

DEP SPECIFICATION

**COMPRESSORS – SELECTION, TESTING, AND
INSTALLATION**

DEP 31.29.40.10-Gen.

February 2014

ECCN EAR99

DESIGN AND ENGINEERING PRACTICE



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TABLE OF CONTENTS

1.	INTRODUCTION	5
1.1	SCOPE.....	5
1.2	DISTRIBUTION, INTENDED USE, AND REGULATORY CONSIDERATIONS	5
1.3	DEFINITIONS	5
1.4	CROSS-REFERENCES	6
1.5	SUMMARY OF MAIN CHANGES.....	7
1.6	COMMENTS ON THIS DEP	7
1.7	DUAL UNITS.....	7
2.	GENERAL REQUIREMENTS	8
2.1	SELECTION AND EVALUATION	8
2.2	MAKES AND TYPES OF COMPRESSORS	8
2.3	PROTOTYPE EQUIPMENT	9
2.4	SPECIAL OPERATING REQUIREMENTS	10
2.5	NOISE CONTROL	10
2.6	COMPLETE UNIT RESPONSIBILITY	10
3.	COMPRESSOR TYPE SELECTION.....	11
3.1	GENERAL	11
3.2	AXIAL COMPRESSORS	11
3.3	CENTRIFUGAL COMPRESSORS	11
3.4	RECIPROCATING COMPRESSORS	12
3.5	ROTARY TYPE POSITIVE DISPLACEMENT COMPRESSORS	13
3.6	PACKAGED HIGH-SPEED INTEGRALLY GEARED CENTRIFUGAL COMPRESSORS.....	14
3.7	FANS AND BLOWERS	15
4.	SHAFT SEALS	15
4.1	GENERAL	15
4.2	DRY GAS SEALS	15
4.3	LIQUID SEALS	20
4.4	OTHER SEAL TYPES	20
5.	DESIGN AND TEST REQUIREMENTS	21
5.1	GENERAL	21
5.2	CENTRIFUGAL AND AXIAL COMPRESSORS	22
5.3	RECIPROCATING COMPRESSORS	23
5.4	ROTARY-TYPE POSITIVE DISPLACEMENT COMPRESSORS	24
5.5	PACKAGED HIGH SPEED INTEGRALLY GEARED CENTRIFUGAL COMPRESSORS.....	25
5.6	CENTRIFUGAL FANS	26
6.	INSTALLATION.....	27
6.1	GENERAL	27
6.2	SUCTION STRAINERS	29
6.3	AIR COMPRESSOR INTAKE	29
6.4	PIPING AND LINE-UP	30
6.5	CONDITION MONITORING	35
6.6	SAFEGUARDING AND INSTRUMENTED PROTECTION FUNCTIONS	35
7.	OPERATIONAL AND MAINTENANCE ASPECTS	36
7.1	LIQUID KNOCKOUT FACILITIES	36
7.2	FOULING CONSIDERATIONS.....	36
7.3	SPARE PARTS	37
8.	REFERENCES	38

APPENDICES

APPENDIX 1 DEFINITIONS AND EXAMPLES OF VITAL, ESSENTIAL, AND NON-
 ESSENTIAL SERVICES 40

APPENDIX 2 PRESSURE / VOLUME MAP FOR VARIOUS COMPRESSOR TYPES 41

APPENDIX 3 SELECTION OF DRY GAS SEALS.....42

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the type selection, specification, testing and installation of compressors (including fans and blowers).

This DEP is a revision of the DEP of the same number dated February 2013, 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 authorized access to DEPs does not for that reason constitute an authorization 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, gasification, distribution and supply/marketing. 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.

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.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
Prototype equipment/component	Equipment or component parts that fall outside the Manufacturer's experience of proven operation. Equipment or component parts shall no longer be considered prototype once they have accumulated an uninterrupted operating period of more than 24,000 h in a comparable service. This operating period should have been acquired with at least three units of similar type and size having the same specific loading. Each of the three units shall have accumulated at least an operating time of 8,000 h.

