

DEP SPECIFICATION

SHOP AND FIELD FABRICATION OF PIPING

DEP 31.38.01.31-Gen.

February 2014

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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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for shop and field fabrication and testing of piping, which shall also comply with ASME B31.3.

Pipelines fabricated, installed and inspected in accordance with codes such as ISO 13623, ASME B31.4, ASME B31.8, NEN 3650 and PD8010 are excluded from the scope of this DEP. See also DEP 31.40.00.10-Gen. and DEP 61.40.20.30-Gen.

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 September 2013; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any 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 this DEP, the term **Fabricator** is equivalent to **Manufacturer/Supplier**.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

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

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
Hydrogen Service	Process conditions with a hydrogen partial pressure greater than 7 bara (101.5 psia)
Sour Service	"Sour" service and "moderate/high severity wet H ₂ S" service, both of which are defined in DEP 31.38.01.11-Gen.
Very Toxic	Substances as defined in DEP 01.00.01.30-Gen.

1.3.3 Abbreviations

Term	Definition
GTAW	gas tungsten arc welding
HAZ	heat affected zone
HFIB	high frequency induction bending
ITCS	impact tested carbon steel
PWHT	post weld heat treatment
Q+T	quenched and tempered

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 (7).

1.5 SUMMARY OF MAIN CHANGES

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

Section	Change
3.1	Modified requirement of hot work permit as SHALL [PS] requirement.
3.4.2.1	For wet H ₂ S and low temperature carbon steel piping systems, referencing of corresponding DEP specification has been incorporated.
3.4.2.2	For low alloy steel piping systems, welding requirements review and approval requirements have been incorporated.
3.4.2.3	For welding of duplex stainless steel piping systems, referencing of corresponding DEP specification has been incorporated. Also requirements for welding repair have been updated.
3.7	Preservation requirement for flange faces has been updated.
3.8.1.1	Updated requirement for storage of pipe, valves and fittings.
3.12.2.3	Incorporated alternative method for bolt tensioning.
3.12.3	Incorporated provision for the usage of alternative pattern for bolt tightening method.
4.1	Updated requirement of 48 hrs delay for NDE of welds.
4.2.3	IQI requirements have been updated
4.2.4	Updated requirements for UT examination replacement in lieu of RT examination.

4.2.6	Incorporated reference to DEP 30.10.60.18-Gen for ferrite testing.
4.3.1	Updated hardness testing requirement
4.4	Service test requirement for utility nitrogen service has been updated
Appendix-1 (1.1)	Updated SHALL [PS] requirement to normal 'shall' and also incorporated reference to section 1.2 for heat treatment.
Appendix-4	Inspection classes classification table (Table 4.1) has been updated

1.6 COMMENTS ON THIS DEP

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

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

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

1.7 DUAL UNITS

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

2. MATERIAL CERTIFICATION, COLOUR CODING AND TRACEABILITY

2.1 INTRODUCTION

This section specifies the minimum supplementary requirements for material certification, colour coding and material traceability during fabrication and construction.

2.2 RESPONSIBILITY

The Contractor shall be responsible for ensuring that the requirements specified in this DEP are followed.

2.3 GENERAL REQUIREMENTS FOR CERTIFICATION

Minimum certification requirements for materials and final products shall be as specified in the MESC buying descriptions and specifications. In addition to the requirements of MESC, the following also apply:

- a. Material certificates shall comply with ISO 10474 or EN 10204.
- b. The language used in material certificates shall be English. Certificates in other languages are acceptable provided that these are accompanied by an endorsed, stamped and dated English translation of the original certificate.
- c. Certificates for final products (such as welded fittings) shall include certification of the base material and a copy of the welding procedure qualification applied. If the Manufacturer of a semi-finished product and the Supplier of the base material are not the same, the certificate shall consist of two documents covering both stages of the manufacturing process.
- d. Certificates issued by material stockists or agents are not acceptable.

2.4 COLOUR CODING OF PIPING BULK MATERIALS AND MATERIAL IDENTIFICATION CODES

Colour coding of piping bulk materials and material identification codes shall comply with DEP 31.10.00.10-Gen.

2.5 MATERIAL TRACEABILITY

Material certification, colour coding, intake inspection, storage and material handout SHALL [PS] be strictly controlled to exclude rogue materials from equipment and plant.

The Manufacturer/Supplier shall organise its manufacturing process so that material traceability is ensured, in which case positive alloy material identification after material assembly is not required.

To ensure material traceability the following shall be documented in fully implemented and auditable fabrication and/or construction procedures:

Step 1	Material procurement The purchase order shall specify that the Manufacturer/Supplier shall ship the material certificates together with properly marked materials.
Step 2	Material certification and identification Upon material receipt, the Contractor shall verify that materials are properly marked (colour coding and material identification codes in accordance with DEP 31.10.00.10-Gen.) and match the certificates.
Step 3	Strict separate material storage based on material grade Following verification, the materials shall be stored by material grade.

Step 4	Controlled material issue Bulk materials required for construction/fabrication purposes shall be supplied from their storage area by means of a materials issue voucher which clearly identifies the required material grade and for which construction/fabrication item it is required.
Step 5	Strict separation of material grades At the construction/fabrication site materials grades shall be kept strictly separate and identifiable until such time as the fabricated item is complete and the likelihood of rogue materials being substituted is minimised.

Positive material identification (2.6) of the finished products shall be performed if any of Steps 1 through Steps 5 is not followed completely.

2.6 POSITIVE MATERIAL IDENTIFICATION

Positive material identification (PMI) shall comply with DEP 31.10.00.10-Gen.

If (2.5) is not completely adhered to, as well as where the hydrostatic leak test is replaced by a pneumatic leak test as defined in ASME B31.3, PMI tests shall be performed on completed equipment or assembled parts of equipment at such time as to ensure that no material and construction/fabrication changes are made.

