DEP SPECIFICATION

RECIPROCATING COMPRESSORS (AMENDMENTS/SUPPLEMENTS TO API 618)

DEP 31.29.40.31-Gen.

February 2011
(DEP Circular 82/11 has been incorporated)
ECCN EAR99

DESIGN AND ENGINEERING PRACTICE

DEM1

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PART I INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for reciprocating compressors.

Excluded from the scope of this DEP are air-cooled utility air ("tool air") compressors that discharge at 8.6 barg (130 psig) or below.

This DEP is based on API 618, fifth edition, December 2007. Part III of this DEP amends, supplements and deletes various clauses of API 618.

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 December 1999; see (1.5) regarding the 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.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing and gasification. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process should 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 may 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, commissioning or management of a project or operation of a facility. The Principal may 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.

The **Principal** is the party that initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

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

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

The word **should** indicates a recommendation.

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1.3.2 Specific definitions

Very toxic (substances) substances that are very hazardous for the environment or human health.

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 CHANGES

Clause	Change
General	Process safety requirements have been indicated by the use of the capitalised term "SHALL [PS]".
General	Substantial renumbering of paragraphs due to change in base standard (was API 618 4th edition, now API 618 5th edition

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://sww.shell.com/standards and on the main page of the DEPs DVD-ROM.

1.7 DUAL UNITS

Amended per Circular 82/11
Dual units have been incorporated throughout this DEP.

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.

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PART II GENERAL INFORMATION

This DEP is written in four parts, of which Part III gives amendments and supplements to API 618, fifth edition, December 2007. Wherever reference is made to API 618, it shall be understood to mean API 618 as amended/supplemented by this DEP.

For ease of reference, the clause numbering of API 618 has been used throughout Part III of this DEP. Clauses in API 618 which are not mentioned shall remain valid as written.

A bullet in the margin against certain clauses in API 618 indicates that a decision by the Principal is required. This DEP addresses the decisions required by many of the API 618 bullet clauses. The remaining decisions shall be indicated directly on the relevant data/requisition sheet when provisions are made for them; otherwise they shall be indicated on the data/requisition sheet(s) under the heading 'Additional Requirements' or stated in the purchase order.

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PART III AMENDMENTS/SUPPLEMENTS TO API 618

2 REFERENCED PUBLICATIONS

2.1 *Add to this clause:*

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

3 DEFINITIONS OF TERMS

3.63 *Add new term:*

Hazardous service. Hydrogen service and very toxic service**.** Refer to DEP 31.29.00.33 for other hazardous services in addition to what are mentioned in this DEP.

3.64 *Add new term:*

Hydrogen service. All process conditions with a hydrogen partial pressure greater than 700 kPaa (120 psia).

3.65 *Add new term:*

Very toxic service

Service with substances that are very hazardous for the environment or human health.

3.66 *Add new term:*

Suction and discharge Pressure. Suction and discharge pressures through this standard refer to the pressure at the inlet flange of the suction pulsation dampener and the outlet pressure of the discharge dampener.

3.67 *Add new term*

Super-nut. A specially designed nut that incorporates a number of jack screws equally spaced around its body.

5 REQUIREMENTS

5.3 Conflicting Requirements

Replace this clause by:

In the event of conflict between documents relating to the inquiry or purchase order, the following hierarchy of documents shall apply:

- First level: purchase order and variations thereto
- Second level: data/requisition sheets and drawings
- Third level: this DEP

Any apparent conflict between the requirements of this DEP and any other relevant document in the purchase order the Principal shall be notified for clarification purposes.

5.4 Alternative Designs

Add new clause:

5.4.1 The Vendor's primary quotation shall be in accordance with this DEP. Alternative quotations may be submitted if they offer significant price, delivery, or technical advantage, but shall be clearly defined as alternative proposals.

5.4.2 Alternative quotations shall state deviations from this DEP and complete engineering details of alternative design and/or materials shall be submitted to the purchaser for review.

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6 BASIC DESIGN

6.1 GENERAL

6.1.1 *Add to this clause:*

Compressor ratings shall not exceed the limits of the manufacturer's design and shall be within the manufacturer's actual experience. Only equipment that has proven its reliability in similar service is acceptable. A reference of at least 3 units of the same type and size and with an accumulated experience of 25,000 hours of operation is required. Equipment that does not have an accumulated experience of 25,000 hours is considered prototype. 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.

