TECHNICAL SPECIFICATION

CENTRIFUGAL AND AXIAL COMPRESSORS
(AMENDMENTS/SUPPLEMENTS TO API 617)

DEP 31.29.40.30-Gen.

December 1998
(DEP Circular 23/99 has been incorporated)

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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APPENDICES

PART I INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for centrifugal and axial compressors. It is a revision of the DEP of the same number dated August 1992.

This DEP is based on API Standard 617, sixth edition, February 1995; Part III of this DEP amends, supplements and deletes various clauses of API 617.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP/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 and Manufacturers nominated by them (i.e. the distribution code is "F", as defined in DEP 00.00.05.05-Gen.).

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

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

For the purposes of this DEP the following definitions shall apply:

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

The **Manufacturer** 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 the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets.

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

PART II GENERAL INFORMATION

This specification is written in four parts, of which Part III gives amendments and supplements to API Std 617, sixth Edition, February 1995. Wherever reference is made to API 617, it shall be understood to mean API 617 as amended/supplemented by this specification.

For ease of reference, the clause numbering of API Std 617 has been used throughout Part III of this specification. Clauses in API Std 617 which are not mentioned remain valid as written.

A bullet (•) in the margin against certain clauses (paragraphs) in API Std 617 indicates that a decision by the Principal is required. This DEP addresses the decisions required by most of the API 617 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.

Note: The data/requisition sheets for centrifugal and axial compressors are DEP 31.29.41.93-Gen.

PART III AMENDMENTS/SUPPLEMENTS TO API STANDARD 617

SECTION 1 GENERAL

1.1 SCOPE

Replace the first sentence of this clause by:

See Part I, section 1.1 of this DEP.

1.3 CONFLICTING REQUIREMENTS

Replace this clause by:

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

- upper level : purchase order and variations thereto
- second level : data/requisition sheets and drawings
- third level : this DEP

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

1.4 DEFINITION OF TERMS

In Figure 1, Note 7, replace "1.1.4" **by** "1.4.4"

1.5 REFERENCED PUBLICATIONS

1.5.1 Add to this clause:

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

Add new clause:

1.6 MANUFACTURER'S RESPONSIBILITIES

1.6.1 The Manufacturer shall be responsible for the design and engineering, the total mechanical/aero-dynamic performance, and the guarantee of the entire compressor unit. This includes the compressor, driver, power transmission equipment and all auxiliary equipment furnished by sub-suppliers when purchased by the Manufacturer. This responsibility shall include determining critical speeds and performing the lateral rotor dynamic analysis for each major component of the unit and the torsional analysis for the entire unit, as well as any other analysis specified in the data/requisition sheets.

1.6.2 The Manufacturer shall have an implemented and effective quality system in accordance with ISO 9001 or an equivalent standard acceptable to the Principal.

In addition, the Manufacturer shall have an implemented and effective design release system, which will indicate and present any design changes for approval by the Principal.

1.6.3 The Principal reserves the right to review and check the design of any part of the equipment supplied. For this purpose the Manufacturer shall provide the necessary technical information of the subject part to the Principal to enable such verification or analysis. If required by the Manufacturer, the Principal shall agree not to divulge any of this information to any other party.

In the event of a conflict between the Manufacturer and the Principal regarding the interpretation of these design data, every effort shall be made to arrive at a mutually acceptable solution. If an agreement in this respect cannot be reached, the Principal shall have the right to insist that additional calculations and/or testing shall be made to ensure a design which is satisfactory to all parties involved.

However, it is recognised by the Principal that the Manufacturer's responsibilities, both contractually and in relation to the cost of any modifications and/or testing, shall be limited to

the extent indicated in the Manufacturer's original design, unless it becomes evident that the Manufacturer's design was not adequate for the specified service.

1.6.4 The Manufacturer shall be responsible for co-ordination. This shall include at least:

- obtaining information required for fulfilling his obligations;
- communicating necessary data, specifications and other documents to sub-suppliers;
- negotiating interfaces with his sub-suppliers;
- standardising all components within the train, its auxiliaries and its utility requirements (such as oil type/grade etc.).

1.6.6 Factory representatives shall be provided to assist the Purchaser during initial installation (including piping checks specified in API Std. 617, clause 2.1.14) and initial start-up. An outline of initial start-up procedures shall be prepared by the Manufacturer and shall be agreed upon by all parties involved before operations are commenced.

1.6.7 For reference purpose the physical properties of the process gas (Cp/Cv, molecular weight etc.) may be given on the data/requisition sheets in order to facilitate the compressor calculations. However, the Manufacturer shall base his performance calculations on the gas composition as stated in the data/requisition sheets.

The Manufacturer shall calculate the performance of all proposed compressors using his standard methods for computing the physical properties of the specified gases and shall take full responsibility for any design features affected. The Manufacturer shall state the values of all physical properties of the process gas used in his computations.

If specified in the data/requisition sheets, the Manufacturer shall additionally calculate compressor performance by means of an alternative computational method. If the results of this alternative computation indicate a significant difference in the predicted performance of the selected compressor design, the Manufacturer shall demonstrate to the Principal the validity of his original calculation results and agree with the Principal upon the contractual performance prediction of the compressor.

1.6.8 For compressors in natural gas service the Manufacturer shall in his proposal also calculate and demonstrate with relevant curves the performance of his selected compressor design for a mole weight 5% higher and 5% lower than the specified mole weight for the rated operating conditions. The associated changes in gas composition shall be specified in the data/requisition sheets. If a variable speed unit is used these extended performance predictions shall indicate the speed required to achieve the specified rated operating conditions.

SECTION 2 BASIC DESIGN

2.1 GENERAL

2.1.1 In this clause, replace the words "at least 3 years" **by** "at least 5 years".

Add to this clause:

Compressor ratings, components and auxiliaries shall not exceed the limits of the **Manufacturer**'s design and shall be within his 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 3 units of similar type, size and specific loading have together accumulated a minimum of 24 000 hrs of comparable satisfactory service. In this respect, the Manufacturer shall provide the necessary evidence in his proposal.

2.1.3 Add to this clause:

The Manufacturer shall also state the ability of the compressor to operate at all other conditions specified in the data/requisition sheets.

2.1.4 Replace the first sentence of this clause by:

The head-capacity curve of centrifugal and axial compressors shall have a continuous rise from the normal operating point to the surge point. This rise shall be sufficient to result in an increase of the pressure ratio of at least 5% when operating at specified suction conditions. This requirement shall be met for each setting of adjustable inlet guide vanes or axial stator vanes.

The gradient of the tangent of the compressor head capacity curve shall decrease continuously, never increase, and never become zero from stonewall capacity up to the surge point.

The “stone wall” capacity is defined as the capacity where the decrease in polytropic head is 10% for an increase of 1% in inlet volume capacity. Unless otherwise specified by the Principal, the stone wall capacity shall be at least 110 % of the rated capacity at rated speed. The compressor Manufacturer shall confirm the suitability of the compressor to operate continuously at the stone wall point and any limitation to operate beyond the stone wall point.

For the purpose of operational flexibility the End Of Curve (EOC) capacity is defined as the capacity at rated speed where the polytropic head is 85 % of the polytropic head at rated capacity. If applicable, the EOC capacity shall be stated in the data/requisition sheets.

For identical compressors operating in parallel (if so stated in the data/requisition sheets) the respective heads at the same flow shall not differ by more than 2 % from each other at any point on the curves.

2.1.7 Add to this clause:

(a) All left-handed threads shall be clearly marked.

(b) Any maintenance item with a mass greater than 20 kg shall be provided with lifting lugs or similar dedicated fixed lifting point(s). Screw-in eye-bolts may be used only for bearing housing covers and for internal components where other lifting arrangements are impractical. Holes for eye-bolts shall be permanently marked with the correct bolt size to be used. If this marking is impractical, bolt size information should be clearly indicated in the instruction manual.

2.1.8 Add to this clause:

The inner casing shall be of the horizontally split design. End covers may be of a single piece.

2.1.9 Add to this clause:

If specified in the data/requisition sheets, for offshore installations the total compression

package shall be suitable for the worst ambient offshore conditions, as specified for that location. Compressor units, including auxiliaries, which are installed on floating stations or barges shall be capable of operating at the specified static vessel positions and also of accommodating any specified dynamic vessel movement while in operation.

2.1.10 Replace this clause by:

2.1.10.1 Noise Control

The Contractor shall comply with DEP 31.10.00.31-Gen. and thereby communicate to the Manufacturer the specified equipment noise limitations by using data sheet DEP 31.10.00.94-Gen., which forms part of the requisition. The Manufacturer is responsible for assuring that these equipment noise limitations have been specified.

2.1.10.2 Information to be Submitted with the Tender

The Manufacturer shall submit guaranteed sound power levels and sound pressure levels of the equipment, together with any other relevant information as requested in the data sheet, DEP 31.10.00.94-Gen. The Manufacturer shall indicate what special silencing measures, if any, are proposed in order to meet the specified levels.

If noise enclosures are supplied, the full access to the equipment for maintenance purposes shall be ensured by means of an appropriate design.

2.1.14 In the last sentence of this clause, delete the words "When specified"

2.1.15 Replace this clause by:

All electrical components and installations shall be suitable for the area classification, gas grouping and temperature classes specified by the Principal on the data/requisition sheets.

2.1.16 Add to this clause:

Throughout the service life specified in (2.1.1), spare parts for all components of the unit shall be available for purchase and all manufacturing drawings shall be retained.

2.1.17 Add to this clause:

If air operation is specified in the data/requisition sheets, the Manufacturer shall state in the proposal whether the compressor is capable of operation on air without significant modifications and what constraints apply for this operational mode.