The Contractor shall ensure that auditable measures of quality assurance are in place to verify that welds are made with the consumables specified on the WPS, in particular for the root pass of austenitic stainless steel welds. Also, these measures shall ensure that the degree of oxidation that occurs at the weldments in stainless steel, whether applied as solid material or as cladding, is acceptable in accordance with the criteria given in DEP 30.10.60.31-Gen.

2.7 PROCEDURE FOR CONCESSION REQUEST/MATERIAL SUBSTITUTION

If the Manufacturer/Supplier intends to deviate from the originally specified requirements, it shall provide the Contractor in DEP 30.10.02.90-Gen. with a detailed list of the items, copy of a full description, and with all the particulars of intended deviations and the underlying reasons. All deviations shall be subject to the approval of the Principal.

DEP 30.10.02.11-Gen. may be used in considering material substitutions.

3. PIPING FABRICATION, ASSEMBLY AND ERECTION

3.1 GENERAL

Piping fabrication, assembly and erection shall conform to the requirements of the applicable Codes, or ASME B31.3, and also to the requirements specified in this DEP.

Piping will normally be fabricated on the basis of a "Bill of Materials for Piping", which includes isometric drawings, material lists and (where necessary) additional information. For the content of the Bill of Materials for Piping, see DEP 31.38.01.13-Gen.

The piping fabricator shall be responsible for the accuracy of detailed spool drawings and pipe spool fabrication. In case the detailed spool drawings are provided by a design consultant, the piping fabricator shall approve the detailed spool drawings and remain overall responsible for them. Detailed spool drawings shall identify all connecting equipment and also connecting piping systems.

Hot work on site SHALL [PS] be performed only after a valid work permit has been obtained.

All measures shall be taken to ensure correct positioning and sizing of the components to be welded.

If any fabrication is to be carried out in the vicinity of equipment already installed then, before such fabrication work commences, adequate protection shall be provided to prevent any damage from weld spatter, flame cutting droplets, etc.

Care shall be taken to avoid overloading, damage or undue deformation in any of the piping components at all stages of the work.

3.2 CUTTING AND BEVELLING

Cutting and bevelling shall be in accordance with DEP 30.10.60.18-Gen.

In addition to the above, the following welding requirements shall apply:

- a. Weld bevels for butt welds of pipes and fittings shall be in accordance with ASME B16.25.
- b. Shop-bevelling of field welds is not required if a make-up length (extra length for field cutting to size) is provided. In these cases, bevels shall be prepared after cutting the relevant pipe spool to the required length.
- c. Cutting oil shall be removed.
- d. Grinding wheels for stainless steel shall be resin bonded alumina or silicon carbide. Rubber bonded wheels shall not be used. Wheels shall be dedicated to a single material grade and the fabricator shall ensure wheels used on one material grade are not subsequently used on another grade.
- e. Wire brushes for stainless steel shall be stainless steel. Wire brushes shall be dedicated for use on a single material grade, and the Fabricator shall ensure brushes used on one material grade are not subsequently used on any other material grade.

NOTE: Especially contamination of the surface by use of carbon steel tools, tools previously applied on carbon steel equipment or presence of carbon steel particles can reduce the corrosion resistance of CRAs.

- f. Galvanized materials shall be cut using 'cold' cutting methods.
- g. Pipes for socket weld joints shall be cut square and burrs removed.

3.3 ASSEMBLY OF PIPING COMPONENTS

For butt-welding of all piping components (e.g., pipe ends, fittings and welding neck flanges), a uniform root gap shall be provided as specified in the relevant Welding Procedure Specification.

Clamps, holding devices, etc., shall be used to avoid tack welding in the groove. If the type of holding device used for fit-up requires welding onto structural steel, such temporary attachments shall be made with the same welding procedure specification as for a permanent weld in the structural member. Alignment equipment shall remain in use until both the root pass and hot pass are complete. Attachment welding onto pipe, flanges or fittings is not allowed. Bridge tacks are allowed for small diameter piping (DN 40 and below (NPS 1 ½ and below)).

Branch connection cut-outs shall be carefully bevelled and accurately matched to form a suitable groove for welding and to permit complete penetration of the welds at all points.

Flange bolt holes shall straddle the vertical centreline of the pipe where the flange is installed vertically, and the piping isometric/piping arrangement drawing north-south line where the flange is installed horizontally.

Refer to DEP 31.38.01.11-Gen. for flange misalignment acceptance criteria.

Spacing and orientation of welds shall be in accordance with clause 4.7.4.2 of DEP 30.10.60.18-Gen.

When pneumatic leak test in accordance with ASME B31.3, para. 345.4 is performed in lieu of hydrostatic leak test, the minimum spacing of the longitudinal welds SHALL [PS] be followed.

If the pipe contains a longitudinal weld, this weld SHALL [PS] not be located at the bottom of the pipe after installation; it should be located at least 45° from the bottom of the pipe.

In order to avoid excessive shrinkage stresses during weld solidification, a gap SHALL [PS] be left between the end of the pipe and the stop of the socket-welding component in accordance with ASME B16.11. Failure to include this gap can lead to premature piping failures.

Pipes that are required to be free of scale shall be blast cleaned before further handling by the welding shop.

Radial grooves or scratches on flange faces exceeding limits specified in ASME B16.5, Table 3 are not allowed. Refacing will require the Principal's approval. Any refacing that would reduce the flange thickness to less than the minimum thickness allowed by the relevant code or standard is not allowed. Edge thickness of flanges shall be checked after re-facing.

Where the spool drawings indicate a "field weld" in the pipe, the relevant sections shall be supplied 200 mm (8 in) longer (minimum) with plain ends.