6.1.3 *Replace this clause by:*

The Purchaser shall specify the equipment's normal operating point and all other applicable operating points such as start up, loading and unloading, regeneration, etc.. The vendor shall confirm the compressor's performance and mechanical capabilities at the specified operating points (including valve selections). Unless otherwise agreed by the Purchaser, negative tolerances on capacity shall not apply to any specified operating points.

Replace the third sentence in this clause with: The Manufacturer shall advise the estimated noise levels by completing data sheet DEP 31.10.00.94-Gen., which forms part of the requisition.

6.1.7 Replace the first sentence of this clause by:

Unless otherwise specified in the data/requisition sheets, liquid-cooling systems for lube oil, cylinders and piston rod packing shall be designed for the following conditions on the coolant side:

Modify in this clause:

Fouling factor on the coolant side: 0.25 m^2.K/kW (0.0014 $h.ft^2.°F$/Btu)

Replace the last sentence in this clause with: Provision shall be made for complete venting and draining of the liquid cooling system.

6.1.8 *Replace this clause by:*

All equipment SHALL [PS] be designed to run safely to the relief valve setting including accumulation (see also 7.6.5).

6.1.10 *Add to this clause:*

The application of variable speed drive systems (VSDSs) requires the approval of the Principal.

6.1.12 Replace this clause by:

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.

6.1.14 *Change the last sentence in the clause to:* This may be accomplished by such methods as shouldering or precision cylindrical dowels. Distance piece to cylinder and distance piece to crosshead guide shall be shouldered or registered

6.1.15 *Replace the first sentence of this clause by:*

The combined performance of the compressor and its driver under all operating conditions shall be the responsibility of the Vendor. The combined unit (or complete package, if applicable) shall perform as well on its permanent foundation as it did on the Manufacturer's test stand.

6.1.17 Delete "When specified"

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6.1.18 *Add to this clause:*

NOTE: In accordance with Annex B, this power tolerance refers to the required power at Manufacturer's rated capacity.

6.1.20 *Replace the first sentence of this clause by:* The unit and its auxiliaries shall be suitable for start-up, operation and periods of idleness under the specified environmental conditions.

Add to this clause: For compressors installed in unheated areas, entirely or partly exposed to the environmental conditions, the following minimum requirements shall be provided for:

(i) Dust-tight and watertight enclosure of the crankcase and distance pieces, vented and purged when required.

(ii) If winterizing is required, the heating facilities should include crankcase, oil lines, lubricators and cooling liquid piping, drains, vents, and instruments.

(iii) Complete drainage facilities of all cooling liquid spaces and lines.

6.1.23 *Add to this clause:*

The Vendor shall use SI units in the data sheets, in the proposal and in written guarantees regarding performance of the equipment. Alternate system such as US Customary systems may be used when specified.

6.1.25 *Add new clause:*

The complete compressor unit SHALL [PS] be able to withstand the effects of a fully loaded shutdown of the unit against the safety relief valve set pressure, including accumulation.

In the case of an electrical motor driver (either fixed or variable speed), the complete unit shall be able to withstand the effects of a 2-phase short circuit.

The complete unit shall be capable of a restart with full opposite residual voltage.

6.2 BOLTING

6.2.1 *Add to this clause:*

Details of fasteners requiring hardness control of sour service shall be reviewed by the Principal. Cap screws shall not be used. Cadmium and Zinc plated studs, bolts, and nuts shall not be used

6.2.2 *Add to this clause:*

The application of hydraulic bolt tensioning shall be possible for:

- class 1500 flanges, DN 150 (NPS 6) and larger;
- class 2500 flanges, DN 100 (NPS 4) and larger.

6.2.6 *Add new clause:*

As a minimum, bolts with diameters 35 mm (1-1/2 in) or larger shall be hydraulically tensioned.

6.4 ALLOWABLE SPEEDS

Add to this clause:

Compressor speeds and corresponding average piston speeds shall be limited to the following values:

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Installed power (SI)	Installed power (US)	Maximum compressor speed (60 Hz Systems / 50 Hz Systems)	Maximum average piston speed
26 kW and lower	35 hp or Lower	600 rpm / 600 rpm	300 m/min (1000 ft/min)
27 kW – 335 kW	36 hp – 450 hp	514 rpm / 500 rpm	260 m/min (850 ft/min)
336 kW – 1490 kW	451 hp – 2000 hp	400 rpm / 429 rpm	250 m/min (825 ft/min)
1491 kW and above	2001 hp and above	327 rpm / 333 rpm	225 m/min (750 ft/min)

The average piston speed in compressors handling saturated hydrocarbon gases and in non-lubricated compressor cylinders shall not exceed 210 m/min (700 ft/min).

