

DEP SPECIFICATION

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

DEP 31.29.40.30-Gen.

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DESIGN AND ENGINEERING PRACTICE

DEM1



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PART I INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for axial, centrifugal and expander compressors.

This DEP is based on API Standard 617, 7th edition, July 2002.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual (DEM) 1 – Application of Technical Standards.

This is a revision of the DEP of the same number dated February 2011; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

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

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

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

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

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

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

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

The word **should** indicates a recommendation.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section or clause number is shown in brackets (). Other documents referenced by this DEP are listed in (Part IV).

1.5 SUMMARY OF MAIN CHANGES

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

Section/Clause	Change
2.1.5	Formula change.
2.1.6	Formula change.
Part IV	Added DEP feedback form (DEP 00.00.05.80-Gen.) and DEM1 manual

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
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DEP Standard Form (Other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

PART II GENERAL REQUIREMENTS

Part III of this DEP is written as amendments and supplements to API Std 617, seventh Edition, July 2002.

Wherever reference is made to API Std 617, it shall be understood to mean API Std 617 seventh Edition, July 2002, as amended/supplemented by this DEP.

For ease of reference, the clause numbering of API Std 617 has been used throughout Part III of this DEP.

Clauses in API Std 617 that are not mentioned in this DEP, shall 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 Std 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 under the heading 'Additional Requirements' or stated in the purchase order.

PART III AMENDMENTS/SUPPLEMENTS TO API STANDARD 617

This part covers four chapters of API Std 617:

CHAPTER 1: General Requirements

CHAPTER 2: Centrifugal and Axial Compressors

CHAPTER 3: Integrally Geared Compressors

CHAPTER 4: Expander – Compressors

CHAPTER 1 GENERAL REQUIREMENTS**SECTION 1 GENERAL****1.1 SCOPE**

Replace the first sentence of this clause by:

See Part I, clause 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:

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

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

1.5 DEFINITION OF TERMS

Add new term:

- 1.5.55 minimum pressurization temperature:** The lowest possible temperature of the casing (or container, piping, etc.) at which the casing (or container, piping, etc.) may be pressurized to its design pressure.

Add new term:

- 1.5.56 very toxic substances:** Substances that produce serious harm to health as a result of a single or short-term exposure. Amongst others, as defined in the data/requisition sheets, the following shall be considered very toxic:

- Levels of H₂S exceeding 1,000 ppm mole (vol) in process streams
- Other substances specified by the Principal to be very toxic

1.6 NORMATIVE PUBLICATIONS**1.6.1 Add to this clause:**

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

1.8 UNIT RESPONSIBILITY

Replace this clause by:

- 1.8.1** 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. 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.

- 1.8.2 The Manufacturer shall have an implemented and effective quality system in accordance with ISO 9001. In addition, the Manufacturer shall have an implemented and effective design release system, which indicates and presents any design changes for approval by the Principal.
- 1.8.4 The Manufacturer shall be responsible for co-ordination. This shall include the following as a minimum:
- 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.).
- 1.8.5 The Supplier shall provide a separate quote for factory service technicians to assist the Purchaser during initial installation, commissioning, and startup. This quote shall be provided with the Supplier's final response to the request for proposal (RFP).
- 1.8.6 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 its performance calculations on the gas composition as stated in the data/requisition sheets.

The Manufacturer shall calculate the performance of all proposed compressors using its 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 its original calculation results and agree with the Principal the contractual performance prediction of the compressor.

SECTION 2 BASIC DESIGN

2.1 GENERAL

2.1.1 Performance

2.1.1.3 *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.

2.1.2 *Replace in this clause the words "at least 5 years" by "at least 6 years".*

Add to this clause:

Compressor ratings, components and auxiliaries shall not exceed the limits of the Manufacturer's design and shall be within their 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 h of comparable satisfactory service. In this respect, the Manufacturer shall provide the necessary evidence in his proposal including an end users list.

The compressor shall be designed for a minimum operating period of 12 years between required major overhaul inspections.

2.1.7 *Add to this clause:*

- All left-handed threads shall be clearly marked.
- Any maintenance item with a mass greater than 20 kg (44 lb) 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:*

Floating facilities

Compressor units, including auxiliaries, which are installed on floating facilities 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.