3.4 WELDING

3.4.1 General

All welding shall be in accordance with DEP 30.10.60.18-Gen. and ASME B31.3.

In addition to the above, following welding requirements shall apply:

- a. Before welding is commenced, cutting oil shall be removed.
- b. Impact test requirements for welding procedure qualification for carbon steel and duplex stainless steel process piping operating at design temperatures below 0 °C (32 °F) shall be in accordance with DEP 30.10.02.31-Gen.
- c. For stainless steel piping without back welding of the internal side, the root pass shall be carried out by the GTAW process with an inert gas purge, which shall be maintained until completion of the second pass.
- d. Weld connections for soft seated welded valves and steam traps shall be in accordance with (Appendix 3).
- e. Where socket welded joints are used, a minimum of two weld passes shall be applied on each socket weld.

- f. On carbon steel materials a root pass with a flat profile (< 2 mm (0.08 in) penetration) without undercut and without crevice is required for piping > 6 mm (1/4 in) thick in the following services:
- sour / wet H₂S service;
 - corrosive service;
 - severe cyclic service
- g. On stainless steel materials a root pass with a flat profile (< 2 mm (0.08 in) penetration) without undercut and without crevice is required for piping > 6 mm (1/4 in) thick in the following services:
- corrosive service;
 - in high temperature service - design temperatures above 427 °C (800 °F);
 - Where it is identified on specifications or drawings.

3.4.2 Additional requirements for welding of piping systems

3.4.2.1 Welding of carbon steel and fine grain carbon steel piping systems

For piping systems in high wet H₂S or sour service, the Welding Procedure Qualification SHALL [PS] be done on carbon steel base metal of same grade as used in production welding. The weld metal deposit shall not contain more than 1.00 % nickel. Welding procedure specification and procedure qualification shall also meet the requirements of DEP 30.10.02.15-Gen and 30.10.02.17-Gen.

For fine grain carbon steel piping systems, the Welding Procedure Qualification SHALL [PS] be impact tested at a temperature of minus 50 °C (minus 58 °F), minus 46 °C (minus 50 °F) for weldments with wall thickness greater than 50 mm (2 in), with the following acceptance criteria:

- a. Impact test results as an average of three tests of at least 27 J for standard size specimens (10 mm (3/8 in) x 10 mm (3/8 in)). Only one result may be lower than 27 J, but not lower than 21 J. A multiplication factor of 1.5 applies to impact values for sub-size specimens, as defined in Table 4 of ASTM A 333.
- b. Alternatively, the impact tests may be carried out at minus 46 °C (minus 50 °F) with impact values of at least 33J for standard size specimens.

Welding procedure specification and procedure qualification shall also meet the requirements of DEP 30.10.02.31-Gen.

3.4.2.2 Welding of low alloy steel (1 ¼ Cr – ½ Mo) piping systems

The deposited weld metal, from each lot or batch of welding electrodes and each heat of filler wires, and each combination of filler wire and flux, shall match the nominal chemical composition of the base metal to be welded.

The following chemical composition limits shall be controlled to improve resistance to reheat cracking. The chemical composition restriction applies to the heat analysis.

$$X\text{-bar} = (10P + 5Sb + 4Sn + As) / 100 \leq 12$$

Where,

P, Sb, Sn, and as are in ppm

C is 0.15 % maximum

Cu is 0.20 % maximum

Ni is 0.30 % maximum

Low hydrogen welding consumables, including fluxes, having a maximum of 8 ml of diffusible hydrogen for every 100 g (0.22 lbs) of weld metal, per AWS A4.3, shall be used.

They shall be baked, stored, and used in accordance with the Manufacturer's instructions (holding in electrode oven, length of time out of oven, etc).

For all services, welding requirements shall be reviewed and approved by Principal.

3.4.2.3 Welding of (super) duplex stainless steel piping systems

Welding of (super) duplex stainless steel piping systems shall be performed in accordance with Annex. E of DEP 30.10.60.18-Gen and DEP 30.10.02.35-Gen

The following additional requirements shall be adhered to so as to ensure that the (super) duplex welds meet the intended quality requirements:

- a. Hardness testing test SHALL [PS] be performed per API TR 938-C Section 4.4.
 - For UNS S31803 and S32205, the measured hardness shall not be above 310 HV average, with no reading over 320 HV.
 - For all other grades of duplex stainless steel, the measured hardness shall not be above 350 HV average, with no reading over 360 HV.
- b. Impact test SHALL [PS] be performed as follows :

For Charpy V notch impact tests of the weld metal and HAZ, three specimens for each location are required. The following values are required for full-size specimens:

- For 22Cr grade
 - Weld Metal: 34 J (25 ft-lbs) average and 27 J (20 ft-lbs) minimum at -40 °C (-40 °F)
 - HAZ: 54 J (40 ft-lbs) average and 43 J (32 ft-lbs) minimum at -40 °C (-40 °F)
- For 25Cr grade
 - Weld Metal: 70 J (52 ft-lbs) average and 65 J (48 ft-lbs) minimum at -50 °C (-46 °F)
 - HAZ: 70 J (52 ft-lbs) average and 65 J (48 ft-lbs) minimum at -50 °C (-46 °F)

The orientation of standard size specimens shall be per ASME/BPVC Sec VIII DIV1, UG84. In addition, the weld metal impact specimen shall be removed from the T/2 (mid-wall) position. Furthermore, the HAZ impact specimen location may need to be adjusted to ensure the notch is completely in the HAZ but should be as close as feasible to the T/2 position.

The lateral expansion shall be 0.38 mm (0.015 in) minimum. For 25Cr DSS this value should be obtained at 0.

