

DEP SPECIFICATION

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

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DESIGN AND ENGINEERING PRACTICE

DEM1



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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.

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TABLE OF CONTENTS

PART I	INTRODUCTION	6
1.1	SCOPE	6
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	6
1.3	DEFINITIONS	7
1.4	CROSS-REFERENCES	7
1.5	SUMMARY OF MAIN CHANGES.....	7
1.6	COMMENTS ON THIS DEP	8
1.7	DUAL UNITS.....	8
1.8	NON NORMATIVE TEXT (COMMENTARY).....	8
PART II	GENERAL INFORMATION	9
PART III	AMENDMENTS/SUPPLEMENTS TO ISO 13631.....	10
1	SCOPE	10
2	NORMATIVE REFERENCES.....	10
3	TERMS AND DEFINITIONS.....	10
3.15	standard flow.....	10
3.16	hazardous service.....	10
3.17	sour service.....	10
3.18	very toxic service	10
3.19	accumulation.....	11
3.20	Proven Equipment	11
4	STATUTORY REQUIREMENTS.....	11
5	GENERAL PACKAGE REQUIREMENTS	11
5.1	Compressor package performance curves.....	11
5.3	Drawings	11
5.4	Sound pressure level	11
5.5	Electrical area classification.....	12
5.7	Torsional analysis	12
5.8	Service life	12
5.9	Prototype equipment.....	12
5.10	Unit responsibility.....	13
6	COMPRESSOR.....	13
6.2	Allowable speeds	13
6.3	Allowable discharge temperature	13
6.4	Rod loads	14
6.5	Compressor cylinders	14
6.6	Valves	16
6.7	Pistons, piston rods and piston rings.....	16
6.8	Crankcases, crankshafts, connecting rods, bearings and crossheads	17
6.9	Distance pieces.....	18
6.11	Compressor crankcase lubrication system	18
6.12	Compressor cylinder lubrication	19
6.13	Materials	20
6.14	Power transmission.....	22
7	CAPACITY CONTROL.....	24
7.4	Clearance variation	24
7.5	Bypass systems.....	24
7.6	Valve removal or unloading	24
8	PRIME MOVERS.....	24
8.2	Spark-ignited gas engines	24
8.3	Electric motors	25
9	COOLING SYSTEM	26

9.2	Gas engine.....	26
9.3	Compressor	26
9.4	Types of coolers.....	27
9.6	Arrangement and construction.....	28
10	PRESSURE VESSELS	28
10.1	General	28
10.2	Separators	28
10.3	Pulsation suppression devices	29
11	PIPING AND APPURTENANCES	31
11.1	General	31
11.2	Design	31
11.5	Fabrication	32
11.8	Pipe material and sizes.....	32
11.10	Valves	32
11.13	Start-up screens.....	33
11.15	Coolant piping requirements.....	33
11.16	Instrument piping requirements	33
11.17	Drain and vent piping	33
11.18	Relief valves.....	34
11.19	Blowdown valves	34
12	ELECTRICAL SYSTEMS.....	34
12.1	Codes.....	34
12.7	Power Installations.....	34
13	INSTRUMENTS AND CONTROLS.....	35
13.1	General	35
13.2	Instrument and control panel	35
13.3	Instrumentation	36
13.4	Vibration detectors	36
14	SHUTDOWNS ALARMS AND ANNUNCIATORS.....	37
14.2	Minimum required shutdowns.....	37
14.5	Transmitters	37
14.3	Emergency shutdown systems	37
15	SKIDS	38
15.1	General	38
15.2	Design	39
15.3	Construction	40
15.4	Walkways, stairs and platforms	41
15.5	Buildings for cold weather.....	41
16	PAINT AND PAINTING	41
16.2	Surface preparation	41
17	INSPECTION AND TESTING	41
17.2	Material inspection	41
17.3	Testing	42
18	MARKINGS	42
19	PREPARATION FOR SHIPMENT	42
19.5	Manuals	42
20	CORROSIVE GASES.....	43
20.1	General	43
20.2	Hydrogen sulphide	43
20.3	Carbon dioxide.....	43
ANNEX E	(INFORMATIVE) REPAIRS TO GREY OR NODULAR IRON CASTINGS	44
E.1	GENERAL	44