2.1.9 *Replace this clause by:*

2.1.9.1 The Contractor shall communicate the project noise limits in the data requisition sheets. The Manufacturer shall complete datasheet DEP 31.10.00.94-Gen., which forms part of the requisition.

2.1.9.2 Information to be submitted with the Tender: The Manufacturer shall submit expected sound power levels of the equipment.

- The Manufacturer shall indicate what special silencing measures, if any, are proposed in order to meet the specified levels.
- If noise enclosures are supplied, full access to the equipment for operational and maintenance purposes shall be ensured by means of an appropriate design.
- No fire fighting system shall be installed inside the noise enclosure.
- Gas detectors SHALL [PS] be installed in the noise enclosure. The design of the enclosure shall not obstruct any required cooling of the equipment.

2.1.13 *In the last sentence of this clause, delete the words "When specified".*

2.1.14 *Replace this clause by:*

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

2.1.15 *Add to this clause:*

Throughout the service life specified in (2.1.2), spare parts for all components of the unit shall be available for purchase and all manufacturing drawings shall be retained.

2.1.16 *Add to this clause:*

If open loop atmospheric 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 to this operational mode.

Add new clause:

2.1.17 The Manufacturer shall list in its 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 h in operation. Although the Manufacturer has the right to make continual developments in his product line, 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:

2.1.18 In the event of a design or manufacturing error, faulty material, or damage to a critical compressor part, the damaged component SHALL [PS] be repaired or replaced using original manufacturing methods.

- Critical compressor parts include casing (including heads and nozzles), impellers following overspeed, and shafts.
- If repairs of these critical parts are necessary, the repair methods shall be submitted for approval from the Principal. Additional tests or calculations may be required to prove the effectiveness of the repair and that there will be no detrimental effect on the serviceability of the component.

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

2.2 MATERIALS

2.2.1 General

2.2.1.1 *Replace this clause by:*

Materials of construction shall be as specified in the data/requisition sheets. The Manufacturer may offer alternative materials if its 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 approval of the Principal.

2.2.1.2 *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 approval of the Principal.

2.2.1.6 *Replace this clause, including the notes, by:*

For compressors handling gas containing hydrogen sulphide as defined by standard NACE MR0103, all components including associated systems and ancillaries in contact with the gas SHALL [PS] comply with ISO 15156 or NACE MR0103, as applicable.

- HIC (Hydrogen Induced Cracking) tested plate is required for severe sour service

as determined by the Principal.

- Hardness control (within the limits of NACE MR0175/ ISO 15156 or NACE MR0103) of all components in contact with H₂S shall be demonstrated.
- The Manufacturer shall submit all welding procedures including a cross-sectional hardness survey with the appropriate supporting Procedure Qualification Records. The welding requirements shall meet the requirements of NACE.
- Dissimilar metal welds shall not be used in any components in contact with H₂S.
- The stress level of all carbon and low alloy steel components in contact with sour gas shall be limited to 75% of their specified minimum yield strength. The stress level of other steel alloys shall be approved by the Principal.
- External bolting on the casing and seal glands covered by lagging, insulation, blankets, weather shields, or similar coverings shall also comply with ISO 15156 or NACE MR0103.
- Ferrous materials not covered by ISO 15156 or NACE MR0103 shall not have a yield strength exceeding 620 N/mm² (90,000 psi), nor a maximum hardness of 248 HV10 (Rockwell C 22). 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%.
- In dry conditions, as per severity diagram for carbon or low alloy steel (7.2.1.2), NACE MR0175 shall be applied in case of H₂S partial pressure greater than 0.0030 bar (0.0435 psi). In sour service with wet condition with ppH₂S greater than 0.0030 bar (0.0435 psi), the failure risk is due to wet H₂S. The damage mode is related to hydrogen uptake and hydrogen embrittlement. For the reason above, NACE materials shall apply for hydrocarbons gases with ppH₂S greater than 0.0030 bar (0.0435 psi).
- If the pressure rating of horizontally split casings, handling gases containing hydrogen sulphide, requires a bolt design exceeding the limitations of ISO 15156 or NACE MR0103, as applicable, the Manufacturer may consider a barrel type casing as an alternative to modifying the horizontally split casing design.

NOTE: 1 ISO 15156 shall apply to oil and gas production facilities and natural gas sweetening plants. NACE MR0175 is equivalent to ISO 15156.

NOTE: 2 NACE MR0103 shall apply to other applications (e.g. oil refineries, LNG plants and chemical plants).

