MANUAL

COMPRESSOR SELECTION, TESTING AND INSTALLATION

DEP 31.29.40.10-Gen.

July 1998

DESIGN AND ENGINEERING PRACTICE

PREFACE

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The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users 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 companies to adapt the information set forth in DEPs to their own environment and requirements.

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

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 previous DEP of the same number dated October 1984.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors nominated by them (i.e. the distribution code is "C", as described in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/marketing installations.

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 as regards 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 with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

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

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

The **Principal** is the party which 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 word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Prototype Equipment/ Component

All Prototypes are considered to be 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 hours in a comparable service. This operating period should have been acquired with at least 3 units of similar type and size having the same specific loading. Each of the 3 units shall have accumulated at least an operating time of 8 000 hours.

Vital, Essential and Non-essential service

For definitions and explanation of these services see Appendix 1.

Continuous operation

A service in which it is not expected that the compressor will have to be started/ stopped during normal plant operation.

Intermittent operation

A 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

All process conditions with a hydrogen partial pressure greater than 0.7 MPa (7 bar (abs)).

Very toxic substances

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

- Levels of H_2S exceeding 1 000 ppm mole (vol) in process streams
- Other substances specified by the Principal to be very toxic

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 (8).

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 API standards relevant to the type of compressor or fan concerned, including the amendments/supplements thereto. These are:

DEP 31.29.40.30-Gen	Centrifugal and Axial compressors
DEP 31.29.40.31-Gen	Reciprocating compressors
DEP 31.29.40.32-Gen.	Rotary-type positive displacement compressors
DEP 31.29.40.33-Gen	Packaged, integrally geared, centrifugal plant and instrument air compressors
DEP 31.29.42.30-Gen	Liquid Ring Vacuum Pumps and Compressors
DEP 31.29.47.30-Gen.	Centrifugal fans

2.2 RANGE AND VARIETY OF COMPRESSORS

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

This rationalisation and minimising 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 (TCOO).

2.3 PROTOTYPE EQUIPMENT

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.

The Vendor shall list in his proposal all design features or modifications which are not proven in similar machines produced for the last 5 years or which have not acquired at least 16 000 hours in operation. These design features or modifications are specifically subject to the Principal's approval and proven alternatives may be requested.

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 which may occur during start-up and shutdown procedures associated with the particular process or compression system.

2.5 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, aero- and thermo-dynamic performance 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. TYPE SELECTION

3.1 GENERAL

The choice of the type of compressor (axial, centrifugal, 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.

Note: For selection guidance of the various compressor types see Appendix 2.

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 for high flow applications in duties such as compressing air 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 two years on a comparable duty (i.e. gas composition and operating data).

3.3 CENTRIFUGAL COMPRESSORS

Centrifugal compressors have the potential to operate continuously for at least five years, when properly designed, assembled and maintained. Provided a centrifugal compressor can handle the required flow with acceptable efficiency, then this type of compressor should be the primary selection. For rated discharge flow conditions in excess of 300 m^3/hr, centrifugal compressors shall be the first choice.

As a guideline the maximum discharge temperature shall be kept below 200 °C, unless otherwise specified. For cryogenic application in particular, the temperature differential across the compressor shall be limited to 200 °C.

The maximum number of impellers per casing shall not exceed 9 for single straight through machines. The number of impellers for back-to-back machines or those with inter-cooling shall be limited to 8.

3.4 RECIPROCATING COMPRESSORS

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

Vertical labyrinth piston-type and ring-type compressors should be considered primarily for non-lubricated, non-toxic services and well defined gases since they have proven to be a reliable alternative in many process applications. 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 where 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.

3.4.1 High Speed Reciprocating Compressors

In some applications, particularly offshore operations, higher operating speeds than allowed by DEP 31.29.40.31-Gen. can be advantageous and may then be selected with the explicit approval of the Principal.

High speed reciprocating compressors shall be limited to a maximum driver power of 1 500 kW and a maximum speed of 1 000 r/min.

3.4.2 Diaphragm Type Compressors

For very low flows at high pressures a diaphragm type compressor should be considered.

3.5 ROTARY TYPE POSITIVE DISPLACEMENT COMPRESSORS

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 compressor. Examples are liquid ring compressors for vacuum duty, oil-flooded rotary screw-type compressor for refrigeration service or tool air. For these duties oil flooded rotary screw compressors are acceptable up to 25 bar (abs) discharge pressure.

Oil-injected screw compressors offer advantages in vapour recovery systems due to their ability to handle gases of varying molecular weights, and their favourable single-stage turn-down ratio and compression ratio.

Sliding vane compressors may be considered only if there is proven experience of the type and duty concerned.

The selection of dry running screw compressors or rotary lobe compressors for process duties shall be subject to the approval of the Principal.

Rotary-lobe blowers may be selected for process services up to a discharge pressure of 1.35 bar (abs), only if the required flow cannot be met by a centrifugal fan. Rotary-lobe blowers are normally Manufacturer's standard and are not covered by this DEP.

3.6 PACKAGED HIGH-SPEED INTEGRALLY GEARED CENTRIFUGAL COMPRESSORS

3.6.1 Integrally Geared Multi-Stage Compressors

Packaged high-speed integrally geared centrifugal compressors may be considered for services other than hydrogen services and very toxic gas services. Acceptable services include plant air, instrument air, inert gas and clean non-corrosive process gas duties (e.g. regeneration compressor in an LNG plant, butaniser overheads in a refinery).

Selection of these types of compressors in process duties requires approval of the Principal.

3.6.2 Integrally Geared Single-Stage Compressors

Single-stage integrally geared high-speed compressors may be considered for clean process applications. Having the design advantages of a centrifugal compressor, they shall have preference over reciprocating types.

Selection of this type of compressor requires approval of the Principal.

3.7 FANS AND BLOWERS

Centrifugal fans shall be considered if the required discharge pressure is less than 1.35 bar (abs) at a suction pressure of atmospheric or slightly sub-atmospheric.