PART IV REFERENCES 45

APPENDICES

APPENDIX A DISTANCE PIECE VENT AND DRAIN SYSTEM.....47

APPENDIX B DESIGN OF BUILDINGS FOR COLD WEATHER APPLICATIONS.....54

APPENDIX C REQUIREMENTS FOR COMPRESSOR PACKAGES WITH PROCESS
GAS CONTAINING HYDROGEN SULPHIDE (SOUR GAS) 60

PART I INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for packaged reciprocating compressors with a brake horsepower driver limit of 1750 bhp (1305 kW) for engines and 4000 bhp (2983 kW) for electric motors. Packages built to this DEP are limited to discharge pressures less than, or equal to, 153 barg (2220 psig). Packages built to this DEP and corresponding industry standard 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. Part III follows the clause numbering of ISO 13631 for easy reference.

All clauses of ISO 13631 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 February 2012; 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 word **shall** indicates a requirement.

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

The word **should** indicates a recommendation.

The word **may** indicates a permitted option.

1.3.2 Specific definitions

Term	Definition
Associated Gas	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 or clause 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 full revision of the DEP of the same number dated February 2012. The following are the main non-editorial changes:

Section/Clause	Change
All	Restructured and clarified requirements, enforced shall/should

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://swwww.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

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.

1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

Non-normative text is normally indented slightly to the right of the relevant DEP clause.

PART II GENERAL INFORMATION

Part III of this DEP is written as amendments and supplements to ISO 13631:2002.

1. Wherever reference is made to ISO 13631, it shall be understood to mean ISO 13631:2002 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.

2. Clauses in ISO 13631, which are not mentioned in this DEP, 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.

3. Bulleted clauses not addressed by this DEP shall be dealt with in one of the following ways:
 - a. indicated directly on the relevant data/requisition sheets when provisions are made for them;
 - b. indicated on the data/requisition sheets under the heading 'Additional Requirements';
 - c. stated in the purchase order.



PART III AMENDMENTS/SUPPLEMENTS TO ISO 13631**1 SCOPE**

Replace the first bulleted item of this clause with the following:

1. Reciprocating compressors for petroleum and natural gas industries covered by ISO 13707 (API Std 618)

Replace the bulleted item of this clause with the following:

2. utility or instrument air compressors with a discharge gauge pressure of 9 bar (ga) [130 psig] or less;

Add the following to the list of exclusions:

3. reciprocating compressors covered by ISO 13707 (API Std 618);
4. labyrinth type compressors.

2 NORMATIVE REFERENCES

Add the following to this clause:

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

3 TERMS AND DEFINITIONS**3.15 standard flow**

Add the following to this term:

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

Add the following clauses:

3.16 hazardous service

1. hydrogen service and very toxic service

3.17 sour service

1. Per NACE MR0175/ISO 15156-3, or if specified, refer to (Appendix C) for specific requirements.

3.18 very toxic service

1. Substances that are very hazardous for the environment or human health. For this DEP the term "very toxic" includes Very toxic – acute, chronic, and environment categories per Part III of DEP 01.00.01.30-Gen., unless otherwise specified.
2. Petroleum substances are defined as very toxic only if they contain the following components:
 - a. hydrogen sulphide (CAS# 7783-06-4) at >0.1% vol or 0.06% wt;
 - b. benzene (CAS# 71-43-2) at > 5% wt;
 - c. 1,3-Butadiene (CAS# 106-99-0) at > 1% vol;
 - d. non-petroleum contaminants present at a concentration that triggers the 'very toxic' classification, according to the selected scheme (Part III, 3.1, Item 1 of DEP 01.00.01.30-Gen.).

