

DEP SPECIFICATION

**RECIPROCATING COMPRESSORS
(AMENDMENTS/SUPPLEMENTS TO API 618)**

DEP 31.29.40.31-Gen.

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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" and "instrument air") compressors that discharge at 8.6 barg (130 psig) or below.

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

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 2011; 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. 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 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 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 regards 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.

In API 618, the term Vendor is used and is equivalent to the term "Manufacturer/Supplier" that is used in this DEP.

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.

In API 618, the term Owner is used and is equivalent to the term "Principal" that is used in this DEP.

The lower-case 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
Hydrogen service	All process conditions with a hydrogen partial pressure greater than 700 kPa (120 psia)
Modal Damping	The damping ratio between the total combined structural and material damping and the critical damping of the system under consideration
Multibolt Design Heavy Hex Nut	A specially designed nut that incorporates a number of jack screws equally spaced around its body
Oxygen Service	All process conditions with 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
Proven Equipment	Equipment of which at least three units of similar type, size and specific service and loading have together accumulated a minimum of 24,000 h of comparable satisfactory service.
Prototype	Equipment that does not meet the definition of Proven equipment.
Sour Gas Service	A gas with H ₂ S levels above 100 ppm
Suction and discharge pressure	Suction and discharge pressures through this DEP refer to the pressure at the inlet flange of the suction pulsation dampener and the outlet pressure of the discharge dampener
Very Toxic (substances)	Refer to DEP 01.00.01.30-Gen. for additional details and the definitions of "very toxic - acute", "very toxic - chronic", and "very toxic - environment".

1.3.3 Abbreviations

Term	Definition
FEA	Finite Element Analysis
MAWP	Maximum Allowable Working Pressure
PEFS	Process Engineering Flow Schemes, that are less detailed than Piping and Instrumentation Diagrams (P&IDs)
SIL	Safety Instrumented Function
VSDS	Variable Speed Drive Systems

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 revision of the DEP of the same number dated February 2011. The following are the main, non-editorial changes.

Section/Clause	Change
All	Restructured and clarified requirements, enforced use of shall/should/may for normative statements.
6.10.2.3	Provided generic name for device in SHALL [PS]

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

1. This DEP is written as amendments and supplements to API STD 618, fifth edition, December 2007. Wherever reference is made to API 618, it shall be understood to mean API STD 618, fifth edition, December 2007 as amended/supplemented by this DEP.
2. For ease of reference, the clause numbering of API 618 has been used throughout Part III of this DEP.
3. Clauses in API 618, which are not mentioned in this DEP, shall remain valid as written.
4. 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.

PART III AMENDMENTS/SUPPLEMENTS TO API 618**2 Normative References**

2.1

Add to this clause:

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

3 Definitions Of Terms

Add the following new clauses:

3.63 Hazardous service

1. Hazardous service includes Hydrogen service and very toxic service (1.3.2).
2. Refer to DEP 31.29.00.33-Gen. for hazardous services in addition to those mentioned in this DEP.

3.64 Hydrogen service

1. All process conditions with a hydrogen partial pressure greater than 700 kPa (120 psia) are designated Hydrogen service.

5 Requirements

5.3 CONFLICTING REQUIREMENTS

Replace this clause with the following:

1. In the event of conflict between documents relating to the enquiry or purchase order, the following hierarchy of documents shall apply:
 - a. First level: purchase order and variations thereto
 - b. Second level: data/requisition sheets and drawings
 - c. Third level: this DEP

Add the following new section:

5.4 ALTERNATIVE DESIGNS

1. Alternative quotations may be submitted if they offer significant price, delivery, or technical advantage.

6 Basic Design

6.1 GENERAL

6.1.1

Add the following to this clause:

1. Compressor ratings shall not exceed the limits of the Manufacturer/Supplier's proven design experience (1.3.2).
2. Prototype equipment (1.3.2) shall not be proposed.

6.1.3

Replace this clause with the following:

1. The Contractor shall specify the equipment's normal operating point and all other applicable operating points (e.g., start-up, loading and unloading, and regeneration).
2. The Manufacturer/Supplier shall confirm the compressor's performance and mechanical capabilities at the specified operating points (including valve selections).
3. Negative tolerances on capacity shall not apply to any specified operating points.

6.1.6

Replace the third sentence in this clause with the following:

1. The Manufacturer/Supplier shall advise the estimated noise levels by completing data sheet DEP 31.10.00.94-Gen., which forms part of the requisition.

6.1.8

Replace the first sentence with the following:

1. All equipment SHALL [PS] be designed to run simultaneously at the relief valve setting (including accumulation) and trip speed without damage. (see 7.6.5).
Accumulation is the static head buildup above the gas relief pressure set by the relief valve.