NOTE: Axial fans and fans for HVAC systems are not covered by this DEP. Axial fans of air-cooled heat exchangers are covered by DEP 31.21.70.31-Gen.

4. DESIGN AND TEST REQUIREMENTS

4.1 GENERAL

4.1.1 Shaft Sealing

The type of shaft seal shall be specified on the data/requisition sheets. In selecting the shaft seal type the following **descending order of preference** shall be considered:

1. Dry Gas Seals

Dry gas seals shall be in accordance with DEP 31.29.00.34-Gen.

Dry gas seals may be applied up to a shaft diameter of 250 mm.

For all services, except for air or nitrogen, a dual tandem self-acting dry gas seal arrangement with an intermediate labyrinth and an inert clean buffer gas between the labyrinth and the secondary seal is the first choice, provided the following conditions are met:

a) The prevailing pressure and temperature at the primary seal during operation do not exceed the proven limits of the selected seal size and type. The selection of a single primary seal for a dynamic sealing pressure above 100 bar (ga) shall be subject to the approval of the Principal.

b) The continuous process gas leakage into the flare system is an acceptable emission.

c) The continuous buffer gas leakage into the atmosphere is an acceptable emission.

d) The pressure at the primary seal is sufficient to ensure a proper positive differential pressure under all circumstances, including the maximum transient back pressure of the flare system.

If a) above cannot be met regarding pressure, a triple tandem seal configuration shall be considered, cascading the primary seal pressure in two steps to the flare pressure. Between the second and the third gas seal an intermediate labyrinth and inert buffer gas similar to the dual tandem seal configuration should be applied.

If b) and/or d) cannot be met, the provision of an insert buffer gas between double face-to-face seals at a pressure higher than the highest pressure at the inner seal, under either dynamic static conditions, shall be considered as an alternative.

Note: This configuration may require an secure source of inert gas supply, as run-down without adequate buffer gas pressure may result in seal damage.

Alternative designs, such as a combination of a single dry gas seal and a back-up seal in lieu of above dual tandem seals and a tandem seal arrangement without intermediate labyrinth, require explicit approval of the Principal.

The buffer gas used shall be an inert gas, such as nitrogen. Air shall never be used as buffer gas in a tandem seal arrangement. If inert gas is not available for use as buffer gas, a dual tandem seal arrangement may be employed without such buffer gas supply, but this requires the explicit approval of the Principal.

Between the dry gas seal arrangement and the shaft bearing compartment a suitable labyrinth or close clearance type of seal shall be installed and provided with a separation gas. The separation gas shall be preferably be inert. If inert gas is not available, dry air shall be used.

If buffer gas is not employed and air is used as separation gas, the formation of an explosive gas/air mix as a result of separation air mixing with secondary seal leakage shall be prevented as far as possible by using excess quantities of air to keep the gas/air mixture well outside the explosion limits.

Secondary seal leakage of dual tandem seal arrangements shall not be routed to the flare system but vented to a safe location.

2. Mechanical Contact Seals

Mechanical contact seals should be considered for gas compressors in clean service as

they offer low seal liquid consumption and an adequate static sealing capacity without seal liquid. Moreover, sudden dynamic pressure fluctuations that may occur under off-design conditions have less detrimental effects on this type of seal.

3. Liquid Film Seals

Liquid film seals are to be considered if mechanical and/or thermal conditions in the compressor are beyond the proven capabilities of dry gas seals (in any configuration) or mechanical contact seals. Liquid film type seals may also be applied in services where clean seal gas is not available for dry gas seals and mechanical contact seals cannot be provided with clean buffer gas.

4. Other seal types

Labyrinth type seals may be selected for compressors handling non-toxic and non-flammable gases such as air or nitrogen and are mandatory for oxygen compressors. Restrictive ring type seals should not be selected and their use is strictly subject to the explicit approval of the Principal.

For mechanical contact and liquid film type seals the usual sealing liquid is oil. In considering the oil type the contractor shall carefully evaluate the acceptable type of oil to be used in order to minimise the risk of undesirable reactions between the oil, the process gas or buffer gas and the sealing materials employed.

4.1.2 Casing connections

The orientation of main compressor casing connections and additional requirements for vents, drains, etc.) shall be specified.

4.1.3 Material Selection

Materials for the main compressor components shall be selected in accordance with the DEPs listed below and shall be specified on the data/requisition sheets.

DEP 30.10.02.11-Gen	Metallic materials - selected standards
DEP 30.10.02.31-Gen	Metallic materials - prevention of brittle fracture
DEP 31.29.40.30-Gen.	Centrifugal Compressors
DEP 31.29.40.31-Gen	Reciprocating Compressors
DEP 31.29.40.32-Gen.	Rotary-positive displacement compressors
DEP 31.29.40.33-Gen	Packaged integrally geared centrifugal plant and instrument air compressors
DEP 31.29.42.30-Gen	Liquid ring vacuum pumps and compressors
DEP 31.29.47.30-Gen.	Centrifugal fans

4.1.4 Compressor Transmissions and Drivers

The required type of driver shall be stated on the data sheet together with its relevant specifications. Driver and transmission design requirements are specified in the DEPs listed below:

Gear transmissions shall be in accordance with DEP 31.29.00.32-Gen.

Steam turbines shall be in accordance with DEP 31.29.60.10-Gen.

Gas turbines shall be in accordance with DEP 31.29.70.11-Gen.

Electric motor drivers shall be in accordance with DEP 33.66.05.31-Gen.

VSDS systems shall be in accordance with DEP 33.66.05.33-Gen

Electric motors shall be in accordance with DEP 33.65.05.31-Gen.

Spark ignited gas fuelled engines shall be in accordance with DEP 31.29.90.30-Gen.

Additionally for each compressor type specific requirements governing the type of driver to be selected are given in (4..3.4 & 4.6.2).

4.2 CENTRIFUGAL AND AXIAL COMPRESSORS

Centrifugal and axial compressors shall be in accordance with DEP 31.29.40.30-Gen.

Compressors handling oxygen shall also comply with the requirements of the European Industrial Gases Committee's Code of Practice "Turbo Compressors for Oxygen service".

