

DEP SPECIFICATION

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

DEP 31.29.40.30-Gen.

February 2017

ECCN EAR99

DESIGN AND ENGINEERING PRACTICE

DEM1



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

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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, 8th edition, published September 2014.

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

This DEP is a revision of the same number dated February 2016; 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, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

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

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

1.3 DEFINITIONS

1.3.1 General definitions

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

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

NOTE: In **API STD 617**, the term **Vendor** is used. In this DEP, the term **Vendor** shall be understood to mean the Manufacturer/Supplier.

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.

NOTE: In **API STD 617**, the term **Purchaser** is used. In this DEP, the term **Purchaser** shall be understood to mean 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.

The word **may** indicates a permitted option.

1.3.2 Abbreviations

Term	Definition
CFD	Computational Fluid Dynamics
DGS	Dry Gas Seal
FEA	Finite Element Analysis
PES	Project Execution Strategy
SPEP	Shell Packaged Equipment Solutions

1.4 CROSS-REFERENCES

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

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated February 2016. The only changes are to DEP cross-references to reflect changes in the DEP library in 2017.

1.6 COMMENTS ON THIS DEP

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

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://www.shell.com/standards . Select "Submit DEP Feedback", fill in the online form and submit.
DEP Standard Form (other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

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

1.7 DUAL UNITS

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

1.8 NON NORMATIVE TEXT (COMMENTARY)

Text shown in italic style in this DEP indicates text that is non-normative and is provided as explanation or background information only.

Non-normative text is normally indented slightly to the right of the relevant DEP clause.

PART II GENERAL REQUIREMENTS

Part III of this DEP is written as amendments and supplements to API STD 617, Eighth Edition, September 2014.

Wherever reference is made to API STD 617, it shall be understood to mean API STD 617 Eighth Edition, September 2014, 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 STD 617

This part covers four Parts of API STD 617:

Part 1: General Requirements

Part 2: Nonintegrally Geared Centrifugal and Axial Compressors

Part 3: Integrally Geared Centrifugal Compressors

Part 4: Expander – Compressors

Part 1 GENERAL REQUIREMENTS**3 Terms, Definitions, and Abbreviations****3.1 Terms and Definitions****3.1.19**

Replace definition with the following:

1. Refer to DEP 01.00.01.30-Gen. for determining the minimum design metal temperature.
2. Refer to DEP 31.10.02.31-Gen. for the requirements associated with the minimum design metal temperature.

Add the following new clauses:

3.1.67**Stonewall capacity**

1. The capacity where the decrease in polytropic head is 10 % for an increase of 1 % in inlet volume capacity.

3.1.68**Minimum pressurization temperature**

1. 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.

3.1.69**Very Toxic-acute, -environment, -chronic**

1. Refer to DEP 01.00.01.30-Gen.

3.2 Abbreviations

Add new abbreviations:

1. MCOS Maximum Continuous Operating Speed, also see MCS, clause 3.1.22.
2. AIGV Adjustable Inlet Guide Vane

4 General

4.2 Statutory Requirements

Add the following to this clause:

1. In the event of conflict between documents relating to the inquiry or purchase order, the following hierarchy of documents shall apply:
 - a. First level: Local regulations and statutes
 - b. Second level: Purchase order and variations thereto
 - c. Third level: Data/requisition sheets and drawings
 - d. Fourth level (when indicated in the Purchase Order): PES solution (SPEP)
 - e. Fifth level: this DEP (and by construction, the underlying API document)
2. 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.

Where the Purchase Order indicates a PES solution (SPEP), these conflicts have been approved by Principal during creation of the PES solution and no additional notification is required for those particular conflicts.

4.3 Unit Responsibility

4.3.1

Replace this clause with the following:

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 including the compressor, driver, power transmission equipment and all auxiliary equipment furnished by sub-suppliers.
2. 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.