Average piston speed in compressors that handle dry gases in non-lubricated compressor cylinders shall not exceed 180 m/min (600 ft/min).

The maximum speed of vertical labyrinth piston-type compressors shall be 429 rpm for 50 Hz systems (450 rpm for 60 Hz systems), irrespective of the installed driver power.

6.5 ALLOWABLE DISCHARGE TEMPERATURE

6.5.1 *Replace the first two sentences of this clause by:*

Modify the clause to:

The Vendor shall provide the purchaser with both the predicted and adiabatic discharge temperature rise. Maximum calculated adiabatic discharge temperature of any step shall not exceed 140 °C (285 °F). Maximum calculated adiabatic discharge temperature shall not exceed 130 °C (265 °F) for hydrogen-rich services (molecular weight of 12 or less). These temperature limits, do not apply to relief valve setting conditions. Otherwise, these temperature limits apply to all operating and load conditions.

6.5.2 *Add to this clause:*

Air compressors and oxygen compressors SHALL [PS] not be (piston/packing) lubricated. For these services, vertical labyrinth piston design compressors with carbon graphite packing rings and bushing are preferred. This also applies to oxygen-bearing gases with an oxygen content of 21% volume or greater and to oxygen-bearing gases where the oxygen partial pressure is 10 barg (145 psig) or higher.

Each cylinder shall have its own dedicated temperature measuring point for alarm, and a dedicated temperature measuring point for trip purposes. These temperature measuring points shall be located in the nozzle neck between the cylinder discharge flange and the pulsation bottle, but as close as possible to the discharge valves on the cylinder. Each measuring point shall have its own thermowell.

6.6 ROD LOADINGS

6.6.1

Replace this clause by:

The combined rod load SHALL [PS] not exceed the Manufacturer's maximum allowable continuous combined rod loading for the compressor running gear at any operating load step. These combined rod loads shall be calculated on the basis of the set-point pressure of the discharge relief valve including the allowed accumulation of each stage and the minimum suction pressure corresponding to each load step.

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In the proposal the basis for the Manufacturer's figure shall be provided, including details of related critical stress areas. (See 7.6.5 for relief valve set pressures).

The combined rod loads at normal operating conditions shall also be less than or equal to 80% of the vendor's maximum allowable combined rod loads for the selected compressor frame.

6.6.2 *Add the clause:*

The gas loads at normal operating conditions shall also be less than or equal to 80% of the vendor's maximum allowable gas loads for the selected compressor frame.

6.6.4 *Add to the last sentence:*

”for all applicable loading steps.” If step-less, reverse-flow controls are used for varying load, then vendor shall verify that there is adequate rod reversal for bushing lubrication over the entire control range. The duration of reversal shall not be less than 45 degrees of crank angle, and the magnitude of the rod reversal shall be at least 20% of the actual combined load in the opposite direction.

6.6.6. *Add this clause:*

Rods in sour gas service shall be suitably de-rated to reflect the strength of the materials used, particularly after hardness control, and the stresses allowable in a sour environment . If de-rating of the rod causes the selected frame size to be increased, the frame sizing shall be reviewed and approved by the Principal.

6.7 CRITICAL SPEEDS

6.7.2 *Replace the first sentence of this clause by:*

For compressor units involving either a VSDS, a motor driver, a geared motor driver or turbine driver, the Vendor shall perform a torsional analysis of the complete compressor/(gear)/driver system.

Add to this clause:

If these separation margins cannot be met, the Vendor shall perform an additional response analysis in order to prove that the stress levels at resonance conditions are within well proven limits of the Manufacturer.

Additionally, for compressors with a VSDS, the Vendor shall perform a response analysis of the rotating system during all possible resonance conditions which may occur during run-up and within the complete operating speed range. All possible excitation frequencies and consequent torques shall be considered.

In every response analysis the resulting stresses in the relevant components shall be calculated using a maximum modal damping of 1%. (Modal damping is defined as the damping ratio between the total combined structural and material damping and the critical damping of the system under consideration).