NOTE: 3 In many applications, small amounts of H₂S are sufficient to require materials resistant to sulphide stress corrosion cracking. When there are trace quantities of wet H₂S known to be present or if there is any uncertainty about the amount of wet H₂S that may be present, the purchaser should consider requiring materials that are resistant to sulfide stress corrosion cracking.

2.2.1.7 *Add to this clause:*

Overlays, including chromium plating, iron plating, plasma spray, impregnation, or similar methods, may be applied only if approved by the Principal.

2.2.1.8 *Replace this clause by:*

Austenitic steels shall not be used in services where chloride stress-corrosion cracking is a possibility.

NACE MR0103 shall apply to other applications (e.g., oil refineries, LNG plants and chemical plants).

2.2.1.9 *Add to this clause:*

These limitations are only valid for non-welded components. For welded components with a maximum allowable temperature above 200°C (400°F), the limitations of ISO 15156 or NACE MR0103, as applicable, SHALL [PS] apply.

2.2.1.11 *Replace this clause by:*

Minor parts (such as nuts, springs, washers, gaskets, and keys) shall have a corrosion resistance at least equal, or superior, to the specified main parts.

2.2.1.12 *Add to this clause:*

If the Manufacturer of studs and nuts specifies anti-seizure compounds, modified torque values shall be included in the manuals. Molybdenum disulphide lubricants shall not be used.

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.

2.2.1.13 *Add to this clause:*

The Manufacturer shall specify the Supplier, material, grade, and Shore hardness of all 'O'-rings, including 'O'-rings used in oil seals and dry gas seals, and demonstrate that the selected materials are suitable for the specified operating conditions.

Unless otherwise specified, the minimum rate of de-pressurisation shall be 80% reduction of the maximum discharge pressure within 15 min.

2.2.1.15 Low temperature

2.2.1.15.3 *In the Note, replace the following words "fluid pumping" by "gas compressing" and "pumped fluid" by "compressed gas".*

2.2.1.15.5 *Add to this clause:*

For pressure-containing parts that can operate at a temperature of 0°C (32°F), or below, proposed materials of construction require the approval of the Principal. All non-metallic components shall be designed for the minimum design temperature specified on the data sheets.

Add new clause:

2.2.2.5 Use of cast iron for non-pressure containing components requires approval of the Principal.

2.3 CASINGS

2.3.1 Pressure-containing casings

2.3.1.1 *Add this clause:*

Pressure containing casings SHALL [PS] not be de-rated from their design MAWP and the applied hydrostatic test pressure shall be selected accordingly.

2.3.1.3 *Delete the words: "or cast iron".*

Add to this clause:

Other materials require the written approval of the Principal.

2.3.1.3.1 *Add to this clause:*

Only ductile cast iron in accordance with ASTM A395 or ASTM A571 may be used.

2.3.1.3.2 *Delete this clause:*

2.3.1.7.3 *Add to this clause:*

Unless otherwise specified, 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 allow the use of such equipment.

2.3.1.7.4 *Replace the first sentence in this clause by:*

The minimum quality bolting material for pressure joints shall be ASTM A 193 Grade B7. For compressors in H₂S service, all internal and external bolting on the casing and piping shall be ASTM A193 Grade B7M with 2HM nuts.

2.3.1.9 *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.

2.3.1.10 *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.

2.3.1.10.1 *Replace the clause by:*

The **Supplier** shall obtain repair approval from the Principal before making a major repair to a pressure-containing part (e.g., casing and head flanges). A major repair, for the purpose of purchaser approval only, is any defect that equals or exceeds any three of the criteria specified below.

- Depth of the cavity prepared for repair welding exceeds 50% of the component wall thickness.
- Cavity" is intended a defect that extends from outer surface toward the internal part of the component.
- Length of the cavity prepared for repair welding is longer than 150 mm (6 in.) in any direction.
- Total area of all repairs to the part under repair exceeds 10% of the surface area of the part.

Add new clause:

2.3.1.10.3 Leaks and defects in pressure-containing castings SHALL [PS] 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 requirements specified in (2.3.1.10.1), (2.3.1.10.3.1) and (2.3.1.10.3.2).

