21
7.6	Valve removal or unloading	21
8.	Prime movers	21
8.2	Spark-ignited gas engines	21
8.3	Electric motors	22
9.	Cooling system	23

9.2	Gas engine.....	23
9.3	Compressor	23
9.4	Types of coolers.....	23
9.6	Arrangement and construction.....	24
10.	Pressure vessels.....	24
10.1	General	24
10.2	Separators.....	25
10.3	Pulsation suppression devices	25
11.	Piping and appurtenances	26
11.1	General	26
11.2	Design	27
11.5	Fabrication	27
11.8	Pipe material and sizes.....	27
11.10	Valves	27
11.13	Start-up screens.....	27
11.14	Lube oil piping requirements.....	27
11.15	Coolant piping requirements.....	28
11.16	Instrument piping requirements	28
11.17	Drain and vent piping	28
11.18	Relief valves.....	28
11.19	Blowdown valves	28
12.	Electrical systems.....	29
12.1	Codes.....	29
12.7	Power Installations.....	29
12.10	Ventilation	29
13.	Instruments and controls.....	29
13.1	General	29
13.2	Instrument and control panel	30
13.3	Instrumentation	30
13.4	Vibration detectors	31
14.	Shutdowns alarms and annunciators.....	31
14.2	Minimum required shutdowns	31
14.5	Transmitters	31
14.6	Emergency shutdown systems	31
15.	Skids.....	32
15.1	General	32
15.2	Design	32
15.3	Construction	34
15.4	Walkways, stairs and platforms	34
15.5	Building for cold weather.....	34
16.	Paint and painting.....	34
16.2	Surface preparation	34
17.	Inspection and testing.....	34
17.1	General	34
17.2	Material inspection	35
17.3	Testing	35
18.	Markings	35
18.3	Nameplates.....	35
19.	Preparation for shipment	35
19.5	Manuals.....	35
20.	Corrosive gases	36
20.1	General	36
20.2	Hydrogen sulfide	36

20.3	Carbon dioxide	36
Annex E	Repairs to grey and nodular iron castings (informative).....	36
PART IV	REFERENCES	37

APPENDICES

APPENDIX A	DISTANCE PIECE VENT AND DRAIN SYSTEM.....	40
APPENDIX B	BUILDING DESIGN FOR COLD WEATHER APPLICATIONS	46
APPENDIX C	REQUIREMENTS FOR COMPRESSOR PACKAGES WITH PROCESS GAS CONTAINING HYDROGEN SULFIDE (SOUR GAS)	50

PART I INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for packaged reciprocating compressors with a brake horsepower driver limit of 2,895 kW (4000 hp) and a discharge pressure not exceeding 153 barg (2220 psig). Packages built to this specification are not intended for Hydrogen service.

This DEP is based on ISO 13631:2002. Part III of this DEP amends, supplements and deletes various clauses of ISO 13631:2002. All clauses of ISO 13631:2002 not modified by this DEP remain valid as written.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual DEM 1 – Application of Technical Standards.

This is a revision of the DEP of the same number dated January 2010; see (1.5) regarding the main changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorisation to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to onshore and offshore oil and gas production. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regard to the safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, and commissioning or management of a project or operation of a facility. The Principal may sometimes undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

NOTE: In ISO 13631, the term **Vendor** is used. In this DEP, the term Vendor shall be understood to have the same meaning as Manufacturer/Supplier.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

NOTE: In ISO 13631, the term **Purchaser** is used. In this DEP, the term Purchaser shall be understood to have the same meaning as Principal.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The lower-case word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
Associated Gas	Associated gas is natural gas that is originally found dissolved in crude oil or condensate, from which it is liberated under the influence of changes in pressure and temperature as the crude oil or gas condensate is produced from the reservoir into the production well, and from there into surface facilities

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets (). Other documents referenced by this DEP are listed in (Part IV).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated January 2010. The modifications to this DEP are so extensive that the entire document should be reviewed in its entirety as all sections were modified.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://www.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

PART II GENERAL INFORMATION

Part III of this DEP is written as amendments and supplements to ISO 13631:2002. Wherever reference is made to ISO 13631, it shall be understood to mean ISO 13631 as amended/supplemented by this DEP.