In strength calculations the Manufacturer shall give due consideration to the combined effect of static stresses, alternating bending and torsional stresses as well as the effect of stress raisers, such as stress concentration factors and notch sensitivities. The Manufacturer shall indicate the most highly stressed locations in the system and the safety factor applied at these locations. Safety factors shall be clearly defined.

6.8 COMPRESSOR CYLINDERS

6.8.1.1 *Replace the first sentence of this clause by:*

The MAWP SHALL [PS] be at least equal to the specified relief valve setting plus allowed over pressure.

6.8.1.2 *Replace this clause by:*

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Unless otherwise specified in the data/requisition sheet, horizontal cylinders shall be provided, which shall have top suction and bottom discharge. When vertical cylinders are specifically allowed, e.g. for dry gases, these shall be designed so that complete drainage of the cylinder is possible.

6.8.1.4 *Replace this clause by:*

Step piston or tandem cylinder arrangements are not permitted.

6.8.1.5 *Replace this Paragraph with:*

All cylinders shall be supplied with replaceable liners, In addition, the cylinder shall be thick enough to provide for re-boring to a total of 3.0 mm (1/8 in.) increase over the original diameter. The increase in piston diameter shall not affect the cylinder maximum allowable working pressure, the maximum allowable continuous gas load, or the maximum allowable continuous combined rod load.

6.8.1.8 *Add to this clause:*

Adequate clearance shall be provided to permit the use of torque wrenches, including multipliers for torque values over 300 Nm (220 ft.lbf). If hydraulically tensioned studs are provided, a steel cover shall be fitted to protect the extended threaded stud end.

6.8.1.9 *Add to this clause:*

Studs threading for pressure retaining parts such as cylinder and valve port covers shall be rolled

6.8.1.12 *Add new clause:*

The cylinder bore diameter shall not exceed 800 mm (32.50 in). Larger diameter bores will be considered only with review and approval of the Principal.

6.8.1.13 *Add New Clause:*

When compressor cylinders are shipped as an assembled unit, the cylinder alignment shall be verified and recorded by wire-line methods to establish benchmarks for alignment confirmation once the unit has been installed in the field.

6.8.2 CYLINDER APPURTENANCES

6.8.2.1 *Add to this clause*:

Piston rod run-out shall be measured directly adjacent to the cylinder packing case flange. In addition to the cylinder supports inboard of the cylinder, supports shall be furnished at the outer (head) end of each cylinder. These supports shall be stiff vertically and 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 shims. Only stainless steel shims shall be provided for field installation on supports.

6.8.2.2 In the first sentence of this clause, delete the words "Unless otherwise specified,"

6.8.2.3 *Replace this clause by:* The running bore of a cylinder liner shall have the surface finish between 0.1 and 0.6 µm Ra (4 to 24 µin Ra) (arithmetic average roughness) whether lubricated or dry.

NOTE: Wear ring suppliers shall advise the required surface roughness to achieve maximum lifetime of the proposed rings.

6.8.2.4 *Delete* “If Specified”.

6.8.2.6 *Modify the clause:* Through bolt designs shall not be furnished.

6.8.2.10 *Add new clause;*

Each valve cover shall be drilled to accept the installation of spring loaded RTD to monitor valve temperatures for predictive monitoring.

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6.8.2.11 *Add new clause;*

The Compressor Cylinder shall be designed to mount (1) case mounted accelerometer to it on a non-gasketed surface. The location of each cylinder accelerometer shall be easily accessible in the field. The mounting shall be on a "FLAT" Boss cast into the main part of the cylinder. The boss shall be drilled and tapped to accept an accelerometer acceptable to the Principal.

6.8.3 Cylinder Cooling

6.8.3.3 *Delete 2nd Paragraph:*

6.8.3.4.3 *Replace the 2nd sentence with:*

Coolant inlet temperatures shall be maintained at least 6 K (12 ºF) above the inlet gas temperature (and at least 10 K (20 ºF) above the inlet gas temperature for wet and saturated gas). These limits do not apply to "bone dry" gases.

6.8.3.5.1 *Add to this clause:*

Cooling water jackets for once-through systems shall have removable covers of ample dimension for cleaning purpose.

6.8.3.5.2 *Replace this clause by:*

When specified in the data/requisition sheet, a self-contained, closed loop jacket coolant system shall be furnished. It shall meet the requirements of 6.8.3.5.3 through 6.8.3.5.5. The scope of supply shall be in accordance with, but not necessarily limited to, Figure G-1, Plan D, of Annex G.