Add new clause:

2.3.1.10.3.1 Repair by Welding

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

- Details of all major weld repairs and the heat treatment shall be recorded and reported to the Principal.
- The repair welding procedures and the repair welder's qualifications shall be in accordance with ISO 15607/ ISO 9606, EN 287/ EN 288, ASTM A488, ASME IX, or equivalent standard approved by the Principal.
- Weld repairs SHALL [PS] not be performed on ductile cast iron (ASTM A395).
- Regardless of the size of the weld repair, any casing of C-1/2Mo, 1-1/4Cr-1/2Mo through to 12 Cr alloy SHALL [PS] be postweld heat treated after repair. Either a local PWHT or a complete casing PWHT shall be performed.

Add new clause:

2.3.1.10.3.2 Repair by plugging:

- Need for repair by plugging SHALL [PS] be reported to the Principal before any repair is carried out.
- Ductile cast iron may be repaired by plugging within the limits specified in

ASTM A395. The drilled holes for plugs shall be carefully examined by dye penetrant to ensure removal of all defective material.

- All necessary repairs not covered by ASTM shall be subject to approval by the Principal.
- Details of all repairs shall be recorded and included in the manufacturing report.

2.3.1.11.1 *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 ASTM A578 (level B) or equivalent approved by the Principal.

To prevent laminar tearing, ASME Section VIII Division I, UG-93 (d)(3) shall be applied to all joints where laminar tearing may become a concern. Inspection methods and acceptance criterion shall be per ASME Section VIII, Division I, Appendix 6 or 8 as applicable.

2.3.1.11.2 *In the last sentence delete the words "When specified".*

2.3.1.11.5 *Replace this clause by:*

All welds in the casing, including those in piping attached to the casing, SHALL [PS] be examined radiographically or ultrasonically. Fillet welds may be examined by magnetic particle or liquid penetrant. See clause (2.3.1.12) for requirements and acceptance criteria.

Residual gauss levels in fabricated steel casings and steel casting that have been weld repaired shall be a maximum of 0.001 tesla (10 gauss).

2.3.1.12 Material Inspection of pressure-containing parts

Replace this clause and its sub-clauses by:

2.3.1.12.1 Material inspection of all major components

Material inspection requirements are summarised in the following table; the procedures and acceptance criteria are given in the subsequent clauses.

Component	Required Material Inspection
Compressor casing – cast	RT (or UT per 2.3.1.12.2.1), and MT or PT; and VT
Compressor casing – fabricated materials	UT, and MT or PT; and VT
Compressor inner barrel	RT or UT, and MT or PT
Compressor fabrication welds:	
-full penetration welds	RT or UT, and MT or PT
-fillet welds	MT or PT
Diaphragms, guide channels	MT or PT, and VT
Labyrinths	VT
Shaft	UT, and MT or PT (see Note 5)
Impellers	RT or UT, and MT or PT, and VT (see 2.3.1.12.6)
Shaft sleeves, balance piston	MT or PT, and VT
Bearing housing, bearings	VT and MT; or UT
Shaft seals	VT

NOTES: 1) VI = Visual Examination
 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 to cast casings where the UT does not provide conclusive results.
- 3) Timing of inspection:
 - VT/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.) that may interfere with the UT examination.
- 4) PT examination shall only be used where MT is not feasible see (2.3.1.12.5).
- 5) Shafts of compressors with a driver rated power above 50 MW (67000 hp) shall have a full UT examination.

2.3.1.12.2 Radiographic examination (RT)

2.3.1.12.2.1 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 (2 in), 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 Principal's approval.

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

2.3.1.12.3 Ultrasonic examination (UT)

2.3.1.12.3.1 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 (1.2 in).

2.3.1.12.3.2 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 A745:

- QL-1 for straight beam with thickness $t = 0$ mm to 75 mm (0 in to 3.000 in)
- QL-2 for straight beam with thickness $t = 76$ mm to 200 mm (3.001 in to 8.000 in) or
- QA-2 for angle beam, all thicknesses.

b) Non-austenitic forgings

Referring to ASTM A388:

- 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 $t = 0$ mm to 37 mm (0 in to 1.500 in);
 - 3 mm for $t = 38$ mm to 150 mm (1.501 to 6.000 in);
 - 6 mm for $t = 151$ mm (6.001 in) 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 (2.3.1.11.1).

After fabrication UT inspection shall be in accordance with ASTM A577.

d) Tubular material

Acceptance criteria in accordance with ASTM E213, in which the calibration notch shall take the following form:

- Shape shall be rectangular;
- Depth shall be maximum 5% of the nominal wall thickness;
- Length shall be 25 mm ± 0.5 mm (1.000 in ± 0.020 in);
- Width shall be no greater than twice the depth.