Add new clause:

2.1.19 The Manufacturer shall list in his proposal all detailed design and material changes that have been introduced in the selected compressor design in similar machines in the last 5 years or which have not acquired at least 16 000 hours in operation. Although continuous developments by the Manufacturer in his product line are recognised, these changes are subject to the Principal's approval. At the discretion of the Principal alternative designs may be requested, if the Manufacturer fails to provide evidence of proven reliability.

Add new clause:

2.1.20 In the event of any design or manufacturing error, faulty material or damage relating to any compressor part, including shaft seals and labyrinths, the component in question shall be replaced unless explicitly accepted by the Principal. Any proposal to recover the component other than by the original manufacturing method, and the proposed method of repair, shall be submitted to the Principal to obtain this approval. Additional tests or calculations may be required to prove (a) the effectiveness or the repair, and (b) that there will be no detrimental effect on the serviceability of the component. At the discretion of the Principal a temporary repair or recovery may be accepted subject to a later replacement of the complete component or assembly by the Manufacturer.

The above requirement shall be applicable until the guarantee period of the original part and its replacement, if any, has expired.

2.2 CASINGS

2.2.3 Add to this clause:

The casing shall be supported from the base plate by vertical supports. Shim packs for vertical alignment shall be between surfaces that do not have relative movement. Shim packs shall have a total thickness of at least 5 mm and shall be made of stainless steel. Provision shall be made to support the machine whilst shims are removed or replaced.

2.2.6 Add to this clause:

The end covers of axial compressor casings shall be of a single piece construction without a split line.

2.2.8 Replace this clause by:

Nodular cast iron (only in accordance with ASTM A 395 or ASTM A 571) or steel may be offered for operating conditions other than those specified in (2.2.7). Other materials require the written approval of the Principal. Grey cast iron shall not be used.

2.2.10 Add to this clause:

Gasket materials shall be asbestos free and suitable for the gas handled. Soft metal gaskets are preferred. Gaskets in high pressure compressors shall be suitable for high rate de-pressurisation. Unless otherwise specified, the rate of de-pressurisation shall be 80% reduction of the maximum discharge pressure within 15 minutes.

2.2.16.2 **Replace this clause by:**

Cap screws (set screws, tap bolts) shall only be used for external bolting where the use of studs is impractical, and only with the Purchaser's approval.

2.2.16.3 **Add to this clause:**

Bolting at casing joints and main process connections shall be designed to be tensioned by an approved hydraulic tensioning method and sufficient space shall be provided to facilitate the use of such equipment.

2.3 INTERSTAGE DIAPHRAGMS AND INLET GUIDE VANES

2.3.1 Add to this clause:

Internal fasteners (bolts and nuts) in the flow path shall be positively locked in place so that under all circumstances they are prevented from entering the gas flow path and subsequently damaging the compressor.

2.3.3 Replace the last sentence of this clause by:

Close clearance sealing by means of stationary labyrinths only is preferred. If rotating labyrinths are are used they shall be replaceable. The use of stationary abradable seals are subject to the approval of the Principal.

2.3.5 Replace this clause by:

Diaphragms with internal liquid cooling shall not be used.

2.4 CASING CONNECTIONS

2.4.1 General

Add new clause:

2.4.1.6 All casing openings for pipe connections shall be not smaller than DN 20 (3/4 inch NPS) and shall be welded to the casing and flanged or, alternatively, machined and studded. All welded connections shall be full penetration butt welded. Openings smaller than DN 25 (1 inch NPS) may be self-reinforced branch fittings of the 'weldolet' type.

Threaded connections shall not be used. Socket welding shall not be used, except where other connection methods are possible and then only with specific approval of the Principal.

2.4.2 Main process connections

2.4.2.1 **Add to this clause:**

The main process connection flanges shall be fully drilled for a connection with studs. Threading in the flanges is not allowed. If this fully drilled type flange connection is not possible, the Manufacturer shall propose a suitable alternative subject to the specific approval of the Principal.

2.4.2.2.1 **Replace this clause by:**

Flat-faced flanges may be used only on nodular cast iron casings and shall have full raised-face thickness.

2.4.2.4 **Replace the words** "cast iron" **with** "nodular cast iron".

2.4.3 Auxiliary connections

2.4.3.1 **Add to this clause:**

Compressors in fouling services, as indicated in the data/requisition sheets, shall be equipped with connections for liquid injection. Horizontally split compressors shall have an injection point at each stage. Radially split compressors shall have an injection point at the inlet of the first impeller of each casing.

If specified in the data/requisition sheets, compressors shall be equipped with connections for borescope inspection of impellers. The details of the location and type/size of connection shall be agreed upon between the Manufacturer and the Purchaser and subject to approval by the Principal.

2.4.3.2 **Replace the last sentence of this clause by:**

Unless approved otherwise by the Principal, individual stage drains, including a balance drum cavity drain, shall be provided on all centrifugal compressors. Manifolding of individual drains into a common drain connection shall be done outside the compressor at an accessible location.

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

Auxiliary connections shall be at least DN20 and shall be in accordance with 2.4.1.6.

2.4.3.5 **Replace this clause and its sub-clauses by:**

Auxiliary connections shall not be threaded.

2.4.3.6 **Replace this clause by:**

A pipe nipple, preferably not more than 150 mm long and provided with a welding-neck flange, shall be used for all auxiliary connections which are welded to the compressor. Pipe nipples shall be at least Schedule 80.

Special design individual drain connections to the inner casing of a radially split barrel compressor may be threaded into the inner casing in order to facilitate disassembly of the compressor. The outer casing connections shall be welded.

2.4.3.7 **Replace this clause by:**

Openings in the process gas containing casings that are not connected to piping shall be provided with a blind flange.

2.5 EXTERNAL FORCES AND MOMENTS

2.5.1 Replace the last sentence of this clause by:

For each main process nozzle, the Manufacturer shall furnish in tabular format the following data:

- the maximum allowable forces and moments and combinations thereof for satisfactory continuous operation;
- the maximum allowable forces and moments and combinations thereof under transient conditions such as start-up and (emergency) shut-down;
- expected nozzle movements due to thermal expansion between the cold static and normal full load operating conditions;
- any expected movement in addition to the above as a result of transient conditions.

2.6 ROTATING ELEMENTS

2.6.1 Replace this clause by:

Shafts shall be made of a single piece of forged and heat-treated steel. The shaft shall be forged as close as possible to the final dimensions and then suitably machined. Shafts shall not be made from hot rolled bar stock, except that vacuum re-melted bar may be considered on an individual basis subject to the approval of the Principal.

The application of a built-up rotor construction in axial compressors in hydrocarbon services needs the specific approval of the Principal.

Individual rotor components of axial compressors which have a built-up rotor construction shall each be made of a single piece of forged, heat treated and machined steel.

2.6.3 Add to this clause:

Sleeves shall be made of non-galling materials.

2.6.4 Add to this clause:

The shrink fits of impellers, sleeves, bushings and balance drum shall be adequately maintained under the most adverse conditions that can occur in the compressor in operation, testing, start-up and off-design conditions.

2.6.6 Add to the last sentence of this clause:

" or wear and tear."

2.6.7 From the second sentence of this clause, delete the word "riveted"

Add to this clause:

The mechanical design of the impellers shall have comparable references. The Manufacturer shall demonstrate by means of appropriate calculations (e.g. finite element analysis) that the stress levels in the impellers are within acceptable limits and that the design does not suffer from harmful resonances, excited by any speed harmonic in the machine. If the Manufacturer cannot provide the above evidence, a frequency test shall be performed to confirm that the design is free of any harmful resonances.

The Manufacturer shall demonstrate that all offered impellers in the proposal are within their proven aero-dynamic selection range. If there are not at least three available references in identical or similar services then a specific impeller test may be required at the discretion of the Principal. Model testing is acceptable for this purpose, provided it is done under aero-dynamic and thermo-dynamic similarity conditions and supported by CFD (Computational Flow Dynamics) analysis. The scope of the testing and the proposed test procedures shall be subject to mutual agreement between the Manufacturer and the Principal.

Designs with gas velocities above Mach 0.85 at any location in the compressor are subject to the approval of the Principal.

If the compressor has one or more side stream flows, the Manufacturer shall demonstrate the adequate mixing of the main and side stream flows at the inlet of the relevant impellers, either by at least three references in similar service, through theoretical calculations (CFD) and/or through supporting test results. Taking all transient conditions into account, acceptable temperature and velocity profiles shall be demonstrated to prevail at the impeller inlet. These results shall be submitted to the Principal for approval.

2.6.8 From the first sentence of this clause, delete the word "riveted"

2.6.12 Add to this clause:

Thrust collars shall be hydraulically fitted. Any other assembly method needs the specific approval of the Principal.

2.6.14 Add to this clause:

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

Compressors with in-line impeller arrangements shall have no more than 9 impellers per casing. Compressors with back-to-back impeller arrangements shall have no more than 8 impellers per casing. Compressors with side streams shall have a maximum of 6 impellers per casing in order to have sufficient space for adequate mixing of main and side streams.

Add new clause:

2.6.18 Axial compressor blading

The selected axial compressor rotor and stator blading shall have proven references in similar and/or identical services, otherwise a verification of the blade resonances shall be made. Selected blades shall be subjected to resonance tests to verify the calculated resonance frequencies, modes and interference with possible excitation frequencies.

For each blade row the excitation sources include but are not limited to:

- the blade passing frequency and the related first six harmonics of the rotating and stationary blades two rows upstream and one row downstream of the row in question;
- gas passage splitter frequencies resulting from local flow disturbances;
- irregularities in blade pitch at horizontal casing flanges causing flow disturbances;
- the compressor speed and its first ten harmonics.