- c. Back welding to repair any mismatch (Hi/Low) is not permitted, unless the backwelding procedure is covered by a qualified PQR.
- d. Each type of repair SHALL [PS] be separately qualified, including partial penetration and cap repair, with the following additional items required for the WPS :
 - the method of excavation
 - the nondestructive examination (NDE) techniques applied to ensure removal of defects.

Through-thickness repairs are not permitted.

- e. For the qualification of fillet welds, attachment welds and weld cap repair, only metallurgical (microstructure test, detrimental phases examination and pitting corrosion test) and hardness testing is required, provided they are welded with the same consumables as qualified in a butt weld PQR.

- f. In addition to the mechanical tests for PQR validation, metallurgical tests also are required on an intermetallic phase count. The PQR is acceptable when the content of sigma phase does not exceed 0.5%, while the total of all intermetallic phases does not exceed more than 1.0%.

3.4.3 Dissimilar weld joints

The most commonly used dissimilar welds can be classified as follows:

- a. Dissimilar weld joint type-1: P No. 1 to P No. 4/P No. 5/P No. 9 (Carbon steel to low ferritic low alloy steel)
- b. Dissimilar weld joint type-2: P No. 1 to P No. 8 (Carbon steel to austenitic stainless steel)
- c. Dissimilar weld joint type-3: P No.4/P No.5 to P No. 8 (ferritic low alloy steel to austenitic stainless steel)
- d. Dissimilar weld joint type-4: For all other types of dissimilar weld joints

Dissimilar welds may be proposed as piping class break without Principal approval provided:

- a. Dissimilar weld joints type-1 and type-3 (P No.1 to P No.4 / P No.5 or P No.4 / P No.5 to P No.8): The thickest part of the weld or base metal does not exceed 19 mm (3/4 in). P No.1 to P No.4 / P No.5 welds shall be stress relieved.
- b. Dissimilar weld joints type 2 (P No.1 to P No.8): The upper design temperature does not exceed 350 °C (660 °F), effective thickness of the weldment does not exceed 19 mm (3/4 in) and the fluid service is non corrosive.

For dissimilar weld joints of type-4 and all situations outside the above mentioned limitations a prior approval by the Principal is required.

All dissimilar welds shall be maintained in dissimilar weld register. As a minimum dissimilar weld register shall contain the following information:

- a. Weld identifier
- b. Relevant drawing identifier (PEFS / MEFS /isometric or equipment fabrication drawing)
- c. P numbers of the alloys to be welded and brief description of the weld
- d. Applicable welding procedure identifier (includes the name of the organization, which welded such weld.)

Dissimilar weld joints shall be designed in accordance with Annex K of DEP 30.10.60.18-Gen.

3.4.4 Repair of defects

Injurious surface defects shall be completely removed by grinding. The ground out area shall be repaired by welding if defect removal results in reduction of pipe wall below minimum thickness. The repaired area shall be ground smooth to the pipe contour.

All repairs shall be executed by qualified welders according to approved welding procedures and all requirements of this DEP shall be met.

The removal of weld metal or portions of the base metal may be done by machining, grinding, chipping, oxygen gouging or air carbon-arc gouging.

- a. The unacceptable portions of the weld shall be removed without substantial removal of the base metal and shall be done in such a manner that the remaining weld metal or base metal is not nicked or undercut.
- b. Where carbon arc gouging is used, the edges shall always be ground to remove the hardened surface.
- c. The grooves shall be free from scale, and shall have acceptable contours and shall

be visually and magnetic particle/liquid penetrant examined prior to rewelding, to ensure the defect has been completely removed.

Additional weld metal to compensate for any deficiency in size shall be deposited using procedures as required in the making of the original weld. The surfaces shall be thoroughly cleaned before depositing the additional weld metal. Local repairs shall be inspected 100% by the method prescribed for the original weld with due regard to confirming that the original defect has been removed.

Every possible care shall be taken with repairs to minimize welding stresses.

If planar defects (cracks, lamellar tears, etc.) have to be repaired, every effort shall be made to prevent propagation of the defect during its removal. During the final stages of removal, grinding (not gouging) shall be used. Magnetic particle/liquid penetrant examination shall be carried out to confirm the complete removal of the defect.

Fabricator or Manufacturer shall not repair any repeated injurious defect without the Principal's written approval. Unless otherwise specified, surface defects are considered injurious if the defect extends below the specified minimum wall thickness or is more than 1.6 mm (0.06 in) in depth.

Weld defects shall be repaired in accordance with the requirements of relevant design code.

DSS and SDSS are required to have repair weld procedures qualified covering all repair scenarios. No through thickness repairs are permitted. (Super) duplex stainless steels shall only be subject to 1 weld repair, unless otherwise agreed with the Principal.

3.4.5 Compressor piping system spool fabrication

Butt-welding components shall be lined up accurately and weld roots shall be ground smooth wherever possible. To prevent damage to valves and compressor from welding slag, following options shall be considered:

- a. Gas tungsten arc welding (GTAW) should be used for the root pass of welds. GTAW shall be used for the root pass of welds if it is not possible to grind the root smooth.
- b. Alternatively, chemical cleaning of compressor pipe work shall be considered.

3.5 POST WELD HEAT TREATMENT

Post weld heat treatment (PWHT) methodology and procedure shall be in compliance with the requirements of DEP 30.10.60.18-Gen.

Prior to the start of fabrication, the PWHT procedure shall be submitted for review by the Principal. The PWHT procedure shall include information on heating and cooling rates, maximum thermal gradients, and calibration of thermocouples, thermocouple locations and method of their attachment.

3.6 FINISHING OF SURFACES AND MARKING OF PIPE SPOOLS

Post-fabrication, all welds shall be ground smooth as and when indicated in the welding procedures or on the drawings to allow proper radiographic or ultrasonic examination, and to remove all detrimental spatters, burrs, tack welds and other marks.