Term	Definition
Vital, essential and non-essential service	For definitions and explanation of these services, see (Appendix 1).
Continuous operation	Service in which it is not expected that the compressor will have to be started/stopped during normal plant operation.
Intermittent operation	Service in which it is expected that the compressor will be started/stopped at unspecified intervals, e.g., - Automatic starts and stops at intervals by process operated controls; - Manual starts and stops at intervals by manual control for batch processes.
Hydrogen service	Process conditions with a hydrogen partial pressure greater than 0.7 MPa (7 bar (abs)).
Very toxic substances	Substances that produce serious harm to health as a result of a single or short-term exposure. Further assistance concerning this definition can be found in DEP 01.00.01.30-Gen. Amongst others, as defined in the data/requisition sheets, the following shall be considered very toxic: Levels of H ₂ S exceeding 1,000 ppm mole (vol) in gaseous process streams. Other substances specified by the Principal to be very toxic.

1.3.3 Abbreviations

Term	Definition
CASC	Compressor Anti-Surge Control
DGS	Dry Gas Seal
FAT	Factory Acceptance Test
FCCU	Fluid Catalytic Cracking Unit
PACO	Process Automation, Control, and Optimization
RE	Rotating Equipment
SAT	Site Acceptance Test
SIL	Safety Integrity Level

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 (8).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a minor revision of the DEP of the same number dated February 2013. The following are the main, non-editorial changes.

Section/Clause	Change
4.2.1	Updated dry gas seal monitoring guidance for detection of primary and secondary seal failures

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.

2. GENERAL REQUIREMENTS

2.1 SELECTION AND EVALUATION

The selection of compressors or fans and the technical evaluation of bids from Manufacturers shall be based on the requirements of this DEP together with the requirements of the DEPs relevant to the type of compressor or fan concerned. These are:

Axial, centrifugal and expander compressors (amendments/supplements to API Std 617)	DEP 31.29.40.30-Gen.
Reciprocating compressors (amendments/supplements to API Std 618)	DEP 31.29.40.31-Gen.
Rotary-type positive displacement compressors (amendments/supplements to API Std 619)	DEP 31.29.40.32-Gen.
Packaged, integrally geared, centrifugal plant and instrument air compressors (amendments/supplements to API Std 672)	DEP 31.29.40.33-Gen.
Liquid ring vacuum pumps and compressors (amendments/supplements to API Std 681)	DEP 31.29.42.30-Gen.
Centrifugal fans (amendments/supplements to API Std 560 Appendix E)	DEP 31.29.47.30-Gen.
Packaged reciprocating gas compressors (amendments/supplements to ISO 13631)	DEP 31.29.40.34-Gen.

2.2 MAKES AND TYPES OF COMPRESSORS

Every effort shall be made, consistent with sound engineering practice, to rationalise the variety of makes and types of compressors including drivers and auxiliary equipment selected for any particular project. This rationalisation assists to minimise the stocks of spares held by Operating Units.

This rationalisation shall be applied stringently as long as it does not interfere with the selection of an optimum compressor for the specified operating conditions and does not increase the total cost of ownership (TCO).

The overarching philosophy for Shell is that when reliability is a fundamental driver for the business unit, if a centrifugal compressor will work, it is the favoured option.

As part of selecting the compressor that is fit for purpose, DEP 00.00.07.10-Gen. shall be reviewed. Design Class is an important tool for arriving at the appropriate compressor and auxiliary systems. To illustrate the difference in compressor selection when using Design Class, some examples are given below:

Downstream facilities typically require Design Class 3 compressors. With this category in mind, the following thought process would be followed in order of preference:

- Centrifugal compressor
- Slow-speed reciprocating compressor
- "Other" compressor type

Upstream onshore facilities, not including LNG plants, typically consider Design Class 1 compressors. This has led to the following considerations:

- Flooded screw with the following provisions (up to 25 barg, up to 1500 HP without concern, over 1500 HP after reviewing other options)
- Packaged reciprocating compressor
- If the flows are too high for a packaged reciprocating compressor, review a centrifugal compressor
- Generally a slow-speed reciprocating compressor is not preferred.

