

DEP SPECIFICATION

SHOP AND FIELD FABRICATION OF PIPING

DEP 31.38.01.31-Gen.

February 2017

DESIGN AND ENGINEERING PRACTICE

DEM1



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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 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.

Bending of non-ferrous materials lies outside the scope of this DEP.

Fabrication of tubing systems is outside the scope of this DEP.

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 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 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.

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

1.3.2 Specific definitions

Term	Definition
Coating System	Details of coating, priming and other intermediate layer materials, together with production procedures pertaining to the pre-treatment and coating work or test pieces.
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	Substance that is very hazardous for the environment or human health. "Toxic" substances are classified as such in databases such as the European Chemical Substances Information System (ESIS) and the Globally Harmonised System of Classification and Labelling (GHS). DEP 01.00.01.30-Gen. further classifies very toxic substances as "very toxic - acute", "very toxic - chronic" and "very toxic - environment".

1.3.3 Abbreviations

Term	Definition
DSS	Duplex Stainless Steel
FN	Ferrite Number
GTAW	Gas Tungsten Arc Welding
HAZ	Heat Affected Zone
HFIB	High Frequency Induction Bending
ITCS	Impact Tested Carbon Steel
ITP	Inspection and Test Plan
MPS	Manufacturing Procedure Specification. Reference ISO 9000 Paragraphs 2.7.2.c, 2.7.2.e, 3.4.5 and 3.7.3.
NDE	Non Destructive Examination
PWHT	Post Weld Heat Treatment
Q&T	Quenched and Tempered
SDSS	Super Duplex Stainless Steel
WPS	Welding Procedure Specification

Term	Definition
WPQR	Welding Procedure Qualification Record(s)

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 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.

2. MATERIAL CERTIFICATION, COLOUR CODING AND TRACEABILITY

2.1 INTRODUCTION

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

2.2 GENERAL REQUIREMENTS FOR CERTIFICATION

1. 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.
 - d. 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.
 - e. Certificates issued by material stockists or agents are not acceptable.

2.3 COLOUR CODING OF PIPING BULK MATERIALS AND MATERIAL IDENTIFICATION CODES

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

2.4 MATERIAL TRACEABILITY

1. Material certification, colour coding, intake inspection, storage and material handout shall be controlled to exclude rogue materials from equipment and plant.
2. The Manufacturer/Supplier shall organise its manufacturing process in accordance with DEP 31.10.00.10-Gen. so that material traceability is ensured.
3. The Manufacturer/Supplier shall have documented processes for managing material traceability as defined in Table 2.1.
 - a. The documented processes for managing material traceability SHALL [PS] be subject to approval by the Principal's designated Technical Authority for MMI.
Processes need to be documented, implementable and auditable for the applicable scope of fabrication and construction.

Table 2.1 Material Traceability

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	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.

2.5 MATERIAL IDENTIFICATION

1. 100% of Material identification of the finished products shall be performed in accordance with DEP 31.10.00.10-Gen., if any of steps (Step 1 through Step 5 in Table 2.1) are not followed.

2.6 PROCEDURE FOR CONCESSION REQUEST/MATERIAL SUBSTITUTION

1. If the Manufacturer/Supplier intends to deviate from the originally specified requirements, they shall provide the Contractor in DEP 30.10.02.90-Gen. with a detailed list of the following:
 - a. The items included;
 - b. copy of a full description;
 - c. all the particulars of intended deviations and the underlying reasons.
2. All deviations shall be subject to the approval of the Principal.
3. DEP 30.10.02.11-Gen. may be used in considering material substitutions.

3. PIPING FABRICATION, ASSEMBLY AND ERECTION

3.1 GENERAL

1. 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.
2. Piping shall be fabricated on the basis of a "Bill of Materials for Piping" provided in isometric drawings.

For the content of the Bill of Materials for Piping, see DEP 31.38.01.13-Gen.

3. The piping fabricator shall be responsible for the accuracy of detailed spool drawings and pipe spool fabrication. Refer to (6.1).
 - a. If the detailed spool drawings are provided by a design consultant, the piping fabricator shall approve the detailed spool drawings and retain overall responsibility for them.
 - b. Detailed spool drawings shall identify all connecting equipment and also connecting piping systems.
4. The piping fabricator shall ensure correct positioning and sizing of the components to be welded.
5. If fabrication is to be carried out in the vicinity of equipment already installed, before such fabrication work commences, adequate protection shall be provided in accordance with the applicable HSSE framework to prevent damage from weld spatter or flame cutting droplets.
6. Piping components shall be protected from overloading, damage or undue deformation at all stages of the work.
7. Bending of piping shall be in accordance with (Appendix A).
8. High frequency induction bending of piping shall be in accordance with (Appendix B).

3.2 CUTTING AND BEVELLING

1. Cutting and bevelling shall be in accordance with DEP 30.10.60.18-Gen. or DEP 30.10.60.32-Gen., as applicable.
2. Weld bevels for butt welds of pipes and fittings shall be in accordance with ASME B16.25.
3. 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.
4. Cutting oil shall be removed to ensure the welding area is free from oil.
5. The following apply for grinding wheels:
 - a. Grinding Wheels shall be dedicated to a single material grade, with the fabricator ensuring that wheels used on one material grade are not subsequently used on another grade.
 - b. Grinding wheels for stainless steel shall be resin bonded alumina or silicon carbide.
 - c. Rubber bonded grinding wheels shall not be used.