Each pipe spool shall be clearly marked with identification shown on the fabrication drawing.

3.7 SHIPPING AND PRESERVATION

Preparation for shipping is a critical operation which shall be witnessed and reported through Contractor's quality assurance systems.

Painting for onshore/offshore applications shall comply with DEP 30.48.00.31-Gen.

Painting requirements should be shown on the line list; see data sheet for piping, DEP 31.38.01.92-Gen. Pre-fabricated pipe spools shall be properly protected against corrosion and damage during storage and transport to site.

Preservation of piping systems and components shall be in accordance with 7.2 (static equipment and piping) of DEP 70.10.70.11-Gen., with the following additions:

- a. Flanges shall be fitted with flange protectors, including a proven protection against corrosion for the flange opening and facing. Flange protectors in direct contact with flange faces shall not be of a porous (e.g., wood) material.
- b. Plain and bevelled pipe ends shall be provided with plastic covers. Covers shall be designed so that they have to be removed before piping is installed.
- c. Threads and other machined surfaces shall not be painted and shall be protected during surface preparation and painting. Machined and threaded parts shall be coated with grease or other suitable material as required to prevent corrosion.
- d. Small bore branches and small header attachments shall be adequately braced or otherwise protected to prevent damage during handling, shipping and storage.
- e. Openings in pipe spools shall be sealed to prevent water and other foreign materials from entering during transit and storage.
- f. Socketweld and threaded ends shall be fitted with taped commercial polyethylene caps or plugs. When installed, plastic plugs shall not be painted, so that they are clearly identifiable as temporary plugs.
- g. Valves shall be stored in a manner that will prevent dirt and rain from entering the valve seat and / or body or packing box in order to eliminate the potential for fouling, corrosion and ice build up. Valves DN 50 (NPS 2) and smaller shall be stored indoors. Tightly fitting plastic flange covers or plastic plugs are required.

This practice shall be checked during the quality assurance audits. If more than six months is expected between shipment of shop fabricated spools and field erection, flange faces shall be protected against corrosion by means of an enduring method. An example of this is to flash coat with a primer coating.

Stainless steel weldments shall be pickled and passivated in accordance with DEP 30.10.60.31-Gen. if specified by the Principal.

3.8 INSTALLATION

3.8.1 Storage and handling

3.8.1.1 Storage

Pipe, valves, and fittings shall be stored in a manner that protects them from potentially harmful environments. They should not be stored directly on the ground.

Stacking shall be done in a manner to avoid damage to pipes or coatings.

End protectors on flanges, weld bevels, threads, and socket ends shall be firmly attached.

3.8.1.2 Handling

All material shall be handled with care to prevent damage.

Lined and coated pipe and fittings shall be lifted with wide fabric or rubber-covered slings.

3.8.2 Assembly

3.8.2.1 Threaded joints

Threads shall conform to the requirements of ASME B1.20.1.

Pipe ends shall be reamed clean after threading.

Thread joint sealant shall be applied to the male ends only and in a manner that will prevent the compound from reaching the interior of the pipe. Manufacturer's instructions shall be followed.

Where threaded pipe joints are used (see DEP 31.38.01.11-Gen. for application and restrictions to the use of threaded joints), a thread sealant/lubricant shall be used on the pipe threads of all connections to ensure the threads are tight. Austenitic stainless steel, (super) duplex stainless and nickel base alloy threaded piping joints shall not contain copper or zinc in the thread compound. Only nickel-based lubricants shall be used.

Seal welding of threads shall comply with all requirements in ASME B31.3 and shall consist of 2 passes with rotating starts and stops.

Seal welds shall have a minimum welding dimension Cx in Figure 328.5.2C of ASME B31.3 and the seal weld shall meet all the welding qualification requirements in ASME B31.3 for an equally sized socket weld.

Seal welding of threaded connections shall not be performed where subsequent heat treatment other than post weld heat treatment is required.

Seal welds shall be examined by magnetic particle or liquid penetrant methods.

Threaded connections in Category N or Category M fluid service shall be leak tested with soapy liquid, leak spray or by Nitrogen/Helium sensitive leak testing.

3.8.2.2 Flanged joints

Assembly of flanged joints shall be in accordance with (3.12).

In addition to the above, the following requirements shall apply:

- a. Flanges with damage exceeding the limits specified in Appendix D of ASME PCC-1 shall be replaced.
- b. Flange bolting shall be installed with lubricant compound on the threads and nut faces (except where service explicitly does not allow). No compound or tape shall be applied to flange faces or gaskets.

3.8.2.3 Valves

Valve manufacturer's installation instructions, including bolt torque for the end flanges and gland flange, shall be followed.

Valve handles shall be oriented as shown on the piping isometric / layout drawing,

3.8.3 Erection

Piping shall be erected and supported in a manner that will not put undue strain on pumps, compressors, tanks, vessels or other equipment.

The procedure for connection of piping to equipment shall be as follows:

- a. After the equipment has been set, the pipe shall be connected to the equipment without making any tight connections to flanges.
- b. Flanges shall be checked to assure that no undue strain is induced on the equipment. If pipe is not in correct alignment, it shall be removed and corrected. Alignment corrections shall not be made while the pipe is connected to the equipment.

Piping that has been painted prior to erection shall be handled with care to avoid damage to coatings. Slings protected with fabric or hose sleeves shall be used for lifting. Rollers shall be used for lengths that will be pulled over supporting steel.

Gaskets required for service shall be used during hydrostatic pressure test.

Piping shall be erected in accordance with the piping isometric drawings/piping layout drawings.

Detailed drawings and Manufacturer's instructions shall be followed carefully when installing expansion joints, inline instruments, valves, steam traps, and other special components.