The natural frequencies of all blades shall be at least 10 % above or 10% below any possible excitation frequency within the specified operating speed range. By means of Campbell diagrams the Manufacturer shall demonstrate that each blade row meets this requirement. Campbell diagrams shall show corrected blade natural frequencies to reflect actual operating temperatures and speeds.

In addition, (modified) Goodman diagrams shall be submitted for all blades to prove acceptable stress levels.

If interference between a resonance and an excitation frequency cannot be avoided in the design, the Manufacturer shall provide adequate evidence that the stress levels in the material during resonance will remain at acceptable levels under all conditions.

For those cases where axial compressor blade design is based on theoretical Campbell and Goodman diagrams, full scale blade testing on a representative test rig will be required to verify these calculations. A further verification by means of measurement of the actual blade stresses will be required during a full load test of the compressor. Test procedures are subject to the approval of the Principal.

Compressor blade designs which have been verified by means of a complete FEA analysis of the blades, including the stress levels at resonance conditions, are acceptable, but the same testing as above is also required if there are no proven references.

All rotor and stator blades shall be designed for subsonic flow at every specified operating point. Verification is required that at other conditions no transonic flow occurs either. If requested by the Principal the relative Mach numbers of blades shall be submitted for review and shall not exceed 0.85.

The Manufacturer shall demonstrate the insensitivity of the compressor to an imperfect flow velocity profile (aero-dynamic blade performance) and temperature performance and the tolerance of blade tip clearance. Specifically, transient conditions, such as start-up, defrosting, recycle and/or process trip conditions shall be considered.

2.7 BEARINGS AND BEARING HOUSINGS

2.7.1 General

2.7.1.2 **Delete from this clause the words** "Unless otherwise specified"

Add to this clause:

Unless other types are specified on the data/requisition sheets, Platinum (100 Ohm, three-wire) RTDs shall be used for bearing metal temperature detection and be arranged as follows:

- radial bearings shall have two RTDs within the expected load zone
- thrust bearings shall have five RTDs, three on the active side and two on the inactive side. RTDs shall be located in the highest loaded part of the pad.

If tilting pad bearings are used, each RTD shall be installed in a separate bearing pad. As a minimum one RTD of each radial bearing and two RTDs on the active side and one on the inactive side of the thrust bearing shall be connected to the operator display in the main control room and provided with an alarm function.

Add new clause:

2.7.1.3 Bearing metal temperatures measured at a location not more than 10 mm from the bearing surface shall not exceed 110 °C under any load conditions at the maximum specified oil inlet temperature.

2.7.3 Thrust bearings

2.7.3.7 **Add to this clause:**

If requested by the Principal, the Manufacturer shall provide all details of the rotor thrust balance calculations and the associated specific thrust bearing loading.

2.7.4 Bearing housings

2.7.4.1 **Add to this clause:**

Design details of bearing housings which are integral with the compressor casing require approval by the Principal.

Bearing brackets not integral with the casing shall be suitably doweled to the casing and not designed for further internal rotor alignment, once installed at site.

2.7.4.7 **Replace this clause by:**

Unless otherwise specified on the data/requisition sheets, each compressor/driver unit shall be provided with the following:

- two radial vibration displacement type probes at each radial bearing, located at an angle of 90 degrees with each other;
- three axial position displacement probes at each thrust bearing;
- a key phaser; if gearbox transmission is used, key phasers for both high and low speed shafts shall be installed.

Probes and their installation shall be as specified in API 670.

2.8 SHAFT SEALS

2.8.1 Add to this clause:

If rapid de-pressurisation is specified, the Manufacturer shall confirm that the shaft seals and the sealing system are suitable for this and describe the relevant design features.

2.8.2 Delete from this clause the words "when specified,.."

2.8.3 Add to this clause:

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

1) Dry gas seals (to be read in conjunction with DEP 31.29.00.34-Gen.)

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 emission acceptable to the Principal.

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

d) Taking into account the maximum transient flare system back pressure, the pressure at the primary seal is sufficient to ensure an adequate positive differential pressure under all circumstances.

If a) above cannot be met in terms of 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 third seal an intermediate labyrinth and an inert buffer gas should be applied similar to the dual tandem seal configuration.

If b) and/or d) above cannot be met, double face-to-face seals shall be considered, with an inert buffer gas provided between the seals at a pressure higher than the highest pressure at the inner seal, either dynamic or static.

Alternative designs, such as a combination of a single dry gas seal and a back-up seal instead of the above dual tandem seals are subject to the specific approval of the Principal.

Buffer gas shall be an inert gas such as nitrogen. Air shall not 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 executed without a buffer gas supply, but this needs 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 applied and air is used as separation gas, the formation of an explosive gas/air mix as a result of the separation air mixing with the secondary seal leakage shall be avoided as far as possible by using excess quantities of air to maintain the gas/air mixture well above 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 only for clean gas compressors. Because such seals have low seal liquid consumption and adequate static sealing capacity without seal liquid, they are preferred to liquid film seals. Also sudden dynamic pressure fluctuations, which may occur during off-design conditions, have less detrimental effects on this seal type. Pressure-Velocity values of these seals, if selected, shall be subject to the approval of the Principal.

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 used in view of expected fouling by the compressed gas.

4) Other seal types

Labyrinth type seals are preferred for compressors handling non-toxic and non-flammable gases, such as air or nitrogen and are required for oxygen compressors.

The application of restrictive ring type seals is subject to the approval of the Principal.

2.8.3.4 **Add to this clause:**

The connection between the overhead tank and the compressor seals shall be sized and designed such that:

- friction losses are minimal;
- the required static pressure or differential pressure is maintained at the compressor seal rings under the most adverse static or dynamic conditions.

2.8.3.5 **Replace this clause by:**

If self-acting gas seals are specified they shall be in accordance with DEP 31.29.00.34-Gen.

Each dry gas seal assembly, regardless of its arrangement, shall be cartridge mounted. For uni-directional seals, cartridges shall be designed so that incorrect installation of the cartridges is impossible.

In the event of a total seal failure the gas leakage rate to the flare and into atmosphere shall be limited to a maximum level, which shall be agreed between the Manufacturer and the Principal. An appropriate design of the combination of the restrictive labyrinth between dual or triple tandem seals, the labyrinth between the seals and the bearing compartment, and the venting facilities to flare and safe location shall provide maximum confidence that this maximum leakage rate will not be exceeded.

The venting lines to flare and safe location shall be adequately sized to avoid over-pressurising of the seal/bearing housing in case of a major seal failure.

Tandem seal arrangements without an intermediate labyrinth may only be used with the explicit approval of the Principal.

The seal gas shall be filtered in order to remove all liquids and any contaminants that form residues. The seal gas may be taken from the compressor discharge or interstage point. An alternate seal-gas source may be used and/or may be required during start-up or shutdown.

Sealing gas, buffer gas and separation gas shall be filtered to 5 µm absolute or less. Filters shall be double with a full flow transfer valve and valved and flanged drain and vent connections. Filters in a service of ASME rating class 900 and higher shall have double valves for transfer, vent and drain connections. Filters shall be sized to provide at least 4 000 hours of service before replacement and/or cleaning of elements is required.

Filters and all seal gas, buffer gas and separation gas piping after the filters shall be of austenitic stainless steel. If there is possibility of condensation in these systems, both filters and piping shall be suitably heat traced. Alternatively, suitable coalescer separators may be applied.

Details of the seal Manufacturer's shop test as described in Appendix K shall be included in the proposal.

2.8.4 Add to this clause:

The inward leakage from each seal shall be restricted. For shaft diameters less than 100 mm at the seal, the leakage shall not exceed 50 dm^3 per day per compressor end. For larger shafts, the leakage shall not exceed d/2 dm^3 per day per compressor end, where 'd' is the diameter of the shaft at the seal in millimetres. During the mechanical running test and, if specified, the complete unit test, the actual measured inward seal leakage shall be at least 40 % of the above maximum values for each individual compressor end.

2.8.9 Add new clause:

Compressors equipped with mechanical contact type or liquid film type seals shall allow future conversion of the shaft seals into a dry gas seal type. This conversion shall be possible without the need for site machining and/or removal of the compressor casing from its base plate.

2.9 DYNAMICS

2.9.1 Critical speeds

2.9.1.4 **Add to this clause:**

The critical speed and separation margin values resulting from the most unfavourable combination of the parameters under (2.9.2.2) shall be used to verify compliance with the criteria in (2.9.2.5) through (2.9.3).

2.9.1.6 **In this clause, delete the words** "unless the resonances are critically damped"

2.9.2 Lateral Analysis

2.9.2.4 **In the first sentence of item b), replace the words** “Equation 2” **by** “Figure 2”.

Add to this clause:

Note: For Figure 2 reference is made to Figure 2 of API 612.

2.9.2.5 **Replace item b) of this clause by:**

b) If the amplification factor is between 2.5 and 4.01, the separation margin from all lateral modes shall be at least:
   - 20 % above the maximum continuous speed; and
   - 10 % below the minimum operating speed.

In item c) and item d) of this clause, replace “3.55” **by** “4.00”

Add to this clause:

e) Any response resulting from resonance(s) below 54 % of the 100 % speed shall be avoided in the design. If the manufacturer is not able to comply with this requirement, he shall obtain a rotor stability analysis (2.9.2.8) from an independent third party to demonstrate the insensitivity of his rotor design to sub-synchronuous instability.