Add the following new clauses:

4.3.2

1. The Manufacturer shall have an implemented and effective quality system in accordance with ISO 9001.
2. The Manufacturer shall have an implemented and effective design release system, which indicates and presents any design changes for approval by the Principal.

4.3.3

1. The Manufacturer shall be responsible for coordination including the following as a minimum:
 - a. Obtaining information required for fulfilling its obligations;
 - b. Communicating necessary data, specifications and other documents to Sub-suppliers;
 - c. Negotiating interfaces with its Sub-suppliers;
 - d. Standardising all components within the train, its auxiliaries and its utility requirements (such as oil type/grade).

4.3.4

1. The Supplier shall provide a separate quote with the Supplier's final response to the request for proposal (RFP) for factory service technicians to assist the Purchaser during initial installation, commissioning, and start-up.

4.3.5

1. The Manufacturer shall base the performance calculations on the gas composition as stated in the data/requisition sheets.
2. 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.

4.3.6

1. The Manufacturer shall:
 - a. calculate the performance of all proposed compressors using its standard methods for computing the physical properties of the specified gases
 - b. take full responsibility for any design features affected.
2. The Manufacturer shall state the equation of state (EOS) and values of all physical properties of the process gas used in computations.

4.3.7

1. If the data/requisition sheet requires the Manufacturer to calculate compressor performance by means of an alternative computational method (this may include use of an alternative EOS) and the result is a significant difference in the predicted performance of the selected compressor design, the following shall apply:
 - a. the Manufacturer to demonstrate the validity of the original calculation results to the Principal
 - b. the contractual performance prediction of the compressor to be agreed mutually between Principal and Manufacturer

4.4 Basic Design**4.4.1 General****4.4.1.1 Performance****4.4.1.1.3**

Add the following to this clause:

1. The Manufacturer shall confirm the ability of the compressor to operate at all other conditions specified in the data/requisition sheets.
2. The Surge Reference Line and Surge Control Line should be chosen as such that "80% plant throughput" operating points in performance diagram for all normal operating conditions specified in requisition are located on the right hand side of SCL and therefore the Anti-surge control valves are still closed.

4.4.1.2

Replace the first sentence of this clause with the following:

1. The equipment (including auxiliaries) covered by this standard shall be designed and constructed for:
 - a. a minimum service life of 20 years
 - b. to deliver at least 6 years of uninterrupted continuous operation, during which time the equipment will not require shutdown to perform maintenance or inspection

Add the following to this clause:

2. Compressor ratings, components and auxiliaries shall not exceed the limits of the Manufacturer's design and be within their actual experience.
3. The compressor shall be designed for a minimum operating period of 12 years between required major overhaul inspections.

4.4.1.3

Replace this clause with the following:

1. Refer to DEP 31.29.60.32-Gen. for the requirements for the cooling water systems, excluding those on process coolers.

4.4.1.6

Add the following to this clause:

1. 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.

4.4.1.7

Add the following to this clause:

1. All left-handed threads shall be clearly marked.
2. 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).
3. Screw-in eye-bolts may be used only for bearing housing covers and for internal components where other lifting arrangements are impractical.
4. The correct bolt size to be for eye-bolts shall be indicated by:
 - a. permanently marking the hole for the eye-bolt;
 - b. only if field marking is impractical, bolt size information to be clearly indicated in the instruction manual.

4.4.1.9

Add the following to this clause:

1. Compressor units installed on floating facilities, including auxiliaries, shall be capable of accommodating any specified dynamic movement while in transport.
2. Compressor units, including auxiliaries, which are installed on floating facilities or barges, shall be capable of:
 - a. operating at the specified static vessel positions
 - b. operating while accommodating any specified dynamic vessel movements (i.e. pitch, roll, velocity) and deflections

4.4.1.10

Replace this clause with the following:

1. The Contractor shall communicate the project noise limits in the data requisition sheets.
2. The Manufacturer shall complete datasheet DEP 31.10.00.94-Gen., which forms part of the requisition.
3. The Manufacturer shall submit expected sound power levels of the equipment with the proposal, including any special silencing measures necessary to meet the specified levels.