Unless approved by Principal, connections and hot tapping to pressurised piping or pressurised equipment is not allowed.

3.9 FINAL CORRECTIONS

If minor adjustments are necessary to satisfy the flange parallelism tolerances specified in DEP 31.38.01.11-Gen., pipe straightening and alignment bending may be performed by the following methods if approved by the Principal:

- a. Local heating or cooling;
- b. Application of force with local heating.

For detailed requirements on final corrections using pipe straightening and alignment bending, see (Appendix 5).

3.10 TOLERANCES

The following dimensional tolerances shall apply:

3.10.1 Length

Length	< 1.5 m (5 ft)	≥ 1.5 m (5 ft)
distance of any two parallel or crossing centre lines	± 1.5 mm (0.06 in)	± 3 mm (0.12 in)
Centre to flange face		
Flange face to flange face		

Where the entire piping system consists of a number of pipe spools that are being fabricated, the overall dimensions shall be limited to ± 9.5 mm (3/8 inch) at 16 °C (60 °F). Cold spring effect shall not be considered.

Location of branch outlets in individual fabricated spools shall have a dimensional tolerance of ±3 mm (± 1/8 in) as measured along the length. The angular alignment between each branch opening and the true flanged or fitting centreline installed at the end of the spool piece shall not exceed ± 0.5°.

3.10.2 Flange face alignment

For flange face alignment, see (Appendix 8).

3.10.3 Other dimensional tolerances

For other dimensional tolerances, see ASME B16.9.

3.11 CLEANING OF PIPE SPOOLS

Fabricated pipe spools shall be cleaned free from weld spatter, scale, grease and dirt.

3.12 ASSEMBLY OF FLANGED JOINTS

3.12.1 General

The assembly of flanged joints shall meet the following requirements:

- a) Foreign material and protective grease shall be removed from flange faces prior to assembly.
- b) After cleaning, a visual inspection is required on both the gasket and the flange facing. Corrosion/pitting of the flange face shall be removed when possible. Severe

corrosion and/or damage of the flange facing shall be re-machined. Especially radial grooves shall be avoided: they shall be no deeper than 0.3 mm (0.012 in) and/or longer than 3 mm (0.12 in). The gaskets themselves shall be free from any visible defects ('new' condition).

- c) All studs and nuts shall be thoroughly cleaned before assembling joints. The threads shall be clean and in good condition. Bolts and threaded studs can be re-used, but only if the stud thread and the nuts are still functional without visible damage on the thread.
- d) Where service allows, an appropriate lubricant shall be applied. The application of lubricants will have a substantial impact on the torque applied. The lubrication properties vary from one lubricant to the other and shall be taken into account when torque is applied. The use of lubricants containing molybdenum disulphide is not allowed for environmental reasons and because its application can result in sulphide stress corrosion in the bolt material

Installation of gaskets shall be as per the following:

- a) Only gaskets as specified in the applicable piping class shall be used. For the re-use of gaskets, reference is made to DEP 31.38.01.11 par. 8.3.1.3 subsection h.
- b) Gaskets used for the installation of orifice assemblies and between flanges located within the required straight length of pipe upstream and downstream of these assemblies shall not protrude into the free area of the pipe.

3.12.2 Flange tightening

The method of flange tightening is dependent upon bolt size, system pressure rating and system service.

Studs shall be long enough to show one and one-half threads after proper tightening.

Bolted flange connections can in general be tightened by the following methods:

3.12.2.1 Conventional spanner/wrenches:

Flange bolts may be tightened by conventional spanners/wrenches on class 150 utility piping systems only, but NOT on GRP flanges, or steel flanges on GRP lap joints.

Adjustable spanners and open end spanners should not be used.

3.12.2.2 Torque wrenches (manual or hydraulic):

Flange bolts shall be tightened by torque wrenches (except for critical services as mentioned in hydraulic bolt tensioning) on all hydrocarbon systems in all pressure classes and utility systems class 300 and above.

Bolt torque values for flanges in GRP systems and/or pipe clamp connectors (PCCs) shall be obtained from the Manufacturer.

3.12.2.3 Hydraulic bolt tensioning:

Hydraulic bolt tensioning provides more uniform bolt stress and eliminates variations due to different lubricants.

Hydraulic bolt tensioning or an equivalent tightening method approved by the Principal which can ensure controlled elongation of bolt such as torque with UT extensometer verification shall be used for tightening the bolts of flanged connections of equipment and piping where operating conditions require the stress distribution in the bolts to be properly controlled to obtain a reliable joint. These conditions generally occur at high pressure and elevated temperature in conjunction with a medium that is difficult to seal.

Flogging of bolts is not permitted because it is inaccurate and unsafe. There is a risk that the bolts, the flange or the gaskets are damaged.

3.12.3 Bolt torquing

Controlled torque wrenching shall be carried out using either manual or hydraulic torque wrenches. The method chosen is dependent upon bolt loading, access, clearance and tooling availability, which can be determined by the site personnel. When the bolt loading requires a torque higher than 678 Nm (500 ft- lbf.) to be applied, hydraulic bolt torquing is recommended.

The required bolt torques for uncoated bolts should be calculated from the bolt stress using the following approximate formula:

The following approximate formula should be used for metric units,

$$T = (0.2 * d_{\text{bolt}} * F_{\text{bolt}})/1000$$

$$F_{\text{bolt}} = (\pi/4) * d_{\text{bolt}}^2 * \sigma_{\text{bolt}}$$

Where:

T Torque (Nm)

d_{bolt} nominal bolt diameter (mm);

F_{bolt} bolt force (N)

σ_{bolt} bolt stress (MPa)

The following approximate formula should be used for USC units,

$$T = (0.2 * d_{\text{bolt}} * F_{\text{bolt}})/12$$

$$F_{\text{bolt}} = (\pi/4) * d_{\text{bolt}}^2 * \sigma_{\text{bolt}} * 1000$$

Where:

T Torque (ft-lbf)

d_{bolt} nominal bolt diameter (in);

F_{bolt} bolt force (lbf)

σ_{bolt} bolt stress (ksi)

Lubricant shall not be applied for the initial tightening of new coated bolts/nuts.