2.9.2.6 **Add to this clause:**

For compressors equipped with abradable labyrinth seals the Manufacturer’s criteria may be applied.

Add new clause:

2.9.2.8 **Rotor stability**

The Manufacturer shall provide positive evidence to the Principal that the selected compressor will not be subject to any form of aero-dynamic instability. This evidence shall be provided in accordance with the following:

1. For compressors in which the gas density at any point is equal to or greater than 60 kg/m^3, the Manufacturer shall carry out a rotor stability analysis in accordance with (2.9.2.8.1 through 2.9.2.8.3).

2. For compressors in which the gas density at any point is below 60 kg/m^3, the Manufacturer shall demonstrate that the machine is not susceptible to rotor instability by providing a reference of at least three compressors in satisfactory service with equal or higher average gas densities and with similar aero-dynamic geometry (i.e. number and size of impellers, specific loading) and type of shaft seals and with a similar ratio of operating speed to the first critical speed. If the Manufacturer is not able to provide this evidence to the satisfaction of the Principal, he shall carry out a rotor stability analysis in accordance with (2.9.2.8.1 through 2.9.2.8.3).

2.9.2.8.1 The rotor stability analysis shall be performed at rated speed for fixed speed machines and through the speed range from minimum operating speed to 125% of maximum continuous speed for variable speed machines. The analysis shall include at least the following considerations:

- any de-stabilising forces, such as interstage labyrinths, oil seal rings etc.;
- the highest gas density that may be encountered with the specified gas compositions;
- the effects of increased seal clearances on rotor stability by assuming both normal clearances and twice the normal clearances for all close clearance points;
- the effects of varying bearing stiffness on rotor stability by assuming both relatively soft and stiff bearing supports.

2.9.2.8.2 As a minimum, the results of the study shall be presented in the following form:

1. A plot of the calculated log decrement as a function of rotor speed for stiff and soft bearing supports only and for the combination of stiff and soft bearing supports and the de-stabilising effects of any close clearance seal, i.e. a minimum of four cases.
2. A table of the damped natural frequencies for all four cases in 1) above.
3. A table showing the changes of the log decrement in the cases under 1) above with twice the normal clearances of the seals, the balance drum and the bearings.
4. A table of the predominant sources of instability.

2.9.2.8.3 The calculated log decrement shall have a minimum positive value of 0.2 for the worst case scenario of (2.9.2.8.2). For variable speed machines this shall be over the speed range from minimum to maximum continuous speed. If the log decrement at any point is less than 0.2, or in any case where the gas density at any point in the compressor exceeds 100 kg/m^3, the Manufacturer shall demonstrate that the machine is not susceptible to rotor instability. This shall be done by providing a reference of at least three compressors in satisfactory service with similar log decrements, with equal or higher average gas densities with similar aero-dynamic geometry (i.e. number and size of impellers, specific loading) and type of shaft seals, and with a similar ratio of operating speed to the first critical speed. If the Manufacturer is not able to provide this positive evidence to the satisfaction of the Principal, a full-pressure, full-speed test in accordance with (4.3.6.9) shall be carried out in order to verify the log decrement and to demonstrate the stability of the compressor. The selected test gas shall be such that actual specified gas densities are achieved throughout the compressor during this test.

Add new clause:

2.9.2.9 **Rotating stall**

The compressor shall be designed to avoid any tendency to develop rotating stall in any rotating or stationary part. If, at any stage of the compressor, the outlet gas velocity angle of the impeller and/or the inlet velocity angle of the diffuser are outside the proven limits of the specific impeller/diffuser combination, the Manufacturer shall provide positive evidence, in the form of a CFD analysis and/or results of model tests, that rotating stall shall not occur in the respective stages. If required by the Principal, the Manufacturer shall also demonstrate that the impeller/diffuser design complies with the criteria known from internationally accepted publications on this matter (e.g. Kobayashi).

2.9.3 Shop verification of unbalanced response analysis

Add new clause:

2.9.3.5 The Manufacturer may offer an alternative shop verification procedure of the unbalanced response analysis, based on a verification in a high speed balancing installation. This procedure shall be submitted to the Principal for approval.

2.9.4 Torsional Analysis

2.9.4.1 **Replace items (c) and (d) by:**

c. Torsional transients such as switch-on and terminal short circuits of all types of electric motors, as well as the start-up of variable speed motors and synchronous motors.
d. Torsional excitation from variable speed drive systems (VSDS) including the worst case transient operation, and reciprocating engines.

2.9.4.3 **Replace this clause by:**

The following requirements shall apply:

a. Torsional criticals at one and two times the electrical supply frequency shall be avoided for motor driven compressors.
b. Torsional criticals at two or more times the running speeds of all shafts shall be avoided, except where corresponding excitation frequencies are unavoidable on VSDS driven compressors in which case they shall be shown to have no adverse effect.
c. In addition to multiples of running speed, torsional excitations that are non-synchronous in nature shall be considered in the analysis.
d. For the torsional analysis of a VSDS motor-driven compressor the Manufacturer shall identify together with the VSDS Supplier all excitation frequencies and their consequences on the train. These frequencies shall include but not be limited to:
   - non-speed dependent excitations such as ripple;
   - integer harmonics;
   - non-integer harmonics;
   - carrier frequency harmonics;
   - switching harmonics between speed control windows.

2.9.4.4 **Add to this clause:**

The Manufacturer shall submit his procedures for carrying out stress analyses and the corresponding criteria to the Purchaser for approval by the Principal.

2.9.4.5 **Delete from this clause the words** "when specified".

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

In addition to the torsional analyses required in (2.9.4.2 through 2.9.4.5), the Manufacturer shall perform a transient torsional vibration analysis for all electric motor driven units. This shall demonstrate that the transient occurrences in the motor have no adverse effect on the complete train.

The analysis shall consider but not be limited to the following transient load cases:

a. switch-on of electric motors;
b. 2-phase and 3-phase terminal short circuits of motors;
c. pulse operation of variable speed motors;
d. asynchronous run-up on synchronous motors.

2.9.5 Vibration and balancing

2.9.5.4 **Replace this clause by:**

High speed balancing is not required for rotors which have their operating speed range below the first rotor bending critical speed.

Unless otherwise approved by the Principal, rotors operating above the first rotor bending critical speed shall be balanced at high speed in accordance with the following procedure:

High speed balancing:

- After initial low speed balancing each complete assembled rotor shall be run at 114 % of maximum continuous speed in order to promote the proper settling of the impellers on the shaft.
- After this run the rotor shall be balanced at low speed (below 1000 r/min) to a balance quality according to ISO 1940, grade G1.
- Subsequently, the rotor shall be balanced at maximum continuous speed or higher to a balance quality according to ISO 1940, grade G1. In addition, the relative shaft displacement at the location of the bearings shall not exceed the limits of 2.9.5.5. High speed balancing shall be done with bearings which are similar to the contract bearings. The stiffness of the bearing supports of the high speed balancing machine shall be as close as practical to the actual calculated stiffness of the compressor bearing supports.
- After the high speed balancing the residual unbalance of the rotor shall be verified at low speed. It shall be within the limits of ISO 1940, grade G 2.5. If the rotor exceeds this limit and corrections are made, the high speed balancing and low speed balance verification shall be repeated.

Rotors that are balanced in accordance with above procedure are exempted from the residual unbalance requirements of (2.9.5.2).

If the Manufacturer considers alternative and/or additional balancing procedures necessary in order to comply with (2.9.5.5) during the mechanical running test, he shall submit a proposal for approval by the Principal.

2.9.5.5 **Replace the last paragraph of this clause by:**

At any speed greater than the maximum continuous speed, up to and including the trip speed of the driver, the vibration at each probe shall not exceed 150 % of the maximum value recorded at the maximum continuous speed at that probe or a value of 10 µm, whichever is greater.

At critical speeds the overall unfiltered peak-to-peak amplitude of vibration shall not exceed 150 % of the above limit. The maximum allowable casing or bearing housing vibration in any plane shall not exceed a value of 3 mm/s (rms).

2.10 LUBE-OIL AND SEAL-OIL SYSTEMS

2.10.4 Add to this clause:

Selection of the same oil type and viscosity grade for the complete machine train should be considered.

2.10.5 Replace this clause by:

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

2.11 MATERIALS

2.11.1 General

2.11.1.1 **Replace this clause by:**

Materials of construction shall be as specified in the data/requisition sheets. The Manufacturer may offer alternative materials if his experience indicates that these would be a better selection, but these proposed materials shall be suitable for the gas composition(s) given in the data/requisition sheets.

Application of alternative materials is subject to the approval of the Principal.

2.11.1.2 **Add to this clause:**

Equivalent materials in accordance with other internationally recognised standards are acceptable, but any deviation from the originally required ASTM standard is subject to the approval of the Principal.

2.11.1.7 **Replace this clause, including the footnote, by:**

For compressors handling gas containing hydrogen sulphide including trace quantities (25 ml/m^3 or more), all components including associated systems and ancillaries in contact with the gas as well as the external bolting on the casing and seal glands shall comply with NACE MRO175. Ferrous materials not covered by NACE MRO175 shall have a maximum hardness of 248 HV10. This hardness limitation also applies to the heat affected zone of welds. Steel plate materials shall comply with the through-thickness tensile test of ASTM A 770 (S3) and shall have a minimum reduction of area of 35%.

If the pressure rating of horizontally split casings, handling gases containing hydrogen sulphide, require a bolt design exceeding the limitations of NACE MRO175, the Manufacturer may consider a barrel type casing as an alternative to modifying the horizontally split casing design.

2.11.1.9 **Add to this clause:**

Overlays may be applied only if approved by the Principal.