Some additional requirements and recommendations for specifying a centrifugal or axial compressor and completing data/requisition sheet DEP 31.29.41.93-Gen. are given below.

4.2.1 Capacity Control

The most economical method for the capacity control of centrifugal and axial compressors (to achieve maximum turndown ratio) is speed variation. The type of variable-speed driver should be selected with account being taken of utility balance and compressor turndown ratio, in terms of both capacity and speed. Variable speed drivers may be selected from:

- steam turbines
- variable speed electric motors (VSDS), dual speed electric motors
- fluid drive couplings, torque converters
- gas turbines (preferably a two-shaft design).

Note: Single-shaft gas turbine drivers, which inherently have a small speed range may be considered in conjunction with suitable process control.

- gas engines and diesel engines

For constant-speed compressor units, capacity control can be achieved by suction throttling or recycle systems. Variable inlet guide vanes shall only be considered for air and clean non-corrosive gases.

4.2.2 Shaft sealing

The type of shaft seal shall be selected in accordance with (4.1.1).

4.2.3 Mounting plates

A common base-plate shall be specified for the compressor and driver if technically feasible.

Speed-increasing gears shall be mounted on the compressor base-plate if separate base-plates are to be employed.

4.2.5 Lubricating oil and seal oil systems

Lubricating oil and seal oil systems shall comply with DEP 31.29.60.32-Gen.

A combined lube and control oil system for driver and driven equipment shall be specified whenever possible (except for aero-derivative type gas turbines).

Guidelines for the selection of lube oil system drivers are given in Appendix 3.

4.2.6 Controls and instrumentation

Instrumentation shall comply with DEP 32.31.09.31-Gen.

4.2.7 Tests

Testing requirements shall be specified in the data requisition sheet. The following guidelines shall apply:

Combined unit test

A combined unit test shall be specified for all combined compressor/driver units. Omission of this test shall require explicit approval of the Principal.

Where several identical compressor/driver units are being procured, combined-unit testing

of the first unit only is acceptable.

Performance test

A performance test in accordance with ASME Power Test Code PTC 10 shall be specified. The class of test shall be indicated on the data sheets.

A full load test (full pressure, full speed) using a gas with comparable density shall be specified if:

- the compressor suction pressure is > 150 bar (abs); or
- the calculated log decrement of the rotor/bearing stability study is < 0.2; or
- the compressor has more than one side-load connection
- the combined compressor/driver unit has no proven precedent in Group services.

4.3 RECIPROCATING COMPRESSORS

Reciprocating compressors shall comply with DEP 31.29.40.31-Gen.

Some additional requirements and recommendations for specifying a reciprocating compressor and completing data/requisition sheet DEP 31.29.43.93-Gen. are given below.

4.3.1 Type of compressors

In the data/requisition sheets it shall be specified whether a vertical-type or a horizontal-type of compressor is required.

For non-lubricated duties, which are normally preferred, an extra long distance piece is required to prevent carry-over of lubricating oil into the cylinder.

All anticipated process conditions and transients (e.g. re-start after shutdown) shall be specified in detail so that the optimum compressor can be selected and the drive power requirements can be correctly stipulated.

4.3.3 Pulsation suppression equipment

As pressure pulsation can have a damaging effect even at moderate pressure levels, a dynamic simulation and mechanical response analysis in accordance with DEP 31.29.40.31 Gen. shall be specified.

The contractor is responsible for ensuring that pulsation damping equipment conforms with the requirements of national and/or local inspection regulations, and he shall specify the applicable design codes on the data/requisition sheet.

4.3.4 Drivers

Electric motors are the drivers of first choice.

For high speed compressors (see 3.4.1), an induction type electric motor with a spacer type coupling may be specified.

Gear transmissions should not be selected. As turbine drives invariably require a gear unit, this type of driver should be restricted to those cases where the available power source makes such a selection unavoidable.

Variable-speed frequency-controlled electric motor drives may be selected as well as gas engines or diesel engines. The minimum allowable speed for adequate lubrication and rod load reversals shall be verified.

4.3.6 Measurement and control Instrumentation

Instrumentation shall comply with DEP 32.31.09.31-Gen.

The type of capacity control shall be specified. Suction valve unloading is preferred. Adjustable speed electric motor drivers may be considered. Variable volume clearance pockets shall not be used for capacity control. The use of fixed clearance pockets requires the approval of the Principal.

Load adjustable suction valves should only be used for reverse flow control in clean gas service and at suction pressures for which reliable operation has been demonstrated.

4.3.7 Tests

For reciprocating compressors, a 4-hour unloaded mechanical running test in accordance with DEP 31.29.40.31-Gen. shall be specified.

It is not normally necessary to specify a full load performance test in order to check capacity since this can be predicted from cylinder dimensions, the speed and the K-value of the gas.

For variable speed drives, a string test shall be considered.

4.4 ROTARY-TYPE POSITIVE DISPLACEMENT COMPRESSORS

Rotary-type positive displacement compressors shall be in accordance with DEP 31.29.40.32-Gen.

Some additional requirements and recommendations for specifying a rotary-type compressor and completing data/requisition sheet DEP 31.29.42.93-Gen. are given below.

4.4.1 Casings

In order to obtain comparable quotations from Manufacturers, the number of stages (i.e. the number of casings) required should be stated. Materials of construction for casings shall be specified, the material being selected to be compatible with the gas handled.

The casings material shall be steel if:

- Rated discharge pressure > 10 bar; or
- Discharge temperature > 250 °C; or
- In flammable or very toxic services.

The orientation and flange rating of the suction and discharge connections shall be specified. Top suction with bottom discharge shall be specified for wet gas duties.

4.4.2 Shaft sealing

The labyrinth-type seal should be specified for non-toxic and non-flammable gases; the mechanical contact type for non-corrosive hydrocarbons, and the liquid-film type for all other duties. Restrictive-ring type seals should not be selected unless approved by the principal.

The usual sealing liquid is oil. The application of other liquids, e.g. water, shall be subject to the approval of the Principal.