6.1.10

Add to this clause:

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

6.1.12

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 or requisition sheets.

6.1.14

Change the last sentence in the clause to the following:

1. This may be accomplished by such methods as shouldering or precision cylindrical dowels.
2. Distance piece to cylinder and distance piece to crosshead guide shall be shouldered or registered fits.

6.1.15

Replace this clause with the following:

1. The combined performance of the compressor and its driver under all operating conditions shall be the responsibility of the Manufacturer/Supplier.

6.1.17

Delete "When specified" from the clause

6.1.18

Add to this clause:

1. In accordance with Annex B, the power tolerance shall be the required power at Manufacturer/Supplier's rated capacity.

Add the following new section:

6.1.27

1. 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.
2. 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.
3. The complete unit shall be capable of a restart with full opposite residual voltage.

6.2 BOLTING**6.2.1**

Add to this clause:

1. Details of fasteners requiring hardness control of sour service shall be subject to review and approval by the Principal.
2. Cap screws shall not be used.
3. Cadmium and Zinc plated studs, bolts, and nuts shall not be used.

6.2.2

Add to this clause:

1. The application of hydraulic bolt tensioning shall be possible for:
 - a. class 1500 flanges, DN 150 (NPS 6) and larger;
 - b. class 2500 flanges, DN 100 (NPS 4) and larger.

Add the following new section:

6.2.6

1. Bolts with diameters 35 mm (1-1/2 in) or larger shall be designed for hydraulic tensioning.

6.4 ALLOWABLE SPEEDS

Add to this clause:

1. Compressor speeds and corresponding average piston speeds shall be limited to the values in Table 6.4:

Table 6.4 Values of compressor speeds and piston speeds

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)

2. 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).
3. Average piston speed in compressors that handle dry gases in non-lubricated compressor cylinders shall not exceed 180 m/min (600 ft/min).
4. 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

6.5.2

Add to this clause:

1. Reciprocating compressors for process air services and oxygen compressors SHALL [PS] not be (piston/packing) lubricated.
2. Reciprocating compressors for air services and services with 21% volume or greater oxygen-bearing gases or where the oxygen partial pressure is 10 barg (145 psig) or higher SHALL [PS] not be (piston/packing) lubricated.
3. Each compressor cylinder shall have:
 - a. a dedicated temperature measuring point for alarm;
 - b. a dedicated temperature measuring point for trip purposes;
 - c. The cylinder temperature measuring points 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;
 - d. a measuring point with its own thermowell.
4. Maximum calculated adiabatic discharge temperature of any step shall not exceed 140 °C (285 °F) as applicable to all operating and load conditions but not to the relief valve setting conditions.
5. Maximum calculated adiabatic discharge temperature shall not exceed 130 °C (265 °F) for hydrogen-rich services (molecular weight of 12 or less) as applicable to all operating and load conditions but not to the relief valve setting conditions.

6.6 ROD AND GAS LOADS

6.6.1

Replace this clause with the following:

1. The combined rod load SHALL [PS] not exceed the Manufacturer/Supplier's maximum allowable continuous combined rod loading for the compressor running gear at any operating load step.
2. The 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.
3. In the proposal the basis for the Manufacturer/Supplier's rod loads calculation shall be provided, including details of related critical stress areas.
 - a. Refer to (7.6.5) for relief valve set pressures.
4. The combined rod loads at normal operating conditions shall be less than or equal to 80% of the Manufacturer/Supplier's maximum allowable combined rod loads for the selected compressor frame.

6.6.2

Add to the clause:

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

6.6.4

Add to the last sentence: "for all applicable loading steps."

Add to the clause:

1. If step-less, reverse-flow controls are used for varying load, then the Manufacturer/Supplier shall verify that there is adequate rod reversal for bushing lubrication over the entire control range.
2. The duration of rod reversal shall not be less than 45 degrees of crank angle.
3. The magnitude of the rod reversal shall be at least 20% of the actual combined load in the opposite direction.

Add the following new section:

6.6.6

1. 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.
2. If de-rating of the rod causes the selected frame size to be increased, the frame sizing shall be subject to review and approval by the Principal.

6.7 CRITICAL SPEEDS

6.7.2

Replace the first sentence of this clause with the following:

1. For compressor units involving either a VSDS, a motor driver, a geared motor driver or turbine driver, the Manufacturer/Supplier shall perform a torsional analysis of the complete compressor/(gear)/driver system.
2. The resultant stresses shall be well within Manufacturer/Supplier's design and reference envelope.