2.11.1.11 **Add to this clause:**

These limitations are only valid for non-welded components. For welded components with a maximum allowable temperature above 200 °C the limitations of NACE MRO175 shall apply.

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

The minimum quality bolting material for pressure joints shall be ASTM A 193 grade B7.

2.11.1.16 **Add to this clause:**

Close tolerance mating parts, such as shaft sleeves, that are made from galling materials and that cannot be disassembled by hydraulic or thermal expansion techniques shall not rely on anti-seizure compound. These items shall have a suitable metallic coating to prevent galling.

2.11.1.17 **Add to this clause:**

The Manufacturer shall specify the supplier, material, grade and shore hardness of all 'O' rings used and demonstrate that the selected materials are suitable for the specified operating conditions.

2.11.2 Pressure containing parts

2.11.2.2 **Add to this clause:**

The Welding Procedure Specifications and Procedure Qualification Records shall be made available to the Purchaser for review and approval upon request.

2.11.2.3 **Add to this clause:**

Destructive mechanical tests, including impact tests if required, shall be carried out on test blocks after all heat treatments have been performed, including those for any repairs.

For weld repairs on fabricated pressure containing parts the following shall apply:

1. Approval by the Principal shall be obtained before any major* weld repair (see definition below) is carried out.
2. All repairs shall meet the inspection requirements and acceptance standards of the original material.
3. Repair procedures for major* weld repairs are subject to the approval of the Principal.
4. Weld repairs shall be suitably heat-treated if this is specified in the relevant material specification. A major* weld repair shall be followed by a suitable heat treatment.
5. Details of all major* weld repairs and the heat treatment shall be recorded and reported to the Principal.

*NOTE: A weld repair is defined as “major” if one or more of the following is true:

- It entails the removal of more than 50% of the wall thickness;
- It extends over a length of more than 150 mm in one or more directions;
- The total surface area of all repairs exceeds 10% of the original surface area.

2.11.2.6 **Replace this clause by:**

Leaks and defects in pressure-containing castings shall not be repaired by peening or burning-in, or by impregnation with plastics or cement compounds. Repair by welding or plugging shall be undertaken only if permitted by the material specification, and then only in accordance with the procedures detailed in (2.11.2.3, 2.11.2.6.1 and 2.11.2.6.2).

2.11.2.6.1 **Replace this clause by:**

Repair by Welding

Weldable grades of castings may be repaired by welding subject to the following criteria:

Items 1 to 6 - as clause (2.11.2.3)

7. The repair welding procedures and the repair welder's qualifications shall be in accordance with ISO 9956/ ISO 9606, EN 287/ EN 288, ASTM A 488, ASME IX or equivalent standard approved by the Principal.
8. Weld repairs shall not be performed on nodular cast iron (ASTM A 395).

2.11.2.6.2 **Replace this clause by:**

Repair by plugging:

1. The need for repair by plugging shall be reported to the Principal before any repair is carried out.
2. Nodular iron may be repaired by plugging within the limits specified in ASTM A 395. The drilled holes for plugs shall be carefully examined by dye penetrant to ensure removal of all defective material.
3. All necessary repairs not covered by ASTM shall be subject to approval by the Principal.
4. Details of all repairs shall be recorded and included in the manufacturing report.

2.11.2.9.1 **Add to this clause:**

Plates from which pressure-containing components are to be cut, forged, rolled or formed in any other manner shall be subject to systematic ultrasonic inspection for laminations in accordance with BS 5996 (Grade L4) or ASTM A 578 (level B).

2.11.2.9.5 **Replace this clause by:**

All welds in the casing, including those in piping attached to the casing, shall be examined radiographically or ultrasonically. See sub-section 2.11.4 for required procedures and acceptance criteria.

2.11.3 Replace this clause by:

For pressure-containing parts that may operate at a temperature of 0 °C or below, the selected material shall fulfil the minimum impact energy requirements specified in DEP 30.10.02.31-Gen.

2.11.4 Replace this clause, and its sub-clauses, by:

2.11.4 Material inspection

2.11.4.1 The material inspection requirements are summarised in the following table; the procedures and acceptance criteria are given in the subsequent sections.

COMPONENT	REQUIRED MATERIAL INSPECTION
Compressor casing – cast	RT (or UT per 2.11.4.2.1), and MT or PT
Compressor casing – fabricated	UT, and MT or PT
Compressor inner barrel	RT or UT, and MT or PT
Compressor fabrication	
-full penetration welds	RT or UT, and MT or PT
-fillet welds	MT or PT
Diaphragms, guide channels	MT or PT, and VI
Labyrinths	VI
Shaft	UT, and MT or PT (see Note 5)
Impellers	RT or UT, and MT or PT, and VI (see 2.11.4.7)
Shaft sleeves, balance piston	MT or PT, and VI
Bearing housing, bearings	VI
Shaft seals	VI
Auxiliary piping	See DEP 31.38.01.31-Gen.

NOTES: 1) VI = Visual Inspection
MT = Magnetic Particle Examination
PT = Liquid Penetrant Examination
RT = Radiographic Examination
UT = Ultrasonic Examination

2) "Casing" includes all items of the pressure boundary of the finished compressor casing (e.g. the casing itself and other parts such as nozzles, flanges, end head, closure plates, shear rings etc.). RT shall be applied on cast casings where the UT does not provide conclusive results.

3) Timing of inspection

- VI/MT/PT shall be performed after final heat treatment in the final machined condition.
- RT/UT of castings may be performed before or after final heat treatment if it is followed by MT/PT after the heat treatment. Otherwise, RT/UT of castings shall be performed after final heat treatment but they need not be in the final machined condition provided that the thickness is not more than 110 % of the final thickness. In any case the radiographic sensitivity indicator (e.g. penetrameter) shall be selected according to the actual thickness.
- RT of welds and UT of fabricated material and welds shall be performed after final heat treatment.
- UT of wrought material shall be performed prior to any machining operations (e.g. for keyways, drilled holes etc.) which may interfere with the UT examination.

4) PT examination shall only be used where MT is not feasible (see 2.11.4.5).

5) Shafts of compressors with a driver rated power above 50 MW shall have a full UT examination.

2.11.4.2 Radiographic Examination (RT)

2.11.4.2.1 RT of castings shall be performed in accordance with ASME VIII, Division 1, Appendix 7. Critical sections of each casting shall be fully radiographed; where such sections cannot be radiographed and/or for wall thickness above 50 mm, UT shall be used (also in accordance with ASME VIII, Division 1, Appendix 7). The Manufacturer shall submit details of the critical sections proposed to undergo RT/UT, for the Purchaser's approval.

2.11.4.2.2 RT of welds shall be in accordance with ASME VIII, Division 1, UW-51. Coverage shall be 100 %.

2.11.4.3 Ultrasonic Examination (UT)

2.11.4.3.1 UT of welds shall be in accordance with ASME VIII, Division 1, Appendix 12. Coverage shall be 100 %. UT of welds shall be performed for weld thicknesses over 30 mm.

2.11.4.3.2 UT of fabricated material shall be in accordance with ASME V, Article 5. The acceptance criteria shall be as follows:

a) Austenitic forgings

Referring to ASTM A 745:

- QL-1 for straight beam with thickness t = 0 to 75 mm
- QL-2 for straight beam with thickness t = 76 to 200 mm or
- QA-2 for angle beam, all thicknesses.

b) Non-austenitic forgings

Referring to ASTM A 388:

- For straight beam examination, back reflection method, no areas shall have a loss of 95 % or more of the reference back reflection.
- For straight beam examination, reference block method, there shall be no indications equal to or larger than the indication received from the reference block constructed with the following flat bottomed holes:

  1.5 mm for t = 0 to 37 mm;
  3 mm for t = 38 to 150 mm;
  6 mm for t = 151 mm and greater.

- For angle beam examination, there shall be no indications equal to or larger than the indication received from the reference notch or amplitude reference line.

c) Plate material

For material inspection during fabrication see (2.11.2.9.1).
After fabrication UT inspection shall be in accordance with ASTM A 577.

d) Tubular material

Acceptance criteria in accordance with ASTM E 213, in which the calibration notch shall take the following form:

- shape shall be rectangular;
- depth shall be maximum 5 percent of the nominal wall thickness;
- length shall be 25 +/-5 mm;
- width shall be no greater than twice the depth.

2.11.4.4 Magnetic Particle Examination (MT)

MT of castings shall be performed in accordance with ASME VIII, Division 1, Appendix 7.

MT of welds and wrought material shall be performed in accordance with ASME VIII, Division 1, Appendix 6. All surfaces shall be examined.

2.11.4.5 Liquid Penetrant Examination (PT)

PT shall only be performed when specified MT is not possible; in which case it shall be done in accordance with ASME VIII, Division 1, Appendix 7 for castings or Appendix 8 for welds and wrought material (all surfaces to be examined).

2.11.4.6 Visual Inspection (VI)

VI shall be performed in accordance with ASME V, Article 9. All surfaces shall be inspected. Acceptance criteria for pressure-containing steel castings shall be in accordance with MSS SP-55. Acceptance criteria for other parts shall be in accordance with the material specification and the Manufacturer's documented procedures.

2.11.5 IMPELLERS

2.11.5.3 **Add to this clause:**

For all impellers the details of inspection techniques and acceptance criteria shall be subject to the approval of the Principal.

Add new clause:

2.11.6 Material certificates

The Manufacturer shall furnish material certificates in accordance with ISO 10474, of the type as specified in the table below.