4. If noise enclosures are supplied:
 - a. Full access to the equipment for operational and maintenance purposes shall be ensured by means of an appropriate design.
 - b. No firefighting system shall be installed inside the noise enclosure.
 - c. Gas detectors SHALL [PS] be installed in the noise enclosure, or directly in the exhaust of the enclosure ventilation system.
 - d. The design of the enclosure shall not obstruct any required cooling of the equipment.

4.4.1.11

Replace the words "if specified" with:

1. "Only when specified by Principal"

4.4.2 Speed Requirements

4.4.3

Add the following to this clause:

1. Supplier shall submit vibration acceptance criteria to be used when the equipment is on its permanent foundation (evaluated during commissioning and start-up).
2. If the Supplier does not provide values, "vibration acceptance criteria" shall be the lower of:
 - a. 200 % of the A_{vl} values used during FAT (4.8.2.10).
 - b. 66% of the alarm level

4.4.4

In the last sentence of this clause, delete the words "If specified".

4.4.5

Replace this clause with the following:

1. See (Part 1, 4.4.1.6).

4.4.7

In the first sentence of this clause, replace the words "If specified" with the following:

1. Unless otherwise specified by the Principal,

Add the following to this clause:

1. When open loop, atmospheric air operation is specified in the data/requisition sheets, the Manufacturer shall state in the proposal:
 - a. What modifications, if any, are required in order for the compressor to operate on air.
 - b. What constraints, if any, apply to this operational mode.

Add the following new clauses:

4.4.8

1. The Manufacturer/Supplier shall provide details of proven operational experience of identical or similar machines in service and also list in the 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 a total of 24,000 h in operation.

This is 24,000 hours combined for all machines and not per machine.

2. Although the Manufacturers have the right to make continual developments in their product line, these changes shall be subject to review by the Principal.
3. If the Manufacturer fails to provide evidence of proven reliability, then the Principal should request alternate designs, or initiate design review/development release.

4.4.9

1. In the event of a design or manufacturing error, faulty material, or damage to a critical compressor part, the damaged component shall be replaced or repaired. Where repair is chosen, the following apply:
 - a. The repair method shall be subject to the review and approval of the Principal.
 - b. 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.

Critical compressor parts include casing (including heads and nozzles), impellers following overspeed, and shafts.

4.5 Materials

4.5.1 General

Add the following clause:

1. All repairs to pressure containing parts shall be subject to approval by the Principal.

4.5.1.1

Replace this clause with the following:

2. The Manufacturer may offer alternative materials, subject to approval of the Principal, if its experience indicates that these would be a better selection, provided these proposed materials are confirmed to be suitable for the gas composition(s) given in the data/requisition sheets.

4.5.1.2

Add the following to this clause:

1. Equivalent materials in accordance with other internationally recognised standards may be acceptable, subject to approval by the Principal.

4.5.1.6

Replace this clause and the "NOTES" in this clause with the following:

1. For compressors handling gas containing hydrogen sulfide (H_2S) as defined by standard NACE MR0103, all components including associated systems and ancillaries in contact with the gas SHALL [PS] comply with NACE MR0175 / ISO 15156 or NACE MR0103, as applicable.
 - a. NACE MR0175 / ISO 15156 apply to oil and gas production facilities and natural gas sweetening plants. NACE MR0175 is equivalent to ISO 15156.
 - b. NACE MR0103 applies to other applications (e.g., oil refineries, LNG plants and chemical plants).
 - c. In many applications, small amounts of H_2S are sufficient to require materials resistant to sulfide stress corrosion cracking. When there are trace quantities of wet H_2S known to be present or if there is any uncertainty about the amount of wet H_2S that may be present, the purchaser should consider requiring materials that are resistant to sulfide stress corrosion cracking.
2. Hydrogen Induced Cracking (HIC) tested plate shall be used for moderate sour service as determined by the Principal. Refer to DEP 30.10.02.17-Gen.
3. Hardness control (within the limits of NACE MR0175 / ISO 15156 or NACE MR0103) of all components in contact with H_2S shall be demonstrated.
4. 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 MR0175 / ISO 15156 or NACE MR0103 as applicable.
5. Dissimilar metal welds shall not be used in any components in contact with H_2S .
6. The stress level of all carbon and low alloy steel components in contact with sour gas (such that NACE materials restrictions are imposed) shall be limited to 75 % of their specified minimum yield strength. The stress level of other steel alloys shall be subject to approval by the Principal.
7. External bolting on the casing and seal glands covered by lagging, insulation, blankets, weather shields, or similar coverings are subject to (4.5.1), meaning they have DEM1 requirement to comply with NACE MR0175 / ISO 15156 or NACE MR0103, as applicable.
8. Steel plate materials shall comply with the through-thickness tensile test of ASTM A770 (S3) and shall have a minimum reduction of area of 35 %.
9. In dry conditions, as per severity diagram for carbon or low alloy steel (7.2.1.2), NACE MR0175 / ISO 15156 shall be applied in case of H_2S partial pressure (ppH_2S) greater than 0.0030 bar (0.0435 psi).

In sour service with wet condition with ppH_2S greater than 0.0030 bar (0.0435 psi), the failure risk is due to wet H_2S . The damage mode is related to hydrogen uptake and hydrogen embrittlement.

10. NACE materials shall apply for hydrocarbons gases with ppH_2S greater than 0.0030 bar (0.0435 psi).
11. If the pressure rating of horizontally split casings, handling gases containing hydrogen sulfide, requires a bolt design exceeding the limitations of NACE MR0175 / 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.

12. Refer to DEP 39.01.10.12-Gen. for additional requirements on use of martensitic precipitation hardened material in pressure containing and controlling components.

Note, DEP 39.01.10.12-Gen. has a Process Safety, DEM1 requirement forbidding use of such material for pressure containing or pressure controlling service.

4.5.1.7

Add the following to this clause:

1. Refer to clause 4.5.1.6 , Item 1.a and 1.b

4.5.1.9

Add the following to this clause:

1. Overlays, including chromium plating, iron plating, plasma spray, impregnation, or similar methods, may be applied subject to approval by the Principal.

4.5.1.11

Add the following to this clause:

1. For welded components with a maximum allowable temperature above 200 °C (400 °F), the limitations of NACE MR0175 / ISO 15156 or NACE MR0103, as applicable, SHALL [PS] apply.

4.5.1.14

Add the following to this clause:

1. If the Manufacturer of studs and nuts specifies anti-seizure compounds, modified torque values should be included in the manuals.
2. Molybdenum disulfide lubricants should not be used.
3. 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 should have a suitable metallic coating to prevent galling.

4.5.1.15

Add the following to this clause:

1. The Manufacturer should 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.
2. O rings shall be capable of withstanding a rate of depressurization of 80% of maximum pressure in 15 minutes.

4.5.1.16

Delete "if specified" from the first sentence of this clause.

4.5.1.17

Replace in this clause "if specified" with:

1. Only when specified and approved by Principal.

4.5.1.19 Low Temperature Service

4.5.1.19.2

Delete "if specified" from the first sentence of this clause.

4.5.1.19.3

Add the following to the end of the first sentence.

1. Refer to DEP 01.00.01.30-Gen. for the requirements for determination of the minimum design metal temperature.

Normally, this will be the lower of the minimum surrounding ambient temperature or minimum gas compressing temperature; however, the purchaser can specify a minimum design metal temperature based on properties of the compressed gas, such as auto refrigeration at reduced pressures.

4.5.1.19.6

Add the following to this clause:

1. For pressure-containing parts that can operate at a temperature of 0 °C (32 °F), or below, the proposed materials of construction shall be subject to approval by the Principal.