For rotary-type compressors, dry gas seals may be considered only if they have a proven service record. For dry-gas seals the selection requirements of (4.1.1) shall apply.

4.4.3 Lubricating oil and seal oil systems

For rotary-type compressors in Non-spared Essential services, lubricating oil and seal oil systems shall comply with DEP 31.29.60.32-Gen.

4.4.4 Materials and certification

Materials of construction and certification for the main component parts of the compressor shall be specified as far as is practical. Materials shall be selected in accordance with the requirements of (4.1.3).

For oil-free rotary-type compressors handling air, stainless steel (AISI 316) shall be specified for the following components:

- the suction line downstream of the inlet filter
- the inlet silencer
- the intercooler(s)
- the interconnecting piping.

Materials of construction for rotors shall be specified. Rotors for air compressors shall be of 12-Cr steel (ASTM A 182-F6).

4.4.5 Mounting plates

A single base plate shall be provided for the compressor and its driver and also, where applicable, for the gear unit.

4.4.6 Tests

Rotary-type compressors shall be subjected to a mechanical running test as described in DEP 31.29.40.32-Gen.

If specified, the mechanical running test shall be carried out with the gear unit to be supplied.

A performance test with air shall be specified for oil-free rotary compressors. The test shall simulate as far as possible the conditions expected at site, particularly the process temperature.

4.5 PACKAGED HIGH SPEED INTEGRALLY GEARED CENTRIFUGAL COMPRESSORS

Integrally geared multistage compressors for air and inert gases shall be in accordance with DEP 31.29.40.33-Gen.

If applied in process service this type of compressor shall be in accordance with DEP 31.29.40.30-Gen. as far as applicable.

The operating data and conditions, together with the additional requirements for the packaged unit, shall be specified in the data/requisition sheet DEP 31.29.40.93-Gen.

The data/requisition sheet(s) shall be filled in as completely as possible to give the vendors all the necessary information on which to base their tenders.

As these packaged units derive their cost attractiveness from a high degree of standardisation in manufacture, special requirements shall be added only where essential.

4.5.1 Shaft sealing

For air or inert gas services labyrinth type seals are normally selected.

For other services the seal selection criteria of (6.1.1) shall apply.

4.5.2 Lubricating system

The lubricating oil system for these compressors in 'Vital or Essential services (Non-spared)' shall comply with DEP 31.29.60.32-Gen. Acceptable exceptions are an integral oil tank and shaft driven main-oil pump.

4.6 CENTRIFUGAL FANS

Centrifugal fans shall be in accordance with DEP 31.29.47.30-Gen.

Some additional requirements and recommendations for specifying a centrifugal fan and completing data/requisition sheet DEP 31.29.42.93-Gen. are given below.

4.6.1 Type of fan

The fan shall be of the overhung type if the actual inlet flow is less than approximately 100 m^3/s. For larger flows a double inlet, between-bearings fan may be considered; the latter type is subject to approval by the Principal if the inlet temperature is above 200 °C.

4.6.2 Drivers

For centrifugal fans the most economical method of capacity control (down to a certain minimum) is by means of speed variation, hence a variable-speed driver should be selected (e.g. a steam turbine or variable-speed electric motor).

Inlet guide vanes shall only be specified for capacity control of clean, non-corrosive gases.

Gear transmissions should not be used. For steam turbine drive fans, and if required, gearing should be integral with the turbine.

4.6.3 Casing connections

Fan inlet and discharge connections, and their orientation, shall be specified in the data/requisition sheet.

4.6.4 Shaft sealing

For centrifugal fans in particular, labyrinth type seals should be employed in non-flammable, non-corrosive, non-toxic services at ambient temperature. An inert gas sealing system may be considered if leakage (either air to inside or gas to outside) is not allowed for process reasons.

For service above 200 °C a restrictive ring or labyrinth type shaft seal, with a sealing gas system, should be employed.

If a maximum sealing effect is required, mechanical contact type seals may be considered, but this type of seal shall not be specified for service above 200 °C.

4.6.5 Lubrication

Pressure lubrication should be considered for fans in ‘Vital' or Non-spared 'Essential' services.

Grease lubrication for fan bearings of the anti-friction type may only be specified for fans in non-essential services. If re-lubricated bearings are used, a minimum running period of 4 000 hours shall be specified between lubrications.

4.6.6 Mounting plates

For stability column-mounted fans shall be specified with a sub-base plate under the fan and its driver. This sub-base shall be filled with concrete.

If a separate gear unit is necessary, it shall be mounted on the fan base plate.

4.6.7 Testing

Pneumatic testing

Pneumatic testing of the fan casing shall be specified for certain applications such as toxic, flammable, hot and corrosive service.

Performance test

A performance test in accordance with BS 848-1 shall be specified for:

- Fixed-speed electric-motor driven fans, if any head and/or capacity restrictions are not allowed for process reasons.
- Fans with an impeller design that has never been used before for the required process conditions.

For fans with an inlet temperature above 200°C, a full load test at actual operating temperature should be specified if the Manufacturer cannot refer to operating experience of nearly identical fans in the same service.

Combined unit test

For steam turbine driven fans with an integral gear, a complete unit test shall be considered if the same combination has not been tested before, either on a test stand or in actual operation.

For a fan with two different drivers (such as steam turbine + electric motor + overriding clutch) a complete unit test shall be specified.

If several identical units are being procured, complete unit testing of the first unit only should be specified.

Model testing is not acceptable.

5. INSTALLATION

Compressor installation shall be in accordance with DEP 31.29.00.10-Gen and DEP 61.10.08.11-Gen.

5.1 GENERAL LAY-OUT

In deciding upon the location of a compressor, consideration shall be given to maintenance and process operations.

The decision whether to specify overhead cranes shall be based on service classification (Appendix 1) with account being taken of full life-cycle costing, and evaluated against the possible use of a mobile crane. For offshore platforms hoisting facilities shall be evaluated on a case by case basis.

If specified by the Principal, hoisting facilities shall be selected in accordance with DEP 31.25.00.10-Gen.