3.19 accumulation

1. The static head buildup above the gas relief pressure set by the relief valve.

3.20 Proven Equipment

1. Equipment of which at least three units of similar type, size and specific loading have together accumulated a minimum of 24,000 h of comparable satisfactory service.

4 STATUTORY REQUIREMENTS

Delete the second sentence in the first clause.

5 GENERAL PACKAGE REQUIREMENTS

5.1 Compressor package performance curves

Replace this clause with the following:

1. Package performance curves shall:
 - a. be provided by the compressor Manufacturer/Supplier;
 - b. cover the operating conditions described in the attached datasheets and scope documents;
 - c. be drawn for the full speed range;
 - d. cover the full range of pressure and flow conditions over the life of the machine as defined in the attached datasheets;
 - e. include variable volume clearance pocket position or the range thereof;
 - f. indicate the minimum volumetric efficiency, rod load, and horsepower limitations.

5.3 Drawings

Replace this clause with the following:

1. The Manufacturer/Supplier shall lead the necessary package model reviews.
2. Once the design is agreed, in addition to the requirements of ISO 13631, the Manufacturer/Supplier shall provide the following documents for final review and approval:
 - a. P&IDs;
 - b. equipment and piping arrangement drawings (left side, right side, and plan view), fuel gas and lube oil diagrams, and instrumentation diagrams.
3. All drawings shall be submitted in native file format for inclusion in project models and for review.

5.4 Sound pressure level

Replace the second sentence of this clause with the following:

1. The equipment furnished by the Vendor shall not exceed the maximum sound pressure level required by the purchaser.

Add the following to the clause:

1. The Manufacturer/Supplier shall submit estimated sound pressure levels for the quoted equipment package.

5.5 Electrical area classification

Replace this clause with the following:

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

5.7 Torsional analysis

Replace this clause with the following:

1. The Vendor shall:
 - a. provide a torsionally sound system;
 - b. perform an analysis to demonstrate (a).
2. The Manufacturer/Supplier shall perform a torsional study and provide the torsional report on all new packages built to Principal's specification.
3. The Torsional study shall apply a minimum 2.0 shaft stress design safety factor in calculations.
4. A torsional study is not required only when identical components with demonstrated acceptable field performance from previous jobs are used.
5. A torsional analysis report shall be provided by the Manufacturer/Supplier.
6. The Supplier shall be responsible to coordinate with the compressor and the prime-mover manufacturers to produce torsional analysis report.

Add the following to this clause:

3. Torsional natural frequencies of the driver-compressor system (including couplings and any gear unit) shall be avoided:
 - a. within 10% of any operating shaft speed;
 - b. within 5% of any other multiple of operating shaft speed in the rotating system up to, and including, the tenth multiple.
4. 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 the following new clause:

5.8 Service life

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

Add the following new clause:

5.9 Prototype equipment

1. If the Vendor proposes to supply equipment that is not proven (3.20), then the quotation shall:
 - a. state that the offered equipment is not proven;
 - b. be accompanied by sufficient data for the Principal to thoroughly investigate the equipment's suitability for the intended duty.

Add the following new clause:

5.10 Unit responsibility

1. The Manufacturer/Supplier responsibilities shall include the following:
 - a. In regards to the package:
 - i. the design and engineering;
 - ii. the total mechanical and thermodynamic performance;
 - iii. guarantee of the entire compressor unit and associated auxiliary units;
 - iv. prime responsibility for the mechanical integration of the driver and the compressor, power transmission equipment and all auxiliary equipment furnished by sub-suppliers.
 - b. In regards to the components on the package:
 - i. specification of the coupling details;
 - ii. accommodation of any axial forces on the drive shaft assembly;
 - iii. ensuring adequate inertia is provided in the rotating assembly (fly wheel selection);
 - iv. completing all analyses specified in the data/requisition sheets of the compressor and driver train;
 - v. coordination with sub suppliers for couplings, driver, cooling system, lubrication system.