CERTIFICATION OF MATERIALS BY COMPRESSOR PART

COMPONENT	ISO 10474 CERTIFICATE TYPE
Pressure containing parts (casing, end head and main process nozzles)	3.1.B (see note 1)
Shaft/impellers	3.1.B (see note 1)
Shear rings	3.1.B
Internals - inner barrel, diaphragms, guide channels, labyrinths, shaft sleeves, shaft seals	3.1.B
Bolting	3.1.B
All other process and auxiliary piping, flanges and connections	3.1.B

NOTE 1. Positive alloy material identification (PAMI) shall be applied at the time of assembly to pressure containing parts, rotor shafts and impellers which are made of low-alloy steel, high-alloy martensitic steel, ferritic or austenitic stainless steels or nickel alloys.

This shall be used to positively identify that the materials have the specified alloy composition. The method and procedures are subject to approval by the Principal.

Add new clause:

2.11.7 Marking

Marking is required for all pressure casings. Parts with a wall thickness in excess of 5 mm, except those items manufactured from austenitic stainless steel or from nickel alloys, shall be legibly marked by hard-die stamping onto a painted background at a place clearly visible later. Pipes should be marked at a point approximately 250 mm from one end.

Only low-stress stamps (dot-type or round-nosed with a minimum radius of 0.25 mm) shall be used for hard-die stamping.

For items manufactured from austenitic stainless steel or nickel alloys, and for items with a wall thickness of 5 mm or less, the marking shall be applied by stencil using a water-insoluble ink which contains no injurious substances such as metallic pigments, sulphur, sulphides or chlorides which could attack or harmfully affect the material.

The stamping/marking shall include:

- material Manufacturer's symbol and, where applicable, the independent inspector's symbol; these symbols shall be identical to the symbols on the material certificate;
- material identification;
- heat, charge or batch number to relate to the material certificate;
- heat treatment symbol or code, where applicable;
- non-destructive testing symbol or code, where applicable;
- size and schedule, where applicable;
- hydrostatic test pressure, where applicable.

NOTE: Where the size of the item does not permit complete marking, the above identification marks may be substituted by a unique code that is fully traceable to the material certificate for the item.

SECTION 3 ACCESSORIES

3.1 DRIVERS

3.1.4 Replace this clause by:

Unless otherwise specified, steam turbine main drivers shall be in accordance with DEP 31.29.60.31-Gen. and data/requisition sheet DEP 31.29.61.93-Gen. They shall be capable of continuously developing 110 % of the maximum power required for the Purchaser's specified conditions while operating at the corresponding speed under specified steam conditions (minimum inlet steam condition and maximum steam outlet condition unless specified otherwise).

Steam turbine drivers for ancillaries shall be in accordance with DEP 31.29.60.30-Gen. and data/requisition sheet DEP 31.29.61.95-Gen.

3.1.5 Replace this clause by:

Electric motor drivers shall comply with DEP 33.66.05.31-Gen. and with requisition sheet DEP 33.66.05.93-Gen. The electric motor driver shall be capable of developing continuously at least 110% of the highest kW rating (including gear and coupling losses) required for any of the specified compressor operating conditions or 110 % of the highest kW required at the top of the power curve of the compressor at rated speed (including gear and coupling losses), whichever is the greater. Compressors driven by fixed speed motors shall be started at normal suction pressure, unless otherwise specified by the Principal.

3.1.7 Replace this clause by:

Gas turbine drivers shall comply with DEP 31.29.70.31-Gen. and data/requisition sheet DEP 31.29.70.93-Gen. and shall be sized by agreement between the Principal and the Manufacturer.

All discrepancies between the above specification and the gas turbine proposed by the Manufacturer shall be itemised in a separate section of the proposal.

3.1.8 Replace this clause by:

Speed increasers and reducers shall be in accordance with DEP 31.29.00.32-Gen. and shall be sized for the maximum power and speed of the driver under all specified operating and ambient conditions.

3.2 COUPLINGS AND GUARDS

3.2.2 Add to this clause:

Unless otherwise specified or approved by the Principal, non-lubricated spacer type couplings shall be used.

The coupling to shaft connection shall be rated for a minimum of 125% of the maximum driver power and be able to withstand without any slippage or permanent deformation all maximum transient torques that may occur in the complete unit.

The coupling design shall be such that the full rated torque of the coupling including the API 671 service factor of 1.75 is transmitted by friction only and not by the coupling bolts' shear load.

3.2.5 Add new clause:

Coupling guard temperatures, measured on the outside surface, shall not exceed 90°C. The use of oil spray to achieve this temperature is subject to the specific approval of the Principal.

3.2.6 Add new clause:

Component residual unbalance checks in accordance with API 671, clause 2.5.2.2, shall be

made for couplings with a maximum continuous speed in excess of 5000 rpm or for couplings with a maximum continuous speed in excess of 3000 rpm and a rating in excess of 40 MW.

3.2.7 Add new clause:

The randomly assembled coupling shall be balance verified in accordance with clause 2.5.2.3 of API 671 second edition. The maximum allowed residual unbalance (U) shall not exceed:

$$U = 31750\ W/N$$

where U = residual unbalance (gram-millimetres)
W = static mass (kg)
N = maximum continuous speed (r/min)

3.3 MOUNTING PLATES

3.3.1 General

3.3.1.1 **Replace this clause by:**

The equipment shall be furnished with a base plate.

3.3.1.2.6 **Delete the first sentence of this clause**

Add to this clause:

Mounting plates for offshore installations on steel structures shall be supplied with jacking arrangements to facilitate levelling of the mounting plate. For three point mounting the jacking arrangement shall facilitate the removal, replacement and positioning of each mount. The type of jacking arrangement to be used is subject to the approval of the Principal.

3.3.2 Base plates

3.3.2.1 **Add to this clause:**

Base plates for units for offshore applications shall comply with the following minimum requirements:

1. The complete compressor unit, including gear and driver, shall be mounted on a single lift base plate of structural steel. There shall be no limits to the size of the base plate other than those derived from transportation, installation and/or plant lay-out considerations.
2. Where specified, the base plate shall be designed for a three point mounting, and includes all auxiliary oil and shaft sealing systems.
3. The base plate shall be designed to minimise weight. It shall be subject to a dynamic analysis to ensure that its flexibility will not have adverse effects on the rotor dynamic behaviour of the complete train.
4. The complete unit shall be shipped, mounted on its base plate.

3.3.2.2 **In the first sentence of this clause, delete the words** “When specified,”

3.3.2.3 **Add to this clause:**

For offshore installations, base plates shall be suitable for column mounting.

3.3.2.4 **Add to this clause:**

Deflection while lifting shall not exceed 1:1200.

3.3.2.6 **Add to this clause:**

For offshore installations, base plates shall have machined mounting pads.

3.4 CONTROLS AND INSTRUMENTATION

3.4.1 General

3.4.1.2 **Replace this clause by:**

Amended per Circular 23/99

Instrumentation and connections for instruments shall be in accordance with

DEP 32.31.09.31-Gen and DEP 32.31.00.32-Gen.

3.4.2 Control systems

3.4.2.1 **Add to this clause:**

Capacity control of centrifugal compressors with adjustable inlet guide vanes requires the approval of the Principal and is only acceptable in the case of dry, clean and non-corrosive gas.

Axial compressors may be equipped with adjustable stator vanes for capacity and anti-surge control. For each stator vane setting the polytropic head versus inlet flow performance curve shall be continuously rising in accordance with (2.1.4). Compressor performance curves shall include at least six stator vane positions including the fully open and fully closed position.

Variable stator vane control mechanisms shall be of a proven design. They shall include a positive locking of all components under all operating conditions and provide an accurate stator vane position signal back to the control loop.

Variable stator vane actuators shall be provided with an external visible position indicator.

3.4.2.3 **In item a) of this clause, delete the words** "at the compressor control panel"

3.4.2.5 **In this clause, replace the words** "70 % of the maximum continuous speed" **by** "75 % of rated speed"

3.4.4 Instrumentation

3.4.4.2.1 **In this clause, replace the words** "or liquid filled" **by** "with a stem diameter of 6 mm".

3.4.4.3 **In this clause, replace the words** "Type 300" **by** "316L"

Add to this clause:

Thermowells shall be in accordance with standard drawing S 38.100.

3.4.6 Electrical systems

3.4.6.1 **Delete the last two sentences of this clause**

3.4.6.2 **In this clause, replace the words** “(see 2.1.14)” **by the words** “(see 2.1.15)”

3.4.6.3 **In this clause, replace the word** “wiring" **by the words** "wiring or cabling"

Add to this clause:

Instrument and power wiring or cabling, except for power supply to electric motors, shall be connected to terminal strips installed in terminal boxes. Instrument signals and wiring or cabling with different voltages shall be connected to separate terminal boxes. The terminal

boxes shall be mounted in one central location on the base plate. The location of the terminal boxes shall be shown on the layout drawing.

3.4.6.5 **Delete the second sentence of this clause**

3.4.6.7 **Add to the beginning of this clause:**

The Purchaser shall specify whether cabling or wiring in metal conduits shall be used.

a. When cabling is specified the following shall apply:

   Cables shall be of the metal armoured or braided type. They shall be installed on cable trays properly supported to minimise vibration and be segregated so as to prevent interference between voltage levels.

b. When metal conduits are specified the following shall apply.

3.4.6.8 **Delete this clause**

3.4.7 Vibration, position and bearing temperature detectors

3.4.7.1 **Replace this clause by:**

If supplied, non-contacting vibration and axial position transducers shall be installed and calibrated in accordance with DEP 32.31.09.31-Gen and API 670.

3.4.7.2 **Add to this clause:**

….. as amended/supplemented by DEP 32.31.09.31-Gen.