The overall lay-out of a compressor installation shall allow safe access to all operating positions and to overhead lifting equipment if provided. There shall be no unguarded floor openings around machines.

Sufficient space shall be provided at the compressor floor level for dismantling the compressor (for reciprocating compressors including the removal of piston rods), its driver and auxiliary equipment. If two or more compressors are located on the same floor, provision shall be made for a clear floor area that is adequate for the simultaneous overhaul of all compressors, their drivers and associated auxiliary equipment. The permissible floor loading shall be able to withstand the maximum cumulative weight that arises during maintenance.

Special attention shall be given to the ventilation of compressor houses and enclosures, particularly for units in hydrogen services, flammable services and very toxic services. Electrical equipment located in compressor houses/enclosures shall comply with the related area classification.

Installation at grade level shall be considered for axial and centrifugal compressors operating in clean services with top-top connections provided that driver installation is not a problem. Grade level installation shall be weighed up against installation of the compressor train on a table top having either top-top or bottom connections.

The lay-out of auxiliary equipment and the provision of permanent steps and platforms and of adequate clear floor space shall permit easy and safe access to all components for operation and maintenance.

5.2 SUCTION STRAINERS

Temporary strainers shall be provided in the suction line as close as possible to the compressor inlet to safeguard the compressor from ingress of extraneous solids particularly during commissioning operation, except in large piping (DN 750 and above) where they are impractical. Pressure tapping shall be provided across the conical strainer to enable the extent of fouling to be determined. As an alternative to standard on-line differential pressure measurement, pressure gauges may be installed across the strainer up to a system pressure of 10 bar (ga) maximum; above this pressure a DP cell with transmitter shall be installed as this gives more reliable measurements at elevated pressures. The differential pressure across the filter shall be no more than 1.5 bar during the initial compressor pre-commissioning runs. After commissioning the compressor the entire strainer shall be removed if the piping system is considered clean.

The strainers shall be of the conical type fitted with a spool piece of adequate length to facilitate removal (see Standard Drawing S 38.041). Strainers in services below minus 50 °C shall be made of stainless steel.

For severe fouling services installation of permanent type strainers or filters having the capability of on-line cleaning (switch-over) shall be considered.

5.3 AIR COMPRESSOR INTAKE FILTERS

5.3.1 Lay-Out and Mechanical Design

The location of the air intake filters, in particular for axial and centrifugal air compressors (including packaged high speed, integrally geared air compressors), requires careful consideration to optimise the run-time and life of the compressor. Satisfactory access by means of doors in the filter housing and ducting shall be provided and no undue hazard shall be created.

The air intake should be as close as possible to the compressor, to minimise cost and intake pressure losses. It is acceptable to place the intake in Zone 2 areas, but prohibited in Zone 1 areas. The intake shall not be placed beneath a roof of any building in which flammable vapours may accumulate. Process equipment, pipe flanges and open drains shall not be placed within 5 metres of the air intake. Careful consideration shall be given to the area classification surrounding the compressor installation.

The entire air inlet system consisting of filter housing and inlet ducting shall be made of AISI 316L stainless steel. Other materials require approval of the Principal.

Note: Most coatings on carbon steels have proven unsatisfactory. The cost of repair of these systems exceeds the initial procurement cost of stainless steel.

It is essential to ensure that the entire air intake system is completely leak tight. Mastic sealants dry out and fail their use and should be avoided. All welding shall be continuous. Bolted assemblies shall include an elastomer sealant. The pitch of the bolting shall ensure that an airtight joint is achieved. The roof of intake housings and the intake ductwork shall be sloped to shed rainwater. All joints in these components shall be fully welded or, if bolted, have lap joints, not flanged joints, to prevent rainwater leakage into the air intake. In winter, icicles can severely damage the compressor.

The distortion of ducting flanges for flexible joints (rubber/canvas bellows) shall be kept within the tolerances set out by the Manufacturer of the joint. Over stressing of the joint will lead to leakage and will shorten the operating life of the joint. Special attention shall be given to the selection of a suitable type and make of joint.

5.3.2 Filter Design

Contaminants in the air stream cause fouling, corrosion, axial compressor blade failure under extreme conditions and, most importantly, severe efficiency losses. Compressor Manufacturers shall provide details of the maximum allowable quality and quantity of airborne contaminants that can be tolerated without affecting component life. These limits shall be adhered to in the design of the filter.

The environmental conditions at the installation site shall be carefully appraised in order to determine the most suitable air filtration system. The filter design aspects should be discussed and agreed between the Principal and Manufacturer. Axial air compressors in particular are less tolerant of dirt ingress and fouling can have a severe impact on their efficiency. Three-stage high efficiency filters shall therefore be used with these types of compressors. For centrifugal air compressors, including integrally geared units, a less sophisticated air intake filter may be selected if approved by both the Principal and Manufacturer.

Specific attention shall be paid to maintenance during the specification and selection of air filters. Due consideration shall be given to on-line changing of filter elements and access to the filter housing.

Air filter intakes shall be fitted with a rain hood forcing an upward airflow into the filter housing. To prevent rain and snow ingress into the air filter the upward intake shall be supplemented with a suitably designed louver system preventing water mist from entering the filters. There shall also be at least two active filter stages. The underside of the air intake shall not be less than 3 metres above grade level to prevent swirling dust and most insects from entering the filter.

The air inlet filter shall be designed for a maximum pressure drop of 15 mm H_2O with clean filters.

The face area of the air filter shall be such that the approach velocity of the air does not exceed 1.5 m/s in any stage of filtration. Any deviation is subject to approval of the Principal.

Horizontal pulse-type filters should only be considered in dry sandy (i.e. desert) environments as they are vulnerable to the caking of dirt when wet. When one part of the filter is cleaned, the cleared-out dirt should be kept away from the operating filter sections.

5.4 PIPING AND LINE-UP

5.4.1 Depressurisation and Relief

Provisions shall be made for isolating, pressure-relieving and purging the compressor. Unless otherwise specified, as a minimum for centrifugal compressors in very toxic service, provisions shall be made to block-in and depressurise the compressor by means of suction and discharge ROVs and automatic depressurisation to flare (ROV-Remotely Operated Valve).