It is anticipated that there will be continued development in regards to the application of high speed reciprocating compressors, e.g., on reciprocating compressors with air cooled cylinders, in non-critical services as well as integrally geared centrifugal compressors in more and more services because they are more efficient, have wider range of applications, and lower first cost. High-speed reciprocating compressors cannot be applied without the proper review, and in some cases, the application of a Development Release (as applicable in Shell Projects and Technology). This should be reviewed with the Principal.

2.3 PROTOTYPE EQUIPMENT

2.3.1 Selected equipment shall be, in all respects, within the range of the Manufacturer's proven experience, and shall not involve the use or application of any prototype in design or components.

Compressor ratings, components, and auxiliaries shall not exceed the limits of the Manufacturer's design and shall be within its actual experience. Only equipment that has proved its reliability shall be included in the selected compressor unit. In this respect, proven equipment is defined as 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. In this respect, the Manufacturer shall provide the necessary evidence in his proposal.

The Manufacturer shall list in its proposal all design features or modifications that are not proven in similar machines produced for the last five years or which have not acquired at least 16,000 h in operation. These design features or modifications are specifically subject to the Principal's approval and proven alternatives may be requested.

2.3.2 Exception to (2.3.1) may be considered only if all of the following are applicable:

- a. A development study has been done and the subject equipment type, part and/or make have been pre-approved by the Principal. For this equipment an extensive review program during (detailed) design and construction, see (3), including the Principal's involvement, shall be agreed prior to order placement.
- b. The Contractor can demonstrate that there is no proven alternative available. Prior to acceptance of the new design, the Contractor shall present a study report for the Principal's approval, that includes the following:
 - Summary
 - Description of the concept
 - Risk/benefit assessment
 - Fall back if the new development will not function as intended
 - Alternatives considered
 - Feedback requirements (e.g., test run data)
 - Controls during (detailed) design and construction as defined in (3)
- c. Controls during (detailed) design and construction
 - Design considerations, and basis of design by the Manufacturer
 - Verification of detailed design by the Principal, or his designated representative
 - Review of engineering documents, by the Principal
 - Review of construction drawings, by the Principal
 - Additional inspection and testing to what is required in the applicable DEPs
 - Pre-start-up reviews
 - Training of customer staff

- d. Constraints within which the developed equipment should be operated
 - Start-up assistance

2.4 SPECIAL OPERATING REQUIREMENTS

The data/requisition sheet shall indicate all particular operating requirements that the compressor(s) may encounter, e.g., parallel operation, varying molecular weight of gases, varying suction or discharge conditions and toxicity level of the gas mixture.

Special attention shall be given to off-design conditions that may occur during start-up and shutdown procedures associated with the particular process or compression system. The off design condition may include running the compressor with an alternative gas (such as nitrogen) during commissioning and or a maintenance intervention.

2.5 NOISE CONTROL

Noise requirements specified in the data/ requisition sheets shall be met.

- a. In most cases, the sound pressure level (SPL) levels around the equipment shall be less than or equal to 85 dB(A) as average at 1 m (40 in) around the skid.
- b. If a component of the equipment train has a projected SPL above 85 dB(A) average, design modifications and/or acoustical treatment shall be proposed to reduce the level.
- c. The absolute work area noise limit shall be 115 dB(A), unless otherwise approved by the Principal.
- d. Additional information is contained in DEP 31.10.00.31-Gen.

2.6 COMPLETE UNIT RESPONSIBILITY

Compressors, gears, drivers and auxiliaries that make up a complete unit shall be ordered from one Manufacturer, usually the compressor Manufacturer. This Manufacturer shall be responsible for the design co-ordination and the satisfactory mechanical, aerodynamic and thermodynamic performance integrity of the complete unit.

Further, this Manufacturer shall warrant and guarantee all equipment and component parts as stipulated in the relevant specifications and purchase order.

3. COMPRESSOR TYPE SELECTION

3.1 GENERAL

The choice of the type of compressor (axial, centrifugal, integrally geared, reciprocating, or rotary) depends primarily on the required flow to be compressed, the density of the gas in conjunction with the total head (for a given gas, this is the compression ratio) and the duty which has to be performed.