Add the following new clause:

4.5.1.19.8

1. Refer to DEP 31.10.02.31-Gen. for additional requirements for compressors in low temperature service.

Add the following new clauses:

4.5.1.20

1. NACE materials shall have coupons follow along with project material at all heat treatment steps, and tested to demonstrate material properties to be NACE compliant.

4.5.1.21

1. Refer to DEP 39.01.10.12-Gen. for additional requirements on materials in H₂S environments.

4.5.2 Castings

4.5.2.3

4.5.2.3.2

Delete this clause.

4.5.2.5

4.5.2.5.3

Add the following to this clause:

1. Use of cast iron for non-pressure containing components shall be subject to approval by the Principal.

4.5.2.5

4.5.2.5.3

Add the following to this clause:

1. Use of cast iron for non-pressure containing components shall be subject to approval by the Principal.

4.5.3 Forgings

4.5.3.1

Add the following to this clause:

1. Any material not listed in the Annex D of Parts 2, 3 or 4, shall be subject to approval by the Principal.

4.6 Casings

4.6.1 Pressure-containing Casings

4.6.1.1

Add the following to this clause:

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

4.6.1.3

Delete the text "or cast iron" from this clause.

4.6.1.3.1

Add the following to this clause:

1. Ductile cast iron shall be in accordance with ASTM A395 or ASTM A571.

4.6.1.3.2

Delete this clause.

4.6.1.4

Delete the words "or eye bolts" the third sentence of this clause.

4.6.1.7

4.6.1.7.5

Delete "if specified" from the first sentence of this clause

4.6.1.7.6

Replace this clause with the following:

1. The minimum quality bolting material for pressure joints shall be ASTM A193 Grade B7.
2. For compressors in H₂S service, all internal and external bolting on the casing and piping shall be ASTM A193 Grade B7M with Grade 2HM nuts.
3. See (4.5.1.19) for low temperature requirements.

4.6.1.9

Add the following to this clause:

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

Add new clause:

4.6.1.10

1. Any manufacturing process that uses plugging or welding to manufacture a casing part shall be clearly highlighted in the proposal by vendor.

4.6.2 Casing Repairs and Inspections

4.6.2.1

Add the following to this clause:

1. 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.

4.6.2.2

Add the following to this clause:

1. Refer to (Part III, 4.5.1) for requirements on approval for repairs

4.6.2.3

Add the following new clauses:

4.6.2.3.1

1. 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.
2. Leaks and defects in pressure-containing castings shall be reported to the Principal for approval on plan to correct.
3. Repair by welding or plugging shall be undertaken only if permitted by the material specification, and then only in accordance with requirements specified in (4.6.2.2), (4.6.2.3.2) and (4.6.2.3.3).

4.6.2.3.2 Repair by Welding

1. Weldable grades of castings may be repaired by welding subject to the following criteria:
 - a. Details of all major weld repairs (4.6.2.2) and the heat treatment shall be recorded and reported to the Principal.
 - b. The repair welding procedures and the repair welder's qualifications shall be in accordance with ISO 15607 / ISO 9606, ASTM A488, ASME IX, or equivalent standard approved by the Principal.
2. Weld repairs SHALL [PS] not be performed on ductile cast iron.
3. 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, through either a local PWHT or a complete casing PWHT.

4.6.2.3.3 Repair by plugging

1. The need for repair by plugging shall be reported to the Principal and shall be subject to approval by Principal (before any repair is commenced).
2. Ductile cast iron may be repaired by plugging within the limits specified in ASTM A395 and shall be reported to the Principal.
3. The drilled holes for plugs shall be carefully examined by dye penetrant to ensure removal of all defective material.
4. All necessary repairs not covered by ASTM shall be subject to approval by the Principal.
5. Details of all repairs shall be recorded and included in the manufacturing report.

4.6.2.4

4.6.2.4.1

Add the following to this clause:

1. 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.
2. To prevent laminar tearing, ASME Section VIII Division I, UG-93 (d)(3) should be applied to all joints where laminar tearing may become a concern.
 - a. Inspection methods and acceptance criterion shall be per ASME Section VIII, Division I, Appendix 6 or Appendix 8 as applicable.