For ease of reference, the clause numbering of ISO 13631 has been used throughout Part III of this DEP. Clauses in ISO 13631 which are not mentioned shall remain valid as written.

A bullet (●) in the margin against certain clauses in ISO 13631 indicates that a decision by the Principal is required. This DEP addresses the decisions required by many of the ISO 13631 bulleted clauses. The remaining decisions shall be indicated directly on the relevant data/requisition sheets when provisions are made for them; otherwise they shall be indicated on the data/requisition sheets under the heading 'Additional Requirements' or stated in the purchase order.

PART III AMENDMENTS/SUPPLEMENTS TO ISO 13631**1. Scope**

Replace in the first and fifth bullets of this clause:

- 'ISO 13707' with 'ISO13707 (API 618)'
- '0.9 MPa (9 bar)' with '9 bar (ga) [130 psig]'

Add the following to the list of exclusions:

- reciprocating compressors covered by ISO 13707 (API 618);
- labyrinth type compressors.

2. Normative references

Add to this clause:

Documents referenced by this DEP are listed in (Part IV).

3. Terms and definitions**3.15 standard flow**

Add to this clause:

Standard conditions for US Customary units are 14.7 psia and 60°F.

Add new terms:

3.16 hazardous service

hydrogen service and very toxic service

3.17 sour service

Per NACE MR0175/ISO 15156, or if specified, refer to (Appendix C) for specific requirements.

3.18 very toxic service

Substances that produce serious harm to health as a result of a single or short term exposure. The following shall be considered very toxic:

- Levels of H₂S exceeding 600 mg/kg (600 ppm) in process streams.
- Other substances specified by the Principal to be very toxic.

4. Statutory requirements

Delete the second sentence of this clause.

5. General package requirements**5.1 Compressor package performance curves**

Replace this clause with the following:

Package performance curves shall be provided by the compressor Packager and shall cover the operating conditions described in the attached datasheets and scope documents. The curves shall be drawn for the full speed range, and shall cover the full range of pressure and flow conditions over the life of the machine as defined in the attached

datasheets. The curves shall consider variable volume clearance pocket position and shall indicate the minimum volumetric efficiency, rod load, and horsepower limitations.

5.2 Package arrangement

Add to the clause:

There shall be clear access to all parts that require maintenance. Such parts include but are not limited to compressor distance piece side doors, compressor cylinder valves, engine heads, instruments and control valves, belts and couplings.

5.3 Drawings

Replace this clause with the following:

In addition to the requirements of ISO 13631, the Manufacturer/Supplier shall provide P&IDs, Equipment and Piping Arrangement Drawings (left side, right side, and plan view), fuel gas and lube oil diagrams, and instrumentation diagrams. See (19.5) for instrumentation documentation requirements. These drawings shall be submitted in native file format for inclusion in project models and for review. These drawings shall be issued for approval.

5.4 Sound pressure level

Delete "if specified" from the second sentence of the ISO clause.

Add to the clause:

The Manufacturer/Supplier shall submit estimated sound pressure levels of the equipment. The Manufacturer/Supplier shall consult the attached datasheets for the maximum allowable sound pressure level required.

5.5 Electrical area classification

Replace this clause with:

All electrical components and installations SHALL [PS] be suitable for the area classification, gas grouping and temperature classes specified by the Principal in the data/requisition sheets.

5.6 Package installation

Replace the second sentence of this clause with:

The unit and its auxiliaries shall be suitable for start-up, operation and periods of idleness under these specified conditions.

Add to this clause:

For compressors installed in unheated areas, entirely or partly exposed to the atmosphere, the following minimum requirements shall be provided for:

- (i) Dust-tight and water-tight enclosure of the crankcase and distance pieces, vented and purged when required.
- (ii) If winterising is required, the heating facilities should include crankcase, oil lines, lubricators and cooling liquid conduits, drains and vents.
- (iii) Complete drainage facilities of all cooling liquid spaces and lines.