6 COMPRESSOR

6.2 Allowable speeds

Add the following to this clause:

1. The maximum allowable average piston speed shall be as follows:
 - a. produced gas applications ≤ 6.1 m/s (1200 fpm);
 - b. associated gas applications ≤ 4.82 m/s (950 fpm).

6.3 Allowable discharge temperature

Replace this clause with the following:

1. The maximum predicted discharge temperature shall not exceed 140 °C (285 °F).
2. The maximum predicted discharge temperature limit:
 - a. applies to all operating and load conditions (including highest suction temperature specified);
 - b. does not apply to relief valve setting conditions.
3. The Vendor shall provide the Principal with both the predicted and adiabatic discharge temperatures.
4. The alarm and trip shall 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 following:

1. 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.
2. 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 accumulation (3.19)) and the minimum suction pressure at each stage corresponding to each load step.

6.4.1.2

Replace this clause with the following:

1. 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.
2. 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 accumulation (3.19)) and the minimum suction pressure at each stage corresponding to each load step.
3. 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.

6.5 Compressor cylinders

6.5.1 General

Add the following new clause:

6.5.1.4

1. 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 following:

1. The cylinder support shall be designed to avoid misalignment or excessive rod run-out for the following conditions:
 - a. during the warm-up period;
 - b. at actual operating temperature.
2. Piston rod run-out shall be measured directly adjacent to the cylinder packing case flange.
3. Head-end cylinder supports are not required unless indicated by the pulsation study.
 - a. When head-end cylinder supports are supplied, they shall be stiff vertically as well as horizontally in the axis parallel to the crankshaft.

This will reduce cylinder side-sway.
 - b. Vertical adjustment on all cylinder supports shall be achieved solely by the use of precision shims.
 - c. Cylinder head bolts shall not be used to attach head-end cylinder supports to the cylinder.
4. A cylinder end support shall not be used in place of the distance piece support.

6.5.2.2

Add the following to this clause:

1. 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 Cylinder connections**6.5.3.1**

Add the following to this clause:

1. A spiral wound gasket having following components shall be provided between the compressor cylinder and the pulsation bottle:
 - a. graphite filler;
 - b. 316 SS windings;
 - c. 316 SS inner ring;
 - d. carbon steel outer ring (or centering ring).

Add the following new clause:

6.5.3.3

1. Each cylinder end shall be provided with a plugged 13 mm ($\frac{1}{2}$ in) connection suitable for indicator valves.

6.6 Valves**6.6.2 Valve design**

Add the following new clause:

6.6.2.5

1. Thermoplastic valve sealing elements shall be supplied.
2. The Manufacturer/Supplier shall submit valve sealing element material selection to the Principal for review and approval.

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

Add the following to this clause:

Multi-through-bolt designs are not an acceptable method of attaching the piston to the piston rod.

1. Multi-through-bolt designs shall not be used for attaching the piston to the piston rod.
2. Hydraulically tensioned piston-to-piston rod connections should be used in lieu of a standard jam nut connection if the tensioned option is offered as a vendor standard practice.

6.7.3 Piston wear bands

Replace this clause with the following:

1. Non-metallic wear bands are required.
2. Non-metallic wear bands shall not over-run the valve port or counter bore by more than one-half of the axial width of the wear band.
3. The Manufacturer/Supplier shall advise the Principal of material selection.

Add the following new clause:

6.7.7 Guide sleeve

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

Add the following new clause:

6.7.8 Aluminium pistons

1. Aluminium pistons shall be provided only if approved by the Principal.
2. Aluminium pistons shall not rely on threaded plugs in the piston unless approved by the Principal.
3. If threaded plugs are used, the following provisions shall be taken:
 - a. bleed holes shall be provided to limit load on plugs;
 - b. plugs shall have sufficient thread engagement according ASME B1.20.1.