4.6.2.4.3

Delete the words "If specified".

4.6.2.4.6

Replace this clause with the following:

1. All welds in the casing, including those in piping attached to the casing, SHALL [PS] be examined radiographically or ultrasonically.
2. Fillet welds (those not covered by 4.6.2.4.6, Item 1) may be examined by magnetic particle or liquid penetrant.
3. See clause (4.6.3) for requirements and acceptance criteria.
4. 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).

4.6.3 Material Inspection of Pressure-containing Parts

Replace this entire section and clauses with the following:

4.6.3.2 Material Inspection Table

1. Material inspection shall be carried out as summarised in the Table 4.1; the procedures and acceptance criteria are given in the subsequent clauses.

Table 4.1 Summary of Inspection of pressure-containing parts

Component	Required Material Inspection
Compressor casing – cast	RT (or UT per 4.6.3.3), and MT or PT; and VI
Compressor casing – fabricated materials	UT, and MT or PT; and VI
Compressor inner barrel	RT or UT, VI 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 VI
Labyrinths	VI
Shaft	UT, VI, and MT or PT (see 4.6.3.1, Item 5)
Impellers	RT or UT, and MT or PT, and VI (see 4.3.3.6)
Shaft sleeves, balance piston	MT or PT, and VI
Bearing housing, bearings	VI and MT; or UT
Shaft seals	VI

NOTES: 1. Material inspection descriptions:

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 (the casing itself and other parts such as nozzles, flanges, end head, closure plates, shear rings etc.).
3. RT shall be applied to cast casings where the UT does not provide conclusive results.
4. Timing of inspection shall be as follows:
 - a. VI/MT/PT performed after final heat treatment in the final machined condition.
 - b. RT/UT of castings:
 - i. before or after final heat treatment if it is followed by MT/PT after the heat treatment.
 - ii. 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.
 - iii. the radiographic sensitivity indicator (e.g., penetrometer) shall be selected according to the actual thickness.
 - c. RT of welds and UT of fabricated material and welds after final heat treatment.
 - d. UT of wrought material prior to any machining operations (e.g., for keyways, drilled holes) that may interfere with the UT examination.
5. PT examination shall only be used where MT is not feasible see (4.6.3.5).

6. Shafts of compressors with a driver rated power above 50 MW (67000 hp) shall have a full UT examination.
 7. Refer to ASME VIII, Division 1, Appendix 7 for acceptance criteria for inspection of castings.
 - a. Critical sections of each casting shall be fully radiographed.
 - b. UT shall be used for the following:
 - i. where critical sections of casting cannot be radiographed
 - ii. for casting wall thickness above 50 mm (2 in).
 - c. The Manufacturer shall submit details of the critical sections proposed to undergo RT/UT, for the Principal's approval.
- 4.6.3.3 Radiographic examination (RT)
1. RT of welds shall be in accordance with ASME VIII, Division 1, UW-51.
 - a. Coverage shall be 100 %.
- 4.6.3.4 Ultrasonic examination (UT)
- 4.6.3.4.1
1. UT of welds shall be in accordance with ASME VIII, Division 1, Appendix 12.
 - a. Coverage shall be 100%.
 2. UT of welds shall be performed for weld thicknesses over 30 mm (1.2 in).
- 4.6.3.4.2
1. 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, as follows:
 - i. QL-1 for straight beam with thickness $t = 0$ mm to 75 mm (0 in to 3.0 in)
 - ii. QL-2 for straight beam with thickness $t = 76$ mm to 200 mm (3.001 in to 8.000 in)
 - iii. QA-2 for angle beam, all thicknesses.
 - b. Non-austenitic forgings, referring to ASTM A388, as follows:
 - i. For straight beam examination, back reflection method, no areas shall have a loss of 95 % or more of the reference back reflection.
 - ii. 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). 1.5 mm for $t = 0$ mm to 37 mm (0 in to 1.500 in)
 - 2). 3 mm for $t = 38$ mm to 150 mm (1.501 to 6.000 in)
 - 3). 6 mm for $t = 151$ mm (6.001 in) and greater
 - iii. 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
 - i. For material inspection during fabrication see(4.6.2.4.1).
 - ii. After fabrication UT inspection shall be in accordance with ASTM A577.