Add to this clause:

3. If the separation margins in this clause cannot be met, then the Manufacturer/Supplier shall perform an additional response analysis in order to prove that the stress levels at resonance conditions are within the proven limits of the Manufacturer/Supplier.
4. For compressors with a VSDS, the Manufacturer/Supplier shall perform a response analysis of the rotating system during all possible resonance conditions which can occur during run-up and within the complete operating speed range.
 - a. All possible excitation frequencies generated by the compressor, its driver, control components (such as stepless control) and consequent torques shall be considered.
5. In every response analysis the resulting stresses in the relevant components shall be calculated using a maximum modal damping of 1%.
6. In strength calculations the Manufacturer/Supplier shall demonstrate that 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 is within accepted limits.
7. The Manufacturer/Supplier shall indicate the most highly stressed locations in the system and define the safety factors applied at these locations.

6.8 COMPRESSOR CYLINDERS

6.8.1 General

6.8.1.1

Replace the first sentence of this clause with the following:

1. The maximum allowable working pressure (MAWP) SHALL [PS] be at least equal to the relief valve specified set pressure plus accumulation (overpressure).

Accumulation (overpressure) is the static head buildup above the gas relief pressure set by the relief valve.

6.8.1.2

Modify the clause with the following:

1. Delete "Unless otherwise specified" from the first sentence.
2. Replace the second sentence with: Horizontal cylinders shall have top suction and bottom discharge connections.
3. Vertical cylinders should be considered for dry services.
4. Vertical cylinders shall be designed so that complete drainage of the cylinder is possible.

6.8.1.4

Replace this clause with the following:

1. Designs shall not provide/include step piston or tandem cylinder arrangements.”

6.8.1.5

Replace this Paragraph with the following:

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

6.8.1.8

Add to this clause:

1. Clearance shall be provided to permit the use of torque wrenches, including multipliers for torque values over 300 Nm (220 ft-lbf).
2. A steel cover shall be fitted to protect the extended threaded stud end when hydraulically tensioned studs are provided.

6.8.1.9

Add to this clause:

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

Add the following new sections:

6.8.1.12

1. The cylinder bore diameter shall not exceed 800 mm (32.50 in).

6.8.1.13

1. 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:

1. Piston rod run-out shall be measured directly adjacent to the cylinder packing case flange.
2. Supports shall be furnished at the outer (head) end of each cylinder in addition to the cylinder supports inboard of the cylinder.
3. These supports shall be stiff vertically and horizontally in the axis parallel to the crankshaft to reduce cylinder side - sway.
4. Vertical adjustment on all cylinder supports shall be achieved solely by the use of shims.
5. 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

In the first sentence of this clause, delete the words "and cylinders without liners".

Add to this clause:

1. Wear ring Manufacturers/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

Replace the third and fourth sentence of the clause with: Through bolt designs shall not be furnished.

Add the following new sections:

6.8.2.10

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

6.8.2.11

1. The Compressor Cylinder shall be designed with provisions to mount one case mounted accelerometer to it on a non-gasketed surface.
2. The location of each cylinder accelerometer shall be accessible in the field without needing scaffolding.
3. The mounting of the cylinder accelerometer shall be on a "FLAT" Boss cast into the main part of the cylinder.
4. The boss of the cylinder shall be drilled and tapped to accept an accelerometer acceptable to the Principal.

6.8.3 Cylinder Cooling

6.8.3.3 Atmospheric Thermosyphon Coolant Systems

Delete 2nd Paragraph.

6.8.3.4 Forced-liquid Coolant Systems

6.8.3.4.3

Replace the 2nd sentence with:

1. For wet and saturated gas, coolant inlet temperatures shall be maintained at least 10 K (20 °F) above the inlet gas temperature.

These inlet temperature limits do not apply to "bone dry" gases.

6.8.3.5 Cooling Jacket Systems

6.8.3.5.1

Add to this clause:

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

Add the following new section:

6.8.3.5.6

1. Pumps in the cooling system shall be centrifugal pumps in accordance with ASME B73.

6.8.4 Cylinder Connections

6.8.4.1 General

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:

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

6.8.4.2.5

Add to the clause:

1. The use of non-standard (oversized) flanges requires shall be subject to the approval of the Principal.

6.9 VALVES AND UNLOADERS

6.9.1 Valves

6.9.1.1

Add to this clause:

1. Average gas velocities of each head end and crank end shall be shown on the data sheets.
2. The valve Manufacturer/Supplier shall indicate the maximum allowable gas velocity for the proposed design.

6.9.1.2

Add to this clause:

1. Non-metallic (e.g., PEEK, engineered polymers) plate, process poppet or ring type valves shall be supplied.
2. Engineered polymers shall not contain any re-grind or re-processed polymer.
3. Unloaders shall be able to operate at the minimum available air pressure value stated on the datasheet.
4. Other valve designs shall be subject to the approval of the Principal.