The coolant system shall be such that the temperature limits in 6.8.3.5.4, 6.8.3.4.3, and 6.8.3.4.4 are met under all specified operating conditions, including start-up, shutdown and other transients. Coolant systems shall be designed in accordance with the limits of (6.1.7).

6.8.3.5.6 *Add new clause:* Pumps in the cooling system shall be centrifugal pumps unless other types are approved in the data/requisition sheet. Centrifugal Pumps shall be in accordance with ASME B73.

6.8.4 CYLINDER CONNECTIONS

6.8.4.1.6 *Modify the first sentence: Replace* "should" *with* "shall".

6.8.4.1.17 Delete "if specified".

6.8.4.2 Flanges

6.8.4.2.1 *Add to this Clause:*

Gasket contact surfaces and, where used, ring joints shall be in accordance with ASME B16.5 or ASME B16.47. Gaskets used between cylinders and pulsation dampeners shall be the spiral wound type with an inner ring. The flange finish on both the cylinder and pulsation bottles shall be 125 – 250 AARH. For hydrogen service the flange finish shall be 125 - 175 AARH.

6.8.4.2.5 *Add to the clause:*

The use of non standard (oversized) flanges requires the approval of the Principal.

6.9 VALVES AND UNLOADERS

6.9.1.1 *Modify Notes to Read:*

NOTES:
1. The valve lifts used in the above equation shall be shown on the data sheets.
2. Average gas velocities of each head end and crank end shall be shown on the data sheets.

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3. The valve Manufacturer shall indicate his maximum allowable gas velocity for the proposed design.

6.9.1.2 *Add to this clause:*

Non-metallic (e.g. PEEK, engineered polymers) plate, process poppet or ring type valves shall be supplied unless there is evidence of unsatisfactory experience. Engineered polymers shall not contain any re-grind or re-processed polymer. In addition, Unloaders are to operate at minimum available air pressure value stated on the datasheet. Other valve designs will be considered only with the Principals approval.

6.9.1.4 *Replace this clause by:*

Valve seat to cylinder gaskets shall be of soft iron or steel and of solid rectangular design. Metal-jacketed gaskets shall not be used. The proposed type and material of gaskets shall be subject to the approval of the Principal.

6.9.1.6 *Replace this clause by:*

All valves located at the bottom side of a cylinder shall be provided with an arrangement to retain the complete valve assembly and cage in position while the cover plate is removed or installed. A removal and installation system shall be provided.

6.9.1.8 *Add to this clause:*

Center bolt or jackscrew designs are not acceptable.

6.9.1.9 *Add to this clause:*

Valve selection shall be based on at least a three-year operating life. Where valve port dimensions prohibit the selection of valves fulfilling the three-year life requirement the valve Vendor shall indicate this and submit a proposal to overcome it. This proposal may include alternatives such as different valve design, change in swept volume per stroke, number of valves per cylinder end, or different valve diameter.

Replace "If specified", with "Unless otherwise specified" the vendor shall submit a written valve dynamics report to the purchaser.

6.9.1.10 *Add to this clause:*

Metal valve discs or plates and damper plates shall not be supplied unless approved by the Principal. If Metal valve plates are provided, then they shall be fully milled or laser cut; they shall not be punched. In wet gas, dirty gas and sour gas service where ISO 15156 or NACE MR0103 apply, valve plates and rings shall be non-metallic Use of metallic plate or ring type valves shall be approved by Principal.

NOTES:
1. ISO 15156 shall apply to oil and gas production facilities and natural gas sweetening plants. NACE MR0175 is equivalent to ISO 15156.
2. NACE MR0103 shall apply to other applications (e.g. oil refineries, LNG plants and chemical plants).

6.9.2 Unloaders

6.9.2.1 *Add to this clause:*

Capacity unloading hierarchy shall be as follows:

a. Cooled bypass / Recycle Piping. Unless otherwise stated on the data sheet, machine shall be capable of starting with operating suction pressure on each stage. Vendor shall advise the maximum pressure drop across the recycle start up valves.

b. Plug or Port unloaders. Unloaders shall be pneumatically operated unless otherwise specified on the data/requisition sheet. When unloaders are required on cylinders that do not require a full complement of suction valves, plug type unloaders shall be installed on the extra suction ports. Minimum number of valve unloader steps shall be

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