5.7 Torsional analysis

Add to the clause:

The Manufacturer/Supplier shall perform a torsional study and provide the torsional report on all new packages built to Purchaser's specification. It is only acceptable to not perform a

torsional study when identical components are used with demonstrated acceptable field performance from previous jobs.

Delete "When specified" from the beginning of the second sentence.

Add to this clause:

Torsional natural frequencies of the driver-compressor system (including couplings and any gear unit) shall be avoided within 10 percent of any operating shaft speed and within 5 percent of any other multiple of operating shaft speed in the rotating system up to and including the tenth multiple. For motor driven compressors, torsional natural frequencies shall be separated from the first and second multiples of the electrical power frequency by the same separation margins.

Add new clause:

5.8 Service life

The equipment (including auxiliaries) covered by this International Standard shall be designed and constructed for a minimum service life of 20 years, with operating periods of at least 3 years between major maintenance shutdowns (excluding compressor valve replacement and replacement of packing, rings and rider bands).

Add new clause:

5.9 Prototype equipment

If the Vendor proposes to supply prototype equipment then the quotation shall state that the offered equipment is a prototype and it shall be accompanied by sufficient data for the Principal to thoroughly investigate its suitability for the intended duty.

NOTE: Equipment is not considered to be prototype if at least 3 units of similar type and size have each accumulated an operating time of at least 8000 hours in a duty similar to that pertaining to the enquiry in question, with normal maintenance but without significant downtime due to excessive wear or component or system failure.

Add new clause:

5.10 Fault tolerance

The complete compressor unit shall be able to withstand the effects of a fully loaded shutdown of the unit against the safety relief valve's set pressure.

Add new clause:

5.11 Unit responsibility

The Manufacturer/Supplier shall be responsible for the design and engineering, the total mechanical and thermodynamic performance, and the guarantee of the entire compressor unit and associated auxiliary units. The Manufacturer/Supplier shall take prime responsibility for the mechanical integration of the driver and the compressor, power transmission equipment and all auxiliary equipment furnished by sub-suppliers. The Manufacturer/Supplier responsibilities shall include, but not be limited to, specification of the coupling details, accommodation of any axial forces on the drive shaft assembly, ensuring adequate inertia is provided in the rotating assembly (fly wheel selection), completing all analyses specified in the data/requisition sheets of the compressor and driver train, coordination with sub suppliers for couplings, driver, cooling system, lubrication system and the like.

6. Compressor

6.1 General

Add new clause:

Unless otherwise specified, the compressor shall be horizontal and double-acting. Multi-cylinder units shall be of balanced opposed design.

6.2 Allowable speeds

Add to this clause:

The maximum allowable average piston speed for produced gas applications shall be limited to 1200 fpm (6.1 m/s). The maximum allowable average piston speed for associated gas applications shall be limited to 950 fpm (4.82 m/s).

6.3 Allowable discharge temperature

Replace this clause with:

The maximum predicted discharge temperature shall not exceed 140°C (285°F). This temperature limit applies to all operating and load conditions (including highest suction temperature specified), but does not apply to relief valve setting conditions. The Vendor shall provide the Purchaser with both the predicted and adiabatic discharge temperatures.

It is recommended that the alarm and trip be set at 150°C (300°F) and 160°C (320°F) respectively.

6.4 Rod loads

6.4.1 Allowable rod loads

6.4.1.1 *Replace this clause with:*

The combined rod loading shall not exceed 80 % of the Manufacturer/Supplier's maximum allowable continuous rod load at the rated discharge pressure and the normal suction pressure at each stage corresponding to each load step.

The combined rod loading SHALL [PS] not exceed 100 % of the Manufacturer/Supplier's maximum allowable continuous rod loading with discharge pressure equal to set point pressure of the discharge relief valve (including the required overpressure) and the minimum suction pressure at each stage corresponding to each load step.

6.4.1.2 *Replace this clause with:*

The gas loading on the compressor static frame components (e.g., cylinders, heads, distance pieces, crosshead guides, crankcase and bolting) shall not exceed 80 % of the Manufacturer/Supplier's maximum allowable gas load at the rated discharge pressure and the normal suction pressure at each stage corresponding to each load step.