The required bolt torques for coated bolts should be calculated from the bolt stress using the following approximate formula:

The following approximate formula should be used for metric units,

$$T = (0.15 * d_{\text{bolt}} * F_{\text{bolt}})/1000$$

$$F_{\text{bolt}} = (\pi/4) * d_{\text{bolt}}^2 * \sigma_{\text{bolt}}$$

Where:

T Torque (Nm)

d_{bolt} nominal bolt diameter (mm);

F_{bolt} bolt force (N)

σ_{bolt} bolt stress (MPa)

The following approximate formula should be used for USC units,

$$T = (0.15 * d_{\text{bolt}} * F_{\text{bolt}})/12$$

$$F_{\text{bolt}} = (\pi/4) * d_{\text{bolt}}^2 * \sigma_{\text{bolt}} * 1000$$

Where:

T Torque (ft-lbf)

d_{bolt} nominal bolt diameter (in);

F_{bolt} bolt force (lbf)
 σ_{bolt} bolt stress (ksi)

Table-1			
Type of flange material and insulation	Fluid Temperature	Bolt Stress	
		Min.	Max.
Non-insulated carbon steel / Low Alloy steel	-200 °C (-328 °F)	-	-
	20 °C (68 °F)	275 MPa (39.89 ksi) (Note-1, Note-5)	325 MPa (47.14 ksi) (Note-1, Note-5)
	450 °C (842 °F)	275 MPa (39.89 ksi) (Note-1, Note-5)	325 MPa (47.14 ksi) (Note-1, Note-5)
	525 °C (977 °F)	215 MPa (31.18 ksi) (Note-2)	265 MPa (38.44 ksi) (Note-2)
	550 °C (1022 °F)	215 MPa (31.18 ksi) (Note-2)	265 MPa (38.44 ksi) (Note-2)
Insulated carbon steel / Low Alloy steel	-200 °C (-328 °F)	-	-
	20 °C (68 °F)	275 MPa (39.89 ksi) (Note-1, Note-5)	325 MPa (47.14 ksi) (Note-1, Note-5)
	450 °C (842 °F)	215 MPa (31.18 ksi) (Note-2)	265 MPa (38.44 ksi) (Note-2)
	525 °C (977 °F)	215 MPa (31.18 ksi) (Note-2)	265 MPa (38.44 ksi) (Note-2)
	550 °C (1022 °F)	215 MPa (31.18 ksi) (Note-4)	265 MPa (38.44 ksi) (Note-4)
Non-insulated stainless steel	-200 °C (-328 °F)	-	-
	20 °C (68 °F)	275 MPa (39.89 ksi) (Note-3)	325 MPa (47.14 ksi) (Note-3)
	450 °C (842 °F)	275 MPa (39.89 ksi) (Note-3)	325 MPa (47.14 ksi) (Note-3)
	525 °C (977 °F)	215 MPa (31.18 ksi) (Note-3)	265 MPa (38.44 ksi) (Note-3)
	550 °C (1022 °F)	215 MPa (31.18 ksi) (Note-3)	265 MPa (38.44 ksi) (Note-3)
Insulated stainless steel	-200 °C (-328 °F)	275 MPa (39.89 ksi) (Note-3)	325 MPa (47.14 ksi) (Note-3)
	20 °C (68 °F)	275 MPa (39.89 ksi) (Note-3)	325 MPa (47.14 ksi) (Note-3)
	450 °C (842 °F)	275 MPa (39.89 ksi) (Note-3)	325 MPa (47.14 ksi) (Note-3)
	525 °C (977 °F)	215 MPa (31.18 ksi) (Note-3)	265 MPa (38.44 ksi) (Note-3)
	550 °C (1022 °F)	215 MPa (31.18 ksi) (Note-3)	265 MPa (38.44 ksi) (Note-3)
Non-insulated dissimilar	-200 °C (-328 °F)	-	-
	20 °C (68 °F)	275 MPa (39.89 ksi) (Note-1)	325 MPa (47.14 ksi) (Note-1)
	450 °C (842 °F)	275 MPa (39.89 ksi) (Note-1)	325 MPa (47.14 ksi) (Note-1)
	525 °C (977 °F)	215 MPa (31.18 ksi) (Note-2)	265 MPa (38.44 ksi) (Note-2)
	550 °C (1022 °F)	215 MPa (31.18 ksi) (Note-2)	265 MPa (38.44 ksi) (Note-2)
Insulated dissimilar	-200 °C (-328 °F)	-	-
	20 °C (68 °F)	275 MPa (39.89 ksi) (Note-1)	325 MPa (47.14 ksi) (Note-1)
	450 °C (842 °F)	215 MPa (31.18 ksi) (Note-2)	265 MPa (38.44 ksi) (Note-2)
	525 °C (977 °F)	215 MPa (31.18 ksi) (Note-2)	265 MPa (38.44 ksi) (Note-2)
	550 °C (1022 °F)	215 MPa (31.18 ksi) (Note-4)	265 MPa (38.44 ksi) (Note-4)

- NOTES:
1. For stud bolts – A193 Gr.B7 & nuts – A194 Gr. 2H
 2. For stud bolts – A193 Gr.B16 & nuts – A194 Gr. 4
 3. For stud bolts – A193 Gr.B8 Class 2 & nuts – A194 Gr. 8
 4. For stud bolts – 20CrMoVTiB4-10 & nuts – 20CrMoVTiB4-10
 5. Up to 340 °C (650 °F), for stud bolts – A193 Gr.B7M & nuts – A194 Gr. 2HM

6. The recommended bolt values in the table above are valid only for standard piping flanges (ASME B16.5 and ASME B16.47). Specifically for non-standard equipment flanges the required bolt loads need to be determined (calculated) on an individual basis.