3.4.7.4 **Add to this clause:**

….. as amended/supplemented by DEP 32.31.09.31-Gen.

Add new clause:

3.4.7.7 All wire entries into the compressor casings or bearing housings shall be provided with proper sealing against leakage.

3.5 PIPING AND APPURTENANCES

3.5.1 General

3.5.1.1 **Add to this clause:**

….. and DEP 31.38.01.31-Gen.

SECTION 4 INSPECTION, TESTING AND PREPARATION FOR SHIPMENT

4.1 GENERAL

4.1.6 In this clause, delete the words " When specified,"

Add new clause:

4.1.8 Inspection by the Purchaser

The Purchaser shall indicate if, and to what extent, he will witness the Manufacturer's inspection and testing. This may include, but need not be limited to, the following:

- a check (against outline drawings which have been approved by the Purchaser) of all main dimensions, base plate dimensions, location of foundation bolt holes, size/position/rating of flanges and coupling guard arrangement;
- an inspection of flange face finish, in accordance with (2.4.2.6);
- a verification that the Manufacturer has performed the specified inspections and tests with satisfactory results;
- a verification of the required material certificates and (to the extent specified) their traceability to the respective components;
- a check of casing wall thickness;
- measurement of the running clearances;
- a visual check for good workmanship and finish of internals;
- verification of taper fits with matched plug and ring set;
- verification of machinery alignment and operability of contract special tools;
- performance and mechanical run testing.

4.2 INSPECTION

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

The Manufacturer shall keep the data listed below available for examination by the Principal or his representative upon request. The data shall be kept for at least 10 years or shall be offered to the Principal thereafter.

4.2.1.5 **In this clause, delete the words** "When specified".

4.3 TESTING

4.3.2 Hydrostatic test

4.3.2.1 **Add to this clause:**

Hydrostatic test shall only be done after final machining of the subject component.

4.3.2.3 **In this clause, replace the words** "50 parts per million" **by the words** "10 mg/kg"

4.3.3 Impeller overspeed test

Add to this clause:

Each complete assembled rotor of an axial compressor shall be subjected to an overspeed test at a speed of at least 115 % of the maximum continuous speed for at least 1 minute to demonstrate the integrity of the rotor.

4.3.4 Mechanical running test

4.3.4.1.1 **Add to the beginning of the second sentence the words** "For oil seals, …"

4.3.4.1.9 **Add to this clause:**

Real time display of vibration and frequency analysis shall be available during the test.

4.3.4.2.1 **Add to this clause:**

Fixed speed electric motor driven compressors may be brought up to speed at once.

4.3.4.2.5 **Replace this clause by:**

During the mechanical running test, the lubricating oil and seal oil temperatures shall be held for a minimum period of 30 minutes at the temperature corresponding to the minimum allowable viscosity, and for 30 minutes at the temperature corresponding to the maximum allowable viscosity. Variable speed compressors shall be checked for correct rotor dynamic behaviour through their full speed range during this temperature variation. Oil pressures and temperatures and bearing temperatures shall be measured throughout the test.

4.3.4.3.2 Replace the third sentence of this clause by:

There shall be **NOT** be any load-dependent sub-synchronous vibration at a frequency corresponding with a rotor resonance. Any other sub-synchronous vibration shall be steady and shall not exceed an amplitude of 3 micrometres peak-to peak.

4.3.4.3.6 **In this clause, delete the words** "when specified"

4.3.4.3.7 **In this clause, delete the words** "when specified"

4.3.4.4.1 **Replace the second sentence of this clause by:**

Only oil film type shaft seals shall be removed for inspection following a successful running test; not mechanical contact type nor dry gas seals.

4.3.4.4.4 **Add to this clause:**

Subject to the approval of the Principal, spare rotors for compressors may be exempted from the mechanical running test, provided the following conditions are met:

- Both main and spare rotors have been balanced at high speed in accordance with the requirements of (2.9.5.4).
- The main rotor has successfully completed the mechanical running test.

4.3.6 Optional tests

4.3.6.1 Performance test

4.3.6.1.1 **Add to this clause:**

The performance test shall also adequately demonstrate the compliance of the aero-dynamic performance with the requirements of (2.1.4).

For side stream compressors a minimum of 8 points on the curve shall be verified.

Compressors with side streams shall have a minimum of 8 temperature probes installed in each stage to determine the stage exit temperatures. At 4 locations of the impeller inlet as well as in the side stream both pressure and temperature shall be measured.

Axial compressors shall have the performance map tested at least 6 stator vane settings, including fully open and fully closed. At each setting 5 points, including surge and overload, shall be measured.

4.3.6.1.6 **Replace this clause by:**

If specified in the data/requisition sheets, multi-section compressors, either in a single or multiple casing, shall be tested per section in accordance with (4.3.6.1). Each section shall comply with the requirements of (2.1.4). Individual sectional head (pressure) tolerances shall be as specified in the data/requisition sheets.

Unless otherwise specified, the combined power of all sections involved shall not exceed the limits of (4.3.6.1.2 through 4.3.6.1.4) at the specified guarantee point, but no individual

section shall exceed 106% of the power value specified for that section.

Compressors with side streams shall have their guarantee points per section as indicated on the data/requisition sheets.

If specified in the data/requisition sheets, multi-section compressors, either in a single or multiple casing, shall be guaranteed and tested for each section in accordance with (4.3.6.1).

Compressors with side streams shall have their guarantee points per section as indicated on the data/requisition sheets.

Add new clause:

4.3.6.1.7 If possible, the contract seals shall be used during the performance test.

Add new clause:

4.3.6.1.8 On applications with dry gas seals, the following flows shall be measured during the performance test :

- dynamic seal leakage during the test;
- static leakage before and after the test;
- seal gas and buffer gas flows;
- separation gas flows.

The dynamic seal leakage measurement shall be performed at a speed and sealing pressure as close as possible to the conditions of the seal Manufacturer's shop test (see Appendix H).

The measured leakage rates may be adjusted for differences in conditions (pressure, temperature and speed etc.) between the performance test and seal Manufacturer's shop test by means agreed between the Manufacturer and Principal prior to the test.

The seal shall be acceptable if the adjusted leakage rates are within 150% of the accepted seal Manufacturer's shop test results and the seal gas and buffer gas flows are within the allowable range.

Add new clause:

4.3.6.1.9 During performance testing the original internal clearances and tolerances shall be maintained; increased clearances of the balance drum and/or other close clearance points with a subsequent performance correction is not permitted.

Add new clause:

4.3.6.1.10 Reynolds number correction in accordance with ASME PTC 10 shall not be made in the calculation of compressor performance for class II or III tests. Alternative Reynolds number corrections and/or dedicated Reynolds correction methods for very high pressure applications may be proposed by the Manufacturer, but shall not be made without the specific approval of the Principal.

Add new clause:

4.3.6.1.11 In the performance test procedure, the Manufacturer shall quantify all flows and correction factors for interstage losses, balance losses and other such losses to be considered. The performance procedure including these calculations shall be subject to the Principal's approval before the actual performance test.

Add new clause:

4.3.6.1.12 Only if the performance test cannot be done in accordance with the ASME PTC 10 requirements and tolerances for class II and class III testing, and if the execution of a class I test is not possible, may the Manufacturer propose an alternative proven test procedure and calculation method; this will require the approval of the Principal.

4.3.6.2 Complete unit test

Add to this clause:

For electric motors with variable speed drive system (VSDS) control, provisions shall be made for torsional vibration measurements during testing to check for torsional resonances and to verify the Manufacturer's torsional analysis; this may be for example with strain gauges on the coupling.

For each component in the train the requirements of 4.3.4 will apply during the complete unit test.

Unless otherwise specified and approved by the Principal, all compressors intended for use in Exploration and Production facilities shall be subject to a complete unit test. Even if the test is not specified, the whole unit shall be completely assembled in the Manufacturer’s works, including all auxiliary equipment and instrumentation in the Manufacturer’s scope of supply. Unless otherwise specified, all control and safeguarding systems for these compressor units, including start-up and shut-down logic systems, either mounted on the machine or in a separate panel, shall be subject to a full functional test. This is irrespective of whether these systems are supplied by the Manufacturer, or free-issued to him. The scope of the testing and the applicable procedures shall be agreed between the Principal and the Manufacturer.

4.3.6.5 Helium test

Replace the words "the maximum allowable working pressure" **by the words** "a pressure of 8 bar (ga)"

4.3.6.6 Sound level test

Replace this clause by:

When specified, a sound level test shall be performed on the equipment in accordance with EEMUA (see 2.1.9.1). The acceptance limits shall be as specified by the Contractor, in accordance with DEP 31.10.00.31-Gen., on data sheet DEP 31.10.00.94-Gen. which forms part of the requisition.

4.3.6.7 Auxiliary equipment test

Add to this clause:

Dry gas seals shall be tested individually at full speed and full pressure at the seal Manufacturer's facilities in accordance with Appendix H.

4.3.6.9 Full pressure/ full-load/ full speed test

Add to this clause:

For each component in the train the requirements of (4.3.4) shall apply during full-pressure/full-load testing.

Unless otherwise specified in the order, the performance of natural gas compressors for exploration and production services shall be guaranteed by the Manufacturer within the

tolerances specified below, when operating under the following conditions:

- driven by the contract driver;
- operating on the actual rated gas composition at specified rated suction pressure and temperature.