All pressure-containing parts of reciprocating compressors shall be protected by relief valves, correctly sized and set to operate at not more than the maximum allowable working pressure of the part(s) concerned, or as prescribed in DEP 31.29.40.31-Gen.

Distance piece compartment vent lines of reciprocating compressors shall be sized to prevent over-pressurisation of the compartment in the event of failure of the stuffing box packing.

5.4.2 Line-Up

Installation of compressor piping shall be in accordance with DEP 31.38.01.11-Gen.

Multi-stage reciprocating compressors, designed to operate in parallel, shall have individual interstage equipment.

5.4.3 Anti-Surge Control

For centrifugal, axial and rotary compressors a check valve shall be installed to prevent reverse flow and minimise surge.

The check valve shall be located as close as possilbe downstream of the compressor to minimise inventory.

In order to protect the centrifugal and axial compressors from surge, the discharged air or other gas must be passed on very quickly, therefore the anti-surge recycle connection and anti-surge control valve shall be located upstream of the check valve as close as practical to the compressor discharge connection. To adequately control the suction temperature and thereby preventing the compressor from going into surge, a cooler in the recycle line may have to be considered. The line-up and tie-in point of the recycle line on the suction side of the compressor shall be such that liquid is prevented from entering the compressor.

Recycle lines and their valves shall be sized to handle compressor flow rates under rated conditions, all other specified operating conditions and starting/stopping conditions.

If a recycle line is used for capacity control, the recycle valve shall be capable of smooth control and for this reason an arrangement of two valves in parallel may be considered.

5.5 CONDITION MONITORING

On-line condition monitoring shall be provided for compressor units in essential services. These compressors units shall be monitored with regard to selected mechanical and process parameters in order to assess aerodynamic/thermodynamic performance and mechanical condition.

5.5.1 Condition Monitoring Parameters

Unless otherwise specified, the minimum mechanical and process parameters to be monitored by the condition monitoring system are listed below for the main types of compressors:

Axial and Centrifugal Compressors:

Compressor section inlet and outlet pressure, temperature and flow

Compressor speed (for variable speed drives)

Recycle data such as surge parameter

Radial shaft vibrations with key-phasor

Axial displacement

Bearing white metal temperature

Seal performance parameter

Reciprocating Compressors:

Suction and discharge pressure and temperature per stage

Compressor flow per stage

Recycle flow rate

Rod drop monitoring devices

Provisions for P-V diagram analysis

Main bearing temperatures

Crankcase acceleration level

Piston rod packing leakage

Provisions for valve temperature measurement

For other types of compressors in essential services the requirements for condition monitoring shall be discussed and agreed with the Principal.

5.5.2 Condition Monitoring System

A dedicated data collection and monitoring system shall be provided for condition monitoring purposes. Incorporated into the standard plant instrumentation system, it continuously samples, processes and stores the various condition monitoring parameters.

As a minimum, the condition monitoring system shall have the following capabilities:

a) provide on-line information on the vibration behaviour of equipment, including that required for various real-time and historical analyses. The total storage capacity shall be such that long-term trending can be performed to facilitate machine condition assessment.

b) provide on-line information on the process performance of selected machines, including reporting of calculated efficiencies.

c) provide suitable outputs to plant safeguarding systems and alarm/warnings to plant control and operating system (DCS).

d) allow remote access by means of present and future IT technologies (e.g. LAN and (secured) Internet) for read-out and on-line evaluation of data.

e) allow the capture and storage of rapidly changing transient data during start-up, shut-down and alarm/trip occurrences and have facilities for analysing this data.

f) have a fast sampling rate of various pre-set parameters to enable real time analysis and provide for alarm functions and report facilities.

g) allow inter-communication with standard plant instrumentation systems (DCS) and specific vendor control systems (e.g. compressor anti-surge control and gas/steam

turbine control).

6. OPERATIONAL AND MAINTENANCE ASPECTS

6.1 OPERATING CONDITIONS

The Contractor shall ensure that all specified process conditions are within the proven range of the compressor type considered.

For multi stage compressors handling hydrocarbon gases, the Contractor shall carry out equilibrium calculations at interstage pressure levels in order to determine the quantity and composition of the gas after intercooling and knock-out. To optimise the compressor lay-out and design, the inlet and discharge pressures of each compression stage shall be adjusted for the purposes of selecting compressor components, such as number and type of impellers or number and diameter of reciprocating compressor cylinders. The Contractor shall, for this purpose, involve the selected equipment vendor(s).

In addition for reciprocating compressors the Contractor shall obtain from the compressor Manufacturer the interstage pressures and temperatures at part-load conditions (75% and 50%) so that the interstage equipment and piping can be suitably designed and the RV settings can be determined.

6.2 KNOCK-OUT FACILITIES

In all cases where liquid carry-over can occur (e.g. if the gas entering the compressor emanates from a liquid accumulator after partial condensation, or if intercooling between compression stages results in partial condensation), the Contractor shall make adequate provision for the following:

- separate suction and inter-stage entrained liquid knock-out facilities, to be installed as close as possible to and upstream of the machine for process gas service, the knock-out facilities shall not be integral with the cooler. Knock-out facilities shall be designed in accordance with DEP 31.22.05.11-Gen. For air services knock-out facilities may be combined with the coolers if approved by the Principal;
- prevention of condensation and accumulation of condensate in the line between the knock-out device and the compressor suction, e.g. by insulating, heat tracing and sloping of the line. The line shall be as short as practical, without pockets, and slope down towards the knock-out facilities;
- preventing condensate from the discharge system flowing back into the compressor, particularly when the machine is being shut down;
- a liquid level alarm in the knock-out facility set to operate when a predetermined high level is reached and to shut down the compressor when this level is exceeded. The alarm and cut-out functions shall be entirely separated;
- for reciprocating compressors operating in a service where liquid is entrained, present, coalescing filters shall be preferred.