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

Replace the first sentence of this clause with the following:

1. Crankshafts shall be:
 - a. one piece forged steel;
 - b. heat-treated and machined on all working surfaces and fits.
2. The Manufacturer/Supplier shall:
 - a. specify method of attachment of the flywheel to the crankshaft;
 - b. provide the studies proving that the keyways (when present on the shaft) will not introduce stress risers in the shaft.

6.8.2 Bearings

Replace this clause with the following:

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

6.8.4 Crossheads

Add the following to the clause:

1. Multi-through-bolt designs shall not be used to connect the piston rod to the crosshead.
2. Hydraulically tensioned piston to piston rod connections should be used in lieu of a standard jam nut connection if the tensioned option is offered as a vendor standard practice.

6.8.5 Crankcases

Replace the first sentence of this clause with the following:

1. The crankcase shall be provided with relief devices to protect against rapid pressure rises.

Add the following to this clause:

2. 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 the following to this clause:

1. Close-coupled single compartment (Type 1) distance pieces shall be used for non-flammable or non-hazardous service.
2. Single compartment (Type 2) distance pieces shall be furnished for remote, unmanned production compressors and pipeline booster compressors involved in compressing sweet natural gas.

Eductor systems discharging to combustors or flares, driven by sweet gas, can be used to maintain a slight vacuum in the distance piece.

3. For all services containing flammable, hazardous, or toxic gases, a double-compartment distance piece design (Type 3) SHALL [PS] be furnished with the following:
 - a. A nitrogen purge on the partition packing;
 - b. Vents to flare and atmosphere where the sizing of vents meet the following:
 - i. capacity for a full packing failure;
 - ii. accommodate all normal operating scenarios.

6.9.1.2

Replace the first sentence of this clause with the following:

1. Slinger rings shall be provided to Type 2 or 3 distance pieces to prevent migration and mixing of oil between the crankcase and the compressor cylinders.

6.11 Compressor crankcase lubrication system

6.11.3 Lubrication of oil pumps

6.11.3.1

Add the following to this clause:

1. An external relief device shall be provided downstream of the lube oil pump.

6.11.4 Oil filtration

Add the following to this clause:

1. Compressors in critical, unsparred applications shall be equipped with:
 - a. dual filters with a differential pressure indicator;
 - b. full flow transfer valve;
 - c. valved vent and drain connections.
2. A valved oil sampling connection shall be provided between oil filter and oil cooler.

6.11.5 Materials

Add the following to this clause:

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

6.11.7 Lubricating oil heater

Add the following to this clause:

1. If a lube oil heater and/or a lube oil circulating heater system is specified in the data/requisition sheets all of the following shall apply:
 - a. A low lube oil level in the reservoir or crankcase shall:
 - i. prevent operation of the immersion heater.
 - ii. generate an independent alarm signal.
 - b. A high temperature switch (TSH) shall:
 - i. be provided in the lube oil reservoir or in the control element of the heater;
 - ii. generate an independent alarm signal.
 - c. Electrical starters/contactors shall be provided by the Contractor.
 - d. Electrical starters/contactors shall be located remotely in the Motor Control Center (MCC).

6.12 Compressor cylinder lubrication**6.12.1 Cylinder lubrication**

Replace this clause with the following:

1. A divider block-distribution system for compressor cylinder bore and piston rod packing shall be provided with the following features and design elements:
 - a. suited for variable flow;
 - b. weatherproof construction;
 - c. includes provisions for compressor pre-lube prior to compressor start-up;
 - d. equipped with:
 - i. a reservoir with an external level indicator;
 - ii. no flow alarm;
 - iii. lube rate measurement via proximity switch;
 - iv. double check valves installed as close to the injection point;
 - v. 300 series austenitic SS tubing;
 - vi. a resettable, spring loaded indicator pin to indicated plugged lines on each primary divider block;
 - vii. overpressure protection by a device between the pump and the injection point;
 - viii. liquid filled pressure gauges;
 - ix. balancing valves when system differential pressures exceed 68 barg (1000 psig).