To achieve joint tightness the following procedure shall be adhered to:

- To achieve uniform joint load/stress distribution, the bolts shall be tightened in three stages representing 30%, 60% and 100% of the torque values (calculated as per TABLE-1).
- At each stage of tightening, bolts shall be tightened in a controlled sequence. The chart below is a recommended method. Other cross pattern tightening methods may be used if approved by the Principal.
- Finally the bolts shall be chased round using the 100 % torque value (calculated per Table 1), until no nut movement occurs.

Bolts numbered clockwise around the flange	
4 bolt flange	1,3,2,4.
8 bolt flange	1, 5, 3, 7, 2, 6, 4, 8.
12 bolt flange	1, 7, 4, 10, 2, 8, 5, 11, 3, 9, 6, 12.
16 bolt flange	1, 9, 5, 13, 3, 11, 7, 15, 2, 10, 6, 14, 4, 12, 8, 16.
20 bolt flange	1, 11, 6, 16, 3, 13, 8, 18, 5, 15, 10, 20, 2, 12, 7, 17, 4, 14, 9, 19.
24 bolt flange	1, 13, 7, 19, 4, 16, 10, 22, 2, 14, 8, 20, 5, 17, 11, 23, 6, 18, 12, 24, 3, 15, 9, 21.
28 bolt flange	1, 15, 8, 22, 4, 18, 11, 25, 6, 20, 13, 27, 2, 16, 9, 23, 5, 19, 12, 26, 3, 17, 10, 24, 7, 21, 14, 28.
32 bolt flange	1, 17, 9, 25, 5, 21, 13, 29, 3, 19, 11, 27, 7, 23, 15, 31, 2, 18, 10, 26, 6, 22, 14, 30, 8, 24, 16, 32, 4, 20, 12, 28.

For guidance on bolt torque values for uncoated (lubricated) bolts, see (Appendix 6). In line with ASME PCC1, the nut factor applied has been conservatively set at 0.2. For new coated (unlubricated) bolts as defined in line with piping class DEP 31.38.01.15-Gen., bolt torque values shall be taken as 75 % of the respective torque values reported in (Appendix 6).

As an alternative to the above mentioned, a more detailed approach may be considered for calculating required bolt torque in specific cases. The lack of reliable and relevant data on actual friction for each bolt dimension, type of antiseize compound and application temperature, negatively affects the application of this practice on a wider scale.

Alternatively, proven bolt tightening practice (e.g., ASME PCC-1) may be used, subject to approval by the Principal.

3.12.4 Hydraulic bolt tensioning

Hydraulic bolt tensioning enables high integrity jointing to be achieved by uniformly stretching the bolt shanks in the cold condition by means of hydraulic oil pressure. The elongation produced in the bolts corresponds to the calculated load required to make the flanged joint.

Hydraulic bolt tensioning, or an equivalent tightening method approved by the Principal which can ensure controlled elongation of bolt such as torque with UT extensiometer verification shall be applied in the following cases:

Service	ASME Rating Classes	Bolt Diameter (in)
All	All	≥ 2
All	≥ 1500	$\geq 1 \frac{1}{2}$
Hydrogen	≥ 600	$\geq 1 \frac{1}{2}$
Critical applications (to be agreed between the Contractor and the Principal).	All	≥ 1

Whilst the bolts are elongated, the nuts can easily be run down the thread by hand, until they bear against the flange. When the hydraulic pressure is released virtually all of the bolt extension is retained over its active length between the nuts, and the required bolt load is obtained.

Extended bolts required for hydraulic bolt tensioning are specified in the piping classes according to the table above. Hydraulic bolt tensioning outside of this table should be planned well in advance since special extended bolts are required. The extended length of the bolts required for bolt tensioning is at least one nut height.

After the tightening procedure is complete the extended thread lengths shall be protected against corrosion and damage to allow the nuts to be subsequently unscrewed. In the loosening procedure the bolts are stretched again and the nuts unscrewed easily providing the threads have been protected.

For bolt-tensioning equipment, see DEP 70.08.10.11-Gen.

4. INSPECTION, TESTING AND CLEANING

4.1 GENERAL

All inspection and testing is the responsibility of the Contractor. For inspection and testing activities, an inspection test plan (ITP) shall be prepared for each piping system.

The ITP shall identify all mandatory and surveillance inspection requirements for welded joints together with the stages at which each activity is to be performed, and shall provide the following information:

- Piping system to be inspected
- Inspection activity to be performed
- Reference to applicable specification acceptance criteria
- Types of inspection verifying document provided
- Contractor's mandatory and surveillance inspection points
- Principal's required 'Hold', 'Witness' and 'Review points'.

The Principal shall approve the ITP.

All dimensions shall be checked to ensure that the fabrication meets the requirements of the isometric drawings within the specified tolerances. Inspection shall be carried out before any paint, coating, or lining is applied.

All visual inspection of completed welds shall be carried out as soon as practical after the item has cooled down to ambient temperature.

For low alloy steels (e.g. 1.25Cr-0.5Mo, 2.25Cr-1Mo, 5Cr-0.5Mo, and 9Cr-1Mo) as well as martensitic and ferritic stainless steels, NDE shall be carried out no sooner than 48 hours following completion of welding.

For carbon steel weldments, NDE shall be carried out no sooner than 48 hours following completion of welding, unless the recommendations for the avoidance of hydrogen cracking