(Appendix 2) of this DEP contains a pressure-volume map displaying the capabilities of the various compressor types covered by this document.

3.1.1 Performance envelope of axial and centrifugal compressors

All specified operating points shall be selected within the proven operating envelope as specified in DEP 31.29.40.30-Gen. Stonewall operation is not allowed for any specified operating condition. Stonewall operation is allowed only as a resultant condition, where flow and head are not specified. Stonewall operation may cause impeller and seal damage.

For multi-stage centrifugal compressors handling hydrocarbon gases, it is necessary to carry out equilibrium calculations at interstage pressure levels in order to determine the quantity and composition of the gas after intercooling and liquid knockout. The inlet and discharge pressures of each compression stage shall be adjusted for the purpose of selecting compressor components such as number and type of impellers.

3.2 AXIAL COMPRESSORS

Axial compressors can handle large volume flows and are more efficient than centrifugal compressors. However, centrifugal compressors have wider operating ranges and are less vulnerable to surge and less susceptible to fouling.

Axial compressors should be considered only for high flow applications in duties such as compressing air with an adequate suction filtration system to prevent airborne contaminate fouling/deposits or clean, non-corrosive gases. A complete design review shall be carried out if a qualified Manufacturer cannot demonstrate that an identical axial compressor has operated fully satisfactorily for at least 24,000 h on a comparable duty (i.e., gas composition and operating data).

3.3 CENTRIFUGAL COMPRESSORS

3.3.1 Flow considerations

Centrifugal compressors should be the primary selection provided that a centrifugal compressor can handle the required flow with acceptable efficiency.

For rated discharge flow conditions in excess of 300 m³/h (175 cfm), centrifugal compressors shall be the first choice. Clear justification is required if other compressor type is selected which must be agreed by the Principal.

For discharge flows less than 300 m³/h (175 cfm) and/or compressors, which have one or more closed impellers with a discharge width below 4 mm (5/32 in), centrifugal compressors shall only be applied with the approval of the Principal.

3.3.2 Temperature considerations

The maximum compressor discharge temperature shall be kept below 200 °C (400 °F) under all operating conditions, including full recycle and starting conditions, unless otherwise specified.

The maximum compressor operating temperature for specific hydrocarbon services is often lower than 200 °C (400 °F). Specific applications such as olefins cracked gas trains or wet gas compressors require lower temperature limits to avoid polymerisation or coking.

In general, the normal operating discharge temperature should be maintained below 88 °C (190 °F) for olefins cracked gas compressors and below 100 °C (212 °F) for FCCU wet gas compressors.

For compressor designs where fluoroelastomers (FKM) are utilized for splitline or shaft sealing, the maximum allowable discharge temperature should be limited to 180 °C (350 °F).

For cryogenic application in particular, the temperature differential across the compressor shall be limited to 200 °C (400 °F).

3.3.3 Miscellaneous considerations

Double flow casings or double suction impellers shall not be used unless approved by the Principal.

The use of more than two compressor casings in a single drive train requires Principal approval.

Single section compressors with in-line impeller arrangements shall have no more than nine impellers per casing. Two section compressors shall have no more than eight impellers per casing.

Compressors with one side stream shall have a maximum of seven impellers per casing, for each additional side stream one additional impeller less in order to have sufficient space for adequate mixing of main and side streams.

In the selection of centrifugal compressors, and in the compressor design verification process, the following requirements in DEP 31.29.40.30-Gen. shall be observed:

- a. Impeller flow coefficients shall be as specified in Section 2, clause 2.1.5.
- b. Impeller head coefficients shall be as specified in Section 2, clause 2.1.6.
- c. Shaft L/D ratios shall be as specified in Section 2, clause 2.1.7.
- d. The average impeller inlet MACH number shall be as specified in Section 2, clause 2.1.8.
- e. Machine MACH numbers or impeller inlet MACH numbers shall be as specified in Section 2, clause 2.1.9.
- f. Vaned diffusers or low solidity vaned diffusers shall be as specified in Section 2, clause 2.4.12.
- g. Honeycombed seals, swirl brakes, and/or shunt injections shall be as specified in Section 2, clause 2.6.2.
- h. Rotor dampening shaft bearings shall be as specified in Section 2, clause 2.7.1.3.2.
- i. The application of stage-by-stage intercooled air compressors is subject to the Principal's approval and may only be considered for atmospheric air service. These compressors need clean cooling water and shall not be considered capable of an uninterrupted operation of six years. Instead their availability shall take account of the need to open the compressor and clean the cooler every three to four years.