6.3 FOULING SERVICES

6.3.1 On-line/Off-line washing

Centrifugal compressor on-line and off-line washing provisions shall be provided if the process gas contains unsaturated hydrocarbons, salts or dirt that can form deposits on compressor internals. For this purpose a suitable liquid, compatible with process and product requirements downstream of the injection point, is introduced into the compressor suction and/or each stage of multi stage compressors. The liquid shall be introduced either continuously or at some predetermined frequency in the form of a mist using suitable atomizers. If a cleaning system is specified, the amount of liquid to be used and its distribution within the compressor shall be agreed with the Manufacturer. The compressor Manufacturer shall provide the injection nozzles and connection for the stage cleaning including the necessary piping up to the edge of the skid. If compressor washing facilities are specified, drains located at the lowest point of the casing shall be provided between each section.

Axial type air compressors shall be equipped with cleaning facilities which can perform both

on-line washing and off-line soak washing. The required cleaning method shall be stated on the data sheet.

6.3.2 Compressor Coatings

For axial and centrifugal compressors operating in fouling services, the coating of internals may be considered. Due to the non-stick surface of the coating, fouling can be minimised. In view of the relatively high temperature used during the application process of the coating, details of such coatings processes shall be mutually agreed upon between the compressor Manufacturer and the Principal.

6.5 SPARE PARTS

Availability of equipment in 'Vital and Essential services' should be optimised by means of an appropriate spare parts procedure.

7. REFERENCES

In this manual reference is made to the following publications.

NOTE: The latest issue of each publication shall be used together with any amendments/ supplements/ revisions to such publication.

It is particularly important that the effect of revisions to international, national or other standards shall be considered when they are used in conjunction with DEPs, unless the standard referred to has been prescribed by date.

SHELL STANDARDS

Index to DEPs and Standard Specifications	DEP 00.00.05.05-Gen.
Metallic materials - selected standards	DEP 30.10.02.11-Gen.
Metallic materials - prevention of brittle fracture	DEP 30.10.02.31-Gen
Data/requisition sheet for equipment noise limitation	DEP 31.10.00.94-Gen.
Selected construction materials for shell-and-tube heat exchangers	DEP 31.21.01.31-Gen.
Gas/Liquid separators - Type selection and design rules	DEP 31.22.05.11-Gen.
Guide for the selection of hoisting facilities and weather protection for rotating equipment	DEP 31.25.00.10-Gen.
Installation of Rotating Equipment	DEP 31.29.00.10-Gen.
Special purpose gear units for petroleum, chemical and gas industry services	DEP 31.29.00.32-Gen.
Dry Gas seals (Draft)	DEP 31.29.00.34-Gen.
Centrifugal compressors	DEP 31.29.40.30-Gen.
Reciprocating compressors	DEP 31.29.40.31-Gen.
Rotary-type positive displacement compressors	DEP 31.29.40.32-Gen.
Packaged, integrally geared, centrifugal plant and instrument air compressors	DEP 31.29.40.33-Gen.
Data/requisition sheet for packaged integrally geared, centrifugal plant and instrument air compressors	DEP 31.29.40.93-Gen.
Data/requisition sheet for centrifugal/axial compressors	DEP 31.29.41.93-Gen.
Liquid Ring vacuum pumps and compressors	DEP 31.29.42.30-Gen.
Data requisition sheet for rotary type compressors and fans	DEP 31.29.42.93-Gen.
Data/requisition sheet for reciprocating compressors	DEP 31.29.43.93-Gen.
Centrifugal fans	DEP 31.29.47.30-Gen.
Steam turbines - selection, testing and installation	DEP 31.29.60.10-Gen.
Lubrication, shaft-sealing and control oil systems for special-purpose application	DEP 31.29.60.32-Gen.
Combustion gas turbines - Selection, testing and installation	DEP 31.29.70.11-Gen.
Spark Ignited Gas Fuelled Engines	DEP 31.29.90.30-Gen.
Instrumentation for equipment packages	DEP 32.31.09.31-Gen.
Electric motors	DEP 33.66.05.31-Gen.

Electrical Variable Speed Drives	DEP 33.66.05.33-Gen.
Field inspection prior to commissioning of Mechanical equipment	DEP 61.10.08.11-Gen.

STANDARD DRAWINGS

Temporary conical suction strainer for compressors	S 38.041

AMERICAN STANDARDS

Compressors and exhausters	ASME Power Test Code PTC 10

Issued by:
American Society of Mechanical Engineers,
345 East 47th Street,
New York NY 10017, USA

BRITISH STANDARDS

Fans for general purposes methods of testing performance	BS 848-1

Issued by
British Standards Institution
389 Chiswick High Road
London W4 4AL
England