The gas loading on the compressor static frame components (e.g., cylinders, heads, distance pieces, crosshead guides, crankcase and bolting) SHALL [PS] not exceed 100 % of the Manufacturer/Supplier's maximum allowable gas load with discharge pressure equal to set point pressure of the discharge relief valve (including the required overpressure) and the minimum suction pressure at each stage corresponding to each load step.

In addition, the gas loading on the compressors static frame components (e.g., cylinders, heads, distance pieces, crosshead guides, crankcase and bolting) SHALL [PS] not exceed 100 % of the Manufacturer/Supplier's maximum allowable gas load with blocked final stage discharge and with minimum suction pressure at the first stage as defined by the package data sheets.

6.4.2 Rod load reversal

Replace this clause with:

Unless otherwise specified, the duration of the rod reversal shall not be less than 45 degrees of crank angle, and the magnitude of the peak combined reversed load shall be at least 20 % of the actual combined load in the opposite direction, at each load step.

6.5 Compressor cylinders

6.5.1 General

6.5.1.2 *Replace this clause with:*

Unless otherwise specified in the data/requisition sheets, horizontal cylinders shall be provided, which shall have top suction and bottom discharge.

6.5.1.3 *Add to this clause:*

Clearance shall be provided under the cylinder to allow a tool to be used to support the valve covers.

Add new clause:

6.5.1.4 The cylinder bore diameter shall not exceed 360 mm (14-1/8 in) unless specifically approved by the Principal.

6.5.2 Cylinder/crankcase appurtenances

6.5.2.1 *Replace this clause with:*

The cylinder support shall be designed to avoid misalignment or excessive rod run-out during the warm-up period and at actual operating temperature. Piston rod run-out shall be measured directly adjacent to the cylinder packing case flange.

Head-end cylinder supports are not required unless the pulsation study indicates a need for head-end cylinder supports. When head-end cylinder supports are supplied, they shall be stiff vertically as well as horizontally in the axis parallel to the crankshaft to reduce cylinder side-sway. Vertical adjustment on all cylinder supports shall be achieved solely by the use of precision shims. Cylinder head bolts shall not be used to attach head-end cylinder supports to the cylinder.

Additionally, a cylinder end support shall not be used in place of the distance piece support.

6.5.2.2 *Add to this clause:*

For saturated associated gas, cylinder gas temperatures shall be held above the inlet temperature of the gas to prevent condensation or liquid formation.

6.5.3.1 *Add to this clause:*

A flexitallic gasket with inner and outer rings shall be provided between the compressor cylinder and the pulsation bottle.

6.5.3 Cylinder connections

6.5.3.2 *Replace this clause with:*

Each cylinder end shall be provided with plugged 13 mm (1/2 in) connections suitable for indicator valves. Valves and adaptors, if specified, shall be of a type approved by the Principal. The length of the passage to the valve shall be checked for potential acoustic resonance. Indicator valves shall be capped to prevent leakage; the cap shall be designed to relieve any pressure under the cap before removal.

6.6 Valves**6.6.2 Valve design****6.6.2.1** *Add to this clause:*

In the proposal, the Manufacturer/Supplier shall provide a description of the features applied to meet the requirements of this clause and define the areas where this requirement cannot be met.

Add new clause:

6.6.2.5 Thermoplastic valve sealing elements shall be supplied. The Manufacturer/Supplier shall submit valve sealing element material selection to the Principal for review and approval. The Manufacturer/Supplier shall provide detailed engineering data on the proposed valves describing the valves' reliability and dynamics.

6.7 Pistons, piston rods and piston rings**6.7.1 Piston attachment**

Add to this clause:

Supernuts (or similar) are not an acceptable method of attaching the piston to the piston rod and shall not be used. A hydraulic tensioned connection is preferred over a simple jam nut.

6.7.3 Piston wear bands

Add to this clause:

Non-metallic wear bands are required. The Manufacturer/Supplier shall advise the Principal of material selection.

6.7.5 Piston rod threads

Add to this clause:

Subsequent to all manufacturing processes, the thread area shall be inspected by the wet fluorescent magnetic particle method. All linear indications in the thread area that cannot be removed by light buffing shall be cause for rejection.