2.3.1.12.4 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.

2.3.1.12.5 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).

2.3.1.12.6 Visual Examination (VT)

VT 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 ASTM A 802). Acceptance criteria for other parts shall be in accordance with the material specification and the Manufacturer's documented procedures.

2.3.1.12.7 Hardness testing

Welds and associated heat-affected zones shall be hardness tested. This requirement applies to all repair welds and 10% of all production welds made by each welder or welding operator. Hardness shall be in compliance with the requirements of NACE MR0175 and MR0103. Hardness testing shall be done on coupon's created at the same time as the repair or production welds. Hardness testing on new parts shall not be done as this creates stress risers in the parts at the point of testing.

2.3.2 Pressure casing connections

2.3.2.1 General

2.3.2.1.1 *Delete from this clause the words: "except where threaded connections are permitted by 2.3.2.3"*

Add to this clause:

No threaded connection SHALL [PS] be applied for any pressure casing connection.

2.3.2.1.7 *Replace this clause by:*

If required by the compressor Supplier, casing drains shall be provided. If casing drains are provided, the individual drains shall be manifolded into a common drain connection piped at an accessible location.

2.3.2.2 Main process connections

2.3.2.2.3 *Delete this clause*2.3.2.2.3.1 *Replace this clause by:*

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

2.3.2.2.7 *Delete from this clause the words: "When specified".*

2.3.2.3 Auxiliary connections

2.3.2.3.2 *Add to this clause:*

If approved by the Principal, Grayloc and NORSOK flanges may be used on compressor auxiliary connections when standard ANSI flanges interfere with compressor assembly and disassembly. If Grayloc or NORSOK flanges are used at the compressor, actual customer connections shall still be in accordance with ASME standards.

2.3.2.3.3 *Replace this clause by:*

Auxiliary connections shall be welded and flanged or machined and studded. Socket welded connections are not permitted where there is a possibility of crevice corrosion or in applications where there is the potential for cracking. Socket welded connections are not allowed on lube oil and dry gas seal connections. All welded connections shall be full penetration. Openings smaller than DN 25 (NPS 1) shall be reinforced. No casing connection shall be smaller than DN 20 (NPS ¾).

2.3.2.3.4 *Replace this clause by:*

A pipe nipple, preferably not more than 150 mm (6 in) long and provided with a welding-neck flange, shall be used for all auxiliary connections that are welded to the compressor. Pipe nipples shall be at least Schedule 80.

2.3.2.3.4.1 *Delete this clause*

Note: Requirements are covered in clauses (2.3.2.3.1), (2.3.2.3.2), (2.3.2.3.3) and (2.3.2.3.4).

2.3.2.3.5 *Delete this clause*

Add new clause:

2.3.2.4 Openings in process gas containing casings that are not connected to piping SHALL [PS] be provided with an appropriate gasket and a blind flange of the same pressure rating as the corresponding casing connection flange.

Add new clause:

2.3.2.5 Pressure or temperature connections shall not be made in the main process nozzles.

2.5 ROTATING ELEMENTS

2.5.3 *Add to this clause:*

The Manufacturer shall strive to obtain a combined electrical and mechanical runout of less than 6.35 µm (0.25 mils). If the runout is greater than 6.35 µm (0.25 mils), the Manufacturer shall make two additional attempts for a lower limit by burnishing. After two attempts and if the level is greater than 6.35 µm (0.25 mils), the Manufacturer and the Principal shall discuss other methods, e.g., precision grinding, to reduce the runout. If all other methods to reduce the runout have been used and the level is greater than 6.35 µm (0.25 mils), the Manufacturer and the Principal shall agree on a new acceptance criteria.

2.5.5 *Add to this clause:*

Replaceable thrust collars shall be hydraulically fitted and positively locked into position.

2.5.10 Impellers

2.5.10.1 *Replace this clause by:*

Impellers may be closed, consisting of a hub, blades, and a cover; or semi-open, consisting of a hub and blades. Impellers shall be of welded, brazed, milled or electro-eroded construction. Other manufacturing methods (e.g. casting) may be used if approved by the Principal. Each impeller shall be marked with a unique identification number.

Riveted impellers are not acceptable.