1. Fixed speed compressor

a) The differential pressure at rated flow shall be within 0 to +5%.

b) The flow at surge point shall have + 0% tolerance compared to the predicted surge flow.

c) The actual discharge pressure rise from rated flow to surge shall have a -2% to +2% deviation tolerance from the predicted pressure rise.

d) Any side stream discharge pressure at rated flow shall be within a +0 to -5% tolerance.

e) The differential pressure of any side stream suction pressure at rated flow and the compressor rated suction pressure shall be within a +0 to -5% tolerance.

f) The total absorbed power at rated conditions shall have a maximum tolerance of +4%.

2. Variable speed compressor

a) The speed required to achieve the rated operating conditions shall be within -5% and +5%. For reference purposes this speed is defined as “required 100% speed”.

b) At the “required 100% speed” the compressor performance shall be within the tolerances, as specified under 1b through 1f above.

4.4 PREPARATION FOR SHIPMENT

4.4.1 In this clause, replace the words "6 months" **by the words** "18 months".

Add to this clause:

The equipment shall be shipped in the fewest possible number of base plate sections.

4.4.3.10 **Replace this clause by:**

When a spare rotor is ordered it shall be crated in a metal container for transportation and storage. The crating and storage shall be suitable for 4 years’ outdoor storage in the vertical position. The container shall be equipped with facilities for low pressure nitrogen blanketing.

4.4.3.11 **In this clause, delete the words** "When specified"

4.4.3.12 **Add to this clause:**

Exposed shaft ends shall be protected against physical damage.

Add new clause:

4.4.3.13 Where vapour-phase inhibitor (VPI) or silica gel crystals in bags are installed in large cavities, either for inhibiting corrosion or absorbing moisture respectively, they shall be placed so that they can be removed easily. The bags shall be attached with stainless steel wire and their locations indicated with corrosion resistant tags also fixed with stainless steel wire.

Add new section:

SECTION 6 WEIGHT CONTROL FOR OFFSHORE INSTALLATIONS

For all equipment to be installed on an offshore facility, the Manufacturer shall comply with the following requirements.

6.1 INFORMATION WITH THE PROPOSAL

The Manufacturer shall provide in his proposal estimates of the total installed mass of each compressor unit to be supplied. This mass shall include all auxiliaries and appurtenances, regardless of whether they are being supplied separately or installed on the unit. The estimate shall have an upper tolerance of 10% or 10 kg, whichever is the greater. If an order is placed, the Manufacturer may be required to guarantee his mass estimates prior to the order date.

6.2 ENGINEERING INFORMATION

Within four weeks (or any other period, as specified) after the receipt of an order the Manufacturer shall supply the following information to the Purchaser for review and approval:

1. The mass and location of the centre of mass of the compressor and its main driver in the following situations:

- as intended to be shipped, included packing, shipping constraints, lifting equipment etc.;
- as installed, including all auxiliaries and appurtenances;
- in operation, i.e. including the normal contents of process fluid and lubricants.

2. The mass of any auxiliary component or system to be shipped separately.
3. The mass of any component or item included in the scope of supply which has a mass greater than 200 kg.

6.3 WEIGHT CONTROL DURING MANUFACTURING

The Manufacturer shall have an implemented and effective weight control program. The Purchaser shall be notified of any deviation of more than 5% or 5 kg, whichever is the greater, from the original mass estimate of (6.1) above.

The Manufacturer shall be responsible for verifying the correct mass of all components and auxiliaries, as they are completed in his workshop or as they are received from sub-suppliers.

When all masses of significant components have been verified, the Manufacturer shall review his initial mass estimate and confirm or modify the data by re-issuing the information as required by (6.2) above. This shall be done not later than one month prior to the agreed shipping date of the compressor unit.

Upon completion of the complete compressor unit the Manufacturer shall reverify the mass and issue a certificate on the final mass and centre of mass of the unit.

PART IV REFERENCES

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

Amended per Circular 23/99

SHELL STANDARDS

Index to DEPs and Standard Specifications	DEP 00.00.05.05-Gen.
Metallic materials - prevention of brittle fracture	DEP 30.10.02.31-Gen.
Noise control	DEP 31.10.00.31-Gen.
Data/requisition sheet for equipment noise limitation	DEP 31.10.00.94-Gen.
Special purpose gear units for Petroleum, chemical and Gas Industry service	DEP 31.29.00.32-Gen.
Dry Gas Seal systems for centrifugal compressors	DEP 31.29.00.34-Gen.
Data/requisition sheet for centrifugal compressors	DEP 31.29.41.93-Gen.
Special-purpose steam turbines	DEP 31.29.60.31-Gen.
General purpose Steam turbines	DEP 31.29.60.30-Gen.
Lubrication, shaft-sealing and control oil systems for special-purpose application	DEP 31.29.60.32-Gen.
Data/requisition sheet for special purpose steam turbines	DEP 31.29.61.93-Gen.
Data/requisition sheet for general purpose steam turbines	DEP 31.29.61.95-Gen.
Combustion gas turbines	DEP 31.29.70.31-Gen.
Data/requisition sheet for gas turbines	DEP 31.29.70.93-Gen.
Shop and field fabrication of steel piping	DEP 31.38.01.31-Gen
Instruments for measurement and control	DEP 32.31.00.32-Gen.
Instrumentation for equipment packages	DEP 32.31.09.31-Gen.
Electric motors	DEP 33.66.05.31-Gen.
Requisition sheet for electric motors	DEP 33.66.05.93-Gen.

STANDARD DRAWING

Flanged Thermowells – ANS flange class up to 900 incl.	S38.100

AMERICAN STANDARDS

Special purpose steam turbines for petroleum, chemical and gas industry services	API 612
Centrifugal compressors for general refinery services	API Std 617, 6th edition, February,1995
Non-contacting vibration and axial position monitoring system	API Std 670
Special purpose couplings for refinery service	API Std 671

Issued by:
American Petroleum Institute

Publications and Distribution Section
1220 L Street Northwest
Washington DC. 20005
USA

Boiler and Pressure Vessel Code:	
Section V, Non-destructive examination	ASME V
Section VIII, Pressure vessels	ASME VIII
Section IX, Welding and brazing qualifications	ASME IX

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

Alloy steel and stainless steel bolting materials for high temperature service	ASTM A 193
Practice for ultrasonic examination of heavy steel forgings	ASTM A 388
Ferritic ductile iron pressure-retaining castings for use at elevated temperatures	ASTM A 395
Qualification for procedures and personnel for the welding of steel castings	ASTM A 488
Specification for austenitic ductile iron castings for pressure-containing parts suitable for low temperature service	ASTM A 571
Specification for ultrasonic angle-beam examination of steel plates	ASTM A 577
Specification for straight-beam ultrasonic examination v	ASTM A 578
Recommended practice for ultrasonic examination of austenitic steel forgings	ASTM A 745
Specification for through-thickness tension testing of steel plates for special applications	ASTM A 770
Practice for ultrasonic examination of metal pipe and tubing	ASTM E 213

Issued by:
American Society for Testing and Materials
1916 Race Street,
Philadelphia Pa 19103
USA

Quality standard for steel castings - visual method	MSS SP-55

Issued by:
Manufacturers Standardisation Society
of the Valve and Fittings Industry
5203 Leesburg Pike, Suite 502
Falls Church
Virginia 22041
USA

Sulphide stress cracking resistant metallic material for oil-field equipment	NACE MRO175

Issued by:
NACE International
1440 South Creek Drive
Houston, Texas 77084
USA

BRITISH STANDARD

Methods for ultrasonic testing and specifying quality grades of ferritic steel plate	BS 5996

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

EUROPEAN STANDARDS

Approval testing of welders; fusion welding	EN 287
Specification and qualification of welding procedures for metallic materials	EN 288

Issued by:
CEN Secrétariat Central
Rue de Stassart 36
B-1050 Brussels
Belgium.
Copies can also be obtained from national standards organizations

INTERNATIONAL STANDARDS

Quality systems - model for quality assurance in design, development, production, installation and servicing	ISO 9001
Approval testing of welders - fusion welding	ISO 9606
Specification and approval of welding procedures for metallic materials	ISO 9956
Steel and steel products - inspection documents	ISO 10474

Issued by:
International Organisation for Standardisation
1, Rue de Varembé
CH-1211 Geneva 20
Switzerland.
Copies can also be obtained from national standards organizations.

Add new Appendix:

APPENDIX K DRY GAS SEALS TEST PROCEDURE FOR SEAL MANUFACTURER'S SHOP TEST

The seal Manufacturer's shop test shall conform to the following minimum requirements.

1.0 Test Procedure

The test procedure, test gas, acceptance criteria and method for adjustment of results shall be agreed before the test.

2.0 Overspeed Test

Each rotating seal assembly shall be overspeed tested to the same speed and duration as in API 617, clause 4.3.3.

3.0 Static Leakage Test

Each seal face pair shall be pressurised in steps from atmospheric to the corresponding maximum sealing pressure and the stabilised leakage rate shall be checked.

4.0 Dynamic Test

The means for verifying correct lift-off of seal rotating faces shall be agreed and demonstrated.

Each seal face pair shall be dynamically tested over the range of speeds from minimum to normal and maximum continuous. The sealing pressure shall be up to the maximum specified differential pressure for the cartridge; and at least 70% of this maximum for each seal face pair in a multiple seal assembly.

The test duration shall include at least 1 hour at maximum continuous speed and 5 minutes at trip speed (where applicable).

Stabilised dynamic leakage rates shall be checked.

The seal shall be brought to standstill while still pressurised, and the static leakage rate checked whilst the seal is still at operating temperature.

5.0 Post Test Inspection

After completion of the dynamic tests the seal assembly shall be disassembled to the extent necessary for inspection of the seal faces and the other sealing components.

The seals shall be checked for correct re-assembly. This shall consist of a static leakage test as in 3.0 above as a minimum.