- d. Tubular material, in accordance with ASTM E213, in which the calibration notch shall take the following form:
 - i. Shape rectangular
 - ii. Depth a maximum 5 % of the nominal wall thickness
 - iii. Length 25 mm $\pm$ 0.5 mm (1.000 in $\pm$ 0.020 in)
 - iv. Width no greater than twice the depth

4.6.3.5 Magnetic particle examination (MT)

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

4.6.3.6 Liquid Penetrant Examination (PT)

- 1. PT shall only be performed when specified MT is not possible.
- 2. PT shall be done in accordance with ASME VIII, Division 1, Appendix 7 for castings or Appendix 8 for welds and wrought material.
 - a. All casting, weld and wrought surfaces shall be examined.

4.6.3.7 Visual Examination (VI)

- 1. All surfaces shall be VI inspected in accordance with ASME V, Article 9.
- 2. Acceptance criteria for pressure-containing steel castings shall be in accordance with ASTM A802.
- 3. Acceptance criteria for other parts shall be in accordance with the material specification and the Manufacturer's documented procedures."

4.6.3.8 Hardness Testing

- 1. Welds and associated heat-affected zones shall be hardness tested as follows:
 - a. 100% of all repair welds
 - b. 10 % of all production welds made by each welder or welding operator.
- 2. Hardness shall be in compliance with the requirements of NACE MR0175 and MR0 103 / ISO 15156.
- 3. Hardness testing shall be done on coupons created at the same time as the repair or production welds.
- 4. Hardness testing on new parts shall not be done as this creates stress risers in the parts at the point of testing.

4.6.4 Pressure Casing Connections

4.6.4.1 General

4.6.4.1.1

Replace this clause with the following:

- 1. All connections shall be flanged or machined and studded. All process gas connections to the casing shall be suitable for the MAWP.
- 2. No threaded connection SHALL [PS] be applied for any pressure casing connection.

4.6.4.1.7

Replace this clause with the following:

- 1. If required by the compressor Supplier, casing drains shall be provided.

2. When casing drains are provided, the individual drains should be manifolded into a common drain connection, piped to an accessible location."

4.6.4.2 Main Process Connections

4.6.4.2.6

Add the following to this clause:

1. Ductile or nodular cast iron flanges shall be subject to approval by the Principal.

4.6.4.2.7

Replace this clause with the following:

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

4.6.4.3 Auxiliary Connections

4.6.4.3.2

Add the following to this clause:

1. If approved by the Principal, NORSOK flanges (and possibly other compact flanges) may be used on compressor auxiliary connections when standard ANSI flanges interfere with compressor assembly and disassembly.
2. If flanges other than ANSI are used at the compressor auxiliary connections, actual customer connections shall still be in accordance with ASME standards.

4.6.4.3.3

Replace this clause with the following:

1. Auxiliary connections shall be welded and flanged or machined and studded.
2. All welded connections shall be full penetration.
 - a. Socket welded connections shall not be permitted where there is a possibility of crevice corrosion or in applications where there is the potential for cracking.
 - b. Socket welded connections shall not be allowed on lube oil and dry gas seal connections.
3. Openings smaller than DN 25 (NPS 1) shall be reinforced.
4. Casing connections shall not be smaller than DN 20 (NPS $\frac{3}{4}$).

Delete the following clause and all of its subclauses:

4.6.4.3.8 Requirements for Threaded Connections

Add the following new clauses:

4.6.4.4

1. 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.

4.6.4.5

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