3.4 RECIPROCATING COMPRESSORS

3.4.1 General

If the required flow is too small for a centrifugal compressor, or if the head requires an unacceptable large number of stages, then a reciprocating compressor, horizontal-balanced opposed, shall be considered.

Vertical ring-type compressors may be considered for non-lubricated, non-fouling services and well-defined gases, if they have proven to be a reliable alternative in the specified process application. These compressor types shall be selected well within the Manufacturer's standard range.

Non-lubricated type reciprocating compressors shall be selected for air and oxygen service (and for hydrocarbon service if a regeneration mode with air is required).

For reciprocating compressors in 'vital' or 'essential' services, where operational interruption for maintenance cannot be accepted, a spare unit shall be considered. Sparing philosophy requires approval of the Principal.

For multi-stage compressors handling hydrocarbon gases, it is necessary to carry out equilibrium calculations at interstage pressure levels in order to determine the quantity and composition of the gas after intercooling and liquid knockout. The inlet and discharge pressures of each compression stage shall be adjusted for the purpose of selecting compressor components, such as the number and diameter of reciprocating compressor cylinders.

It is necessary to obtain the interstage pressures and temperatures at part-load conditions (75 % and 50 %) from the compressor Manufacturer so that the interstage equipment and piping can be suitably designed and the RV settings can be determined.

In the selection of a reciprocating compressor for process services the maximum allowable discharge temperatures per stage shall be as follows:

The maximum predicted discharge temperature shall not exceed 140 °C (285 °F).

For non-lubricated service the maximum predicted discharge temperature shall not exceed 130 °C (265 °F).

These temperature limits do not apply to relief valve setting conditions or to labyrinth compressors. These temperature limits apply to all operating and load conditions.

3.4.2 Vertical labyrinth piston-type compressors

For very toxic and/or fouling gases, a vertical labyrinth piston-type compressor, with pressurised gas tight crankcase, may be considered only with the Principal's approval.

For cryogenic industry applications, such as clean dry air, oxygen, nitrogen, argon, LNG boil off gas recovery, a vertical labyrinth piston-type compressor shall be the first choice, if a reciprocating compressor type is required for the service.

For other non-lubricated services, a vertical labyrinth piston-type compressor is acceptable.

3.4.3 High speed reciprocating compressors

In certain selected applications, such as Upstream oil and gas applications, higher rotational operating speeds than allowed by DEP 31.29.40.31-Gen. can be advantageous and may then be selected with the approval of the Principal.

High speed reciprocating compressors shall be limited to a maximum driver power of 3000 kW (4000 hp), a maximum piston speed of 6.1 m/s (1200 ft/min), and a maximum speed of 1200 r/min.

3.4.4 Metal diaphragm type compressors

For very low flows a metal diaphragm type compressor should be considered. Gases are isolated from the reciprocating and hydraulic parts of the compressor by three flexible, thin, metal disks called diaphragms. The motion of the reciprocating piston is transmitted to the diaphragms by the hydraulic fluid.

Metal diaphragm compressors are extensively used for highly flammable, toxic, corrosive and pyrophoric applications such as hydrogen, fluorine, nitrogen tri fluoride (NF₃), silane (SiH₄) as well as for inert gases such as nitrogen, helium, argon. These compressors find application for very low to medium flows, i.e., 50 to approximately 300 mm³/hr (1766 to approximately 10594 ft³/hr) at medium to high pressures, say up to 200 barg to approximately 250 barg (2901 to approximately 3626 psig).

3.5 ROTARY TYPE POSITIVE DISPLACEMENT COMPRESSORS

3.5.1 General

Rotary compressors shall be considered only if there is proven experience of acceptable performance in the duty concerned and only if there are advantages over a reciprocating