INDUSTRIAL GASES COMMITTEE

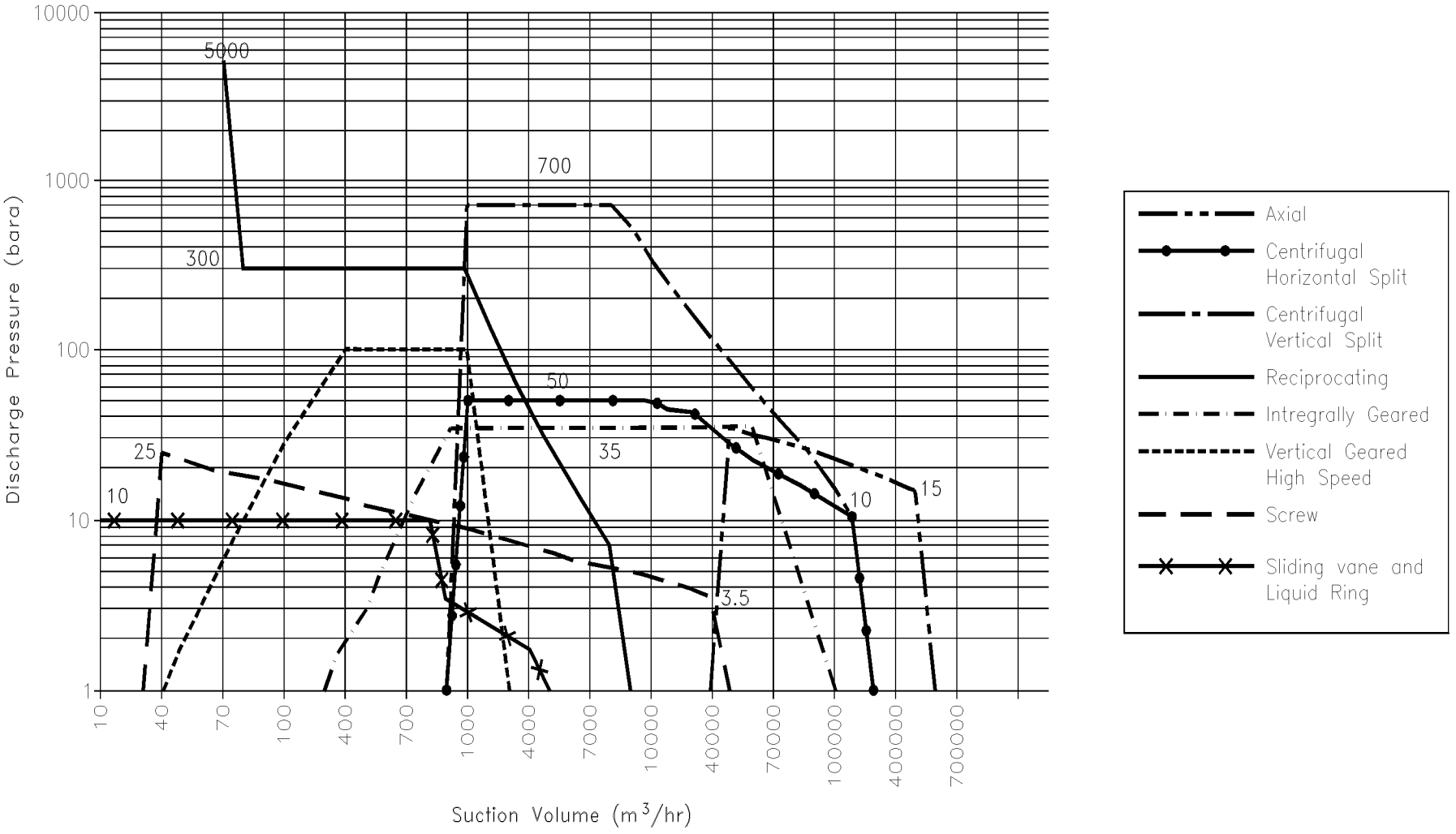
Turbo compressors for oxygen services	IGC code of practice IGC document 27/82/E 1982, 4th Print

Issued by:
Industrial Gases Committee
32, Bd de la Chapelle
75880 Paris
France

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

	SAFETY EQUIPMENT	OTHER EQUIPMENT		
	SERVICE CATEGORY			
	VITAL	ESSENTIAL		NON-ESSENTIAL
		Non-spared equipment	Spared equipment	
Definition	A service in which failure of equipment causes an **unsafe condition** of the plant or installation resulting in **jeopardy to life** and/or **major damage** (fire, explosion etc.).	A service in which failure of equipment renders a plant or process unit **inoperable** or **reduces performance** to a level **unacceptable** to the Principal.	A service in which failure of equipment renders a plant or process unit **inoperable** or **reduces performance** to a level **unacceptable** to the Principal.	All other services.
Selection Criteria	Equipment shall be adequately spared to ensure 100% availability of the service under all circumstances	A decision not to install spare equipment is based upon economic considerations and proven equipment availability. Non-spared equipment availability may be upgraded by means of additional Capex to match required plant availability.	Installed spare equipment is normally selected where potential losses due to equipment outage greatly outweigh equipment Capex. Sparing philosophy shall be economically evaluated and is typically 2x100% or 3x50%.	Economic evaluation required to justify spared equipment.
Driver Selection Criteria	Independent power sources shall be selected to ensure 100% service availability		Independent power sources may be selected, for start-up and utility availability reasons	
Examples	- *firewater pumps with diesel and motor drives;* - *ESD systems;* - *EIA compressor.*	- *HCU feed pump;* - *HCU recycle compressor;* - *FCCU main air compressor;* - *FD and ID fans.*	- *BFW pumps;* - *fractionator bottom pumps;* - *fresh gas compressors (HCU).*	- *drinking water pumps;* - *sewage pumps.*

APPENDIX 2 PRESSURE/ VOLUME MAP FOR VARIOUS COMPRESSOR TYPES



APPENDIX 3 LUBE OIL SYSTEMS ACCORDING TO API 614/672

General guidelines for are provided when specifying and selection of drivers for lube oil systems are given below.

Main driver	**Main lube oil pumps driver**	**Auxiliary lube oil pump driver**	**Emergency lube oil supply/driver**	**Jacking oil pump driver**
Steam turbine	**Primary selection** AC-motor drive (alternatively, steam turbine drive may be selected depending on economics, utility balance and start-up requirements)	AC-motor drive (power source separate from that of main oil pump)	**Primary selection** is an overhead tank. If such a tank would have to be of an impractical size, an emergency lube oil pump with DC or UPS motor drive may be used instead. Emergency lube oil supply may be required for cool down after coast down and for barring hydraulics.	AC or UPS motor drive (Only required for large size compressor trains)
E-motor	**In principle** AC-motor drive (alternatively, steam turbine drive may be selected depending on economics, utility balance and start-up requirements)	AC-motor drive (power source separate from that of main oil pump)	**Primary selection:** overhead tank for coast down of equipment only. If such a tank would have to be of an impractical size, an	AC-motor drive (only required for large size compressor trains)

			emergency lube oil pump with DC or UPS motor drive may be used instead.	
Gas Turbine	Drive by auxiliary gearbox	AC-motor drive Normal source of feeder system	E-motor drive **(DC or UPS)** Required for coast and cool down requirements after power failure; alternatively a high tank may be selected	AC or UPS motor drive (only required for large size gas turbine driven compressor trains)