Add new clause:

6.7.7 Piston rods shall be designed to accommodate a guide sleeve or bullet for proper installation through packing assemblies.

Add new clause:

6.7.8 Aluminum pistons

Aluminum pistons shall only be provided if approved by the Principal.

6.8 Crankcases, crankshafts, connecting rods, bearings and crossheads**6.8.1 Crankshafts**

Replace the first sentence of this clause with:

Crankshafts shall be one piece forged steel and shall be heat-treated and machined on all working surfaces and fits. There shall be no keyways or other potential stress risers machined in the shaft.

The Manufacturer/Supplier shall specify method of attachment of the flywheel to the crankshaft.

6.8.2 Bearings

Replace this clause with:

Replaceable precision-bored shell (sleeve) crankpin bearings and main bearings shall be used. Anti-friction bearings are not acceptable. For compressors with drivers over 1,500 kW (2000 hp), each main bearing shall incorporate a single element three-wire 100 ohm platinum RTD.

6.8.3 Connecting rods

Replace this clause with:

Connecting rods shall be constructed from forged steel with removable cap. They shall be free of any sharp corners. Forced-lubrication passages shall be drilled.

6.8.4 Crossheads

Replace this clause with:

Crossheads shall be cast steel, nodular iron or forged construction. Alternate materials shall be approved by the Purchaser prior to use. Adequate openings for removal of crosshead shall be provided.

A Supernut (or similar) shall not be used to connect the piston rod to the crosshead. A hydraulic tensioned connection is preferred over a simple jam nut.

6.8.5 Crankcases

Delete "If specified," from the first sentence of this clause.

Add to this clause:

When a distance piece vacuum system is supplied, the compressor crankcase shall be vented inside the building, with a desiccant breather.

6.9 Distance pieces

6.9.1 Design

6.9.1.1 *Add to this clause:*

Close-coupled, single compartment (Type 1) distance pieces may be used for non-flammable, non-very-toxic services.

Extra-long, single compartment (Type 2) distance pieces may be furnished for sweet natural gas. If so specified by the Principal, an eductor system driven by sweet process gas shall be used to maintain a slight vacuum in the distance piece or an inert gas may be used for purging the partition packing.

For all other services, a double-compartment distance piece design (Type 3) SHALL [PS] be furnished.

6.9.1.2 *Delete the words "If specified" from this clause.*

Add new clause:

6.9.4 Outer Compartment

The outer compartment of the distance piece adjacent to the cylinder, partitions, covers, bolting and intermediate seal packing shall be designed for a minimum compartment pressure of 3.5 bar (ga) [50 psig].

6.10 Packing cases and pressure packing

6.10.2 Construction

Replace the first two sentences of this clause with:

The packing case and end flange shall be bolted to the cylinder with at least four stud bolts (cap bolts are not allowed).

In the last sentence of this clause, delete the words "cup-to-cup pilot fits and/or".

Add to this clause:

If cup-to-cup pilot fits are supplied they shall be sealed using o-rings. If the cup is not large enough for the o-ring seals, the Manufacturer/Supplier shall grind and lap the mating surfaces. The Vendor's proposal shall clearly state if ground and lapped joints are provided.

Packing cases shall be designed to accommodate piston rod radial movements without metal-to-metal contact between rod and case in the event of loss of the total rider ring height.

Add new clause:

6.10.5 Cooling

The Vendor shall indicate whether cooling is required, and the proposal shall be submitted for review by the Principal. The proposal shall be supported by references to similar or more severe applications.

6.11 Compressor crankcase lubrication system

6.11.3 Lubrication of oil pumps

6.11.3.1 Add to this clause:

If specified, an external relief device shall be provided downstream of the lube oil pump.

6.11.4 Oil filtration

Add to this clause:

If specified, dual filters with full flow transfer valve and valved vent and drain connections shall be provided. A differential pressure indicator shall be provided. A valved oil sampling connection shall be provided between oil filter and oil cooler.

6.11.5 Materials

Add to this clause:

Pumps, filters, valves and coolers shall be of steel. Piping downstream of the filters shall be 316 stainless steel. Copper/copper alloy components are not allowed in any part of the system.