6. The following apply for wire brushes:
 - a. Wire brushes shall be dedicated for use on a single material type, with the fabricator ensuring that brushes used on one material type are not subsequently used on any other material
 - b. Wire brushes for stainless steel shall be stainless steel.

Corrosion Resistant Alloys contaminated by the use of carbon steel tools, tools previously applied on carbon steel equipment or by the presence of carbon steel particles can have significantly reduced corrosion resistance.

Segregation applies at the level of Carbon Steel / Alloy Steel and not between grades of material (e.g., the same tools may be used for 304SS as 316SS)

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

3.3 ASSEMBLY OF PIPING COMPONENTS

1. 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.
2. Clamps and holding devices should be used to avoid tack welding in the groove.
 - a. Bridge tacks may be used for small diameter piping (DN 40 (NPS 1 ½) and below).
 - b. 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.
 - c. Attachments shall not be welded onto pipe, flanges or fittings.
3. Alignment equipment shall remain in use until both the root pass and hot pass are complete.
4. Branch connection cut-outs shall be bevelled in accordance with ASME B31.3 to permit complete penetration of the welds at all points.
5. Flange bolt holes shall straddle the centreline in following scenarios:
 - a. Vertical centreline of the pipe where the flange is installed vertically.
 - b. The piping isometric/piping arrangement drawing north-south line where the flange is installed horizontally.
6. See (Appendix H) for flange misalignment acceptance criteria.
7. Spacing and orientation of welds shall be in accordance with DEP 30.10.60.18-Gen. or DEP 30.10.60.32-Gen., as applicable.
8. When pneumatic leak test is performed in accordance with ASME B31.3, para. 345.4 in lieu of hydrostatic leak test, a minimum spacing of 150 mm (6 in) SHALL [PS] be provided for the longitudinal welds.
9. Longitudinal welds in pipes shall not be located within 45° of the pipe bottom after installation.
10. In order to avoid excessive shrinkage stresses during weld solidification, a gap of 1.5 mm (0.06 in) shall be left between the end of the pipe and the stop of the socket-welding component before welding, in accordance with Figure 328.5.2C of ASME B31.3.

Failure to include this gap can lead to premature piping failures.

11. Pipes that are required to be free of scale shall be blast cleaned before further handling by the welding shop.
12. Radial grooves or scratches on flange faces shall not exceed the limits specified in ASME B16.5, Table 3.
 - a. Refacing shall be subject to the Principal's approval.
 - b. Refacing shall not reduce the flange thickness to less than the minimum thickness allowed by the relevant code or standard.
 - c. Edge thickness of flanges shall be checked after re-facing.
13. Where the spool drawings indicate a "field weld" in the pipe, the relevant sections shall be supplied a minimum of 200 mm (8 in) longer with plain ends.

3.4 WELDING

3.4.1 General

1. All welding shall be in accordance with ASME B31.3 and with one of the following:
 - a. DEP 30.10.60.18-Gen.
 - b. DEP 30.10.60.32-Gen.
2. Before welding is commenced, cutting oil shall be removed.

Contamination affects the weld integrity, the clean zone typically extends 50 mm (2 in) either side of a weld
3. See DEP 30.10.02.31-Gen. for 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).
4. 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 is maintained until completion of the second pass.
5. Weld connections for soft seated welded valves and steam traps shall be in accordance with (Appendix C).
6. Where socket welded joints are used, a minimum of two weld passes shall be applied on each socket weld.
7. 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:
 - a. sour / wet H₂S service;
 - b. corrosive service;
 - c. severe cyclic service
8. 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:
 - a. corrosive service;
 - b. in services with a design temperatures above 427 °C (800 °F);
 - c. 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

1. For weld procedure specification and qualification for piping systems in high wet H₂S or sour service, the following shall apply:
 - a. Welding Procedure Qualification SHALL [PS] be done on the same P-No. as used in production welding.
 - b. Additional Welding Procedure Qualification may be required for specific cases where metallurgical properties, postweld heat treatment, design, mechanical properties or service conditions require welding procedure qualification to be performed on the same grade as used in production welding.
 - c. The weld metal deposit shall not contain more than 1.00% nickel.
 - d. Welding procedure specification and procedure qualification shall meet the requirements of DEP 30.10.02.17-Gen.
2. For fine grain carbon steel piping systems with wall thickness greater than 50 mm (2 in), the Welding Procedure Qualification SHALL [PS] be impact tested according to one of the following:
 - a. at a temperature of minus 50 °C (- 58 °F) with the following acceptance criteria:
 - i. Impact test results of at least 27 J as an average of three tests for standard size specimens (10 mm (3/8 in) x 10 mm (3/8 in)),
 - ii. Only one result may be lower than 27 J, but not lower than 21 J,
 - iii. A multiplication factor of 1.5 applies to impact values for sub-size specimens, as defined in Table 4 of ASTM A333,
 - b. at a temperature of minus 46 °C (minus 50 °F) with the following acceptance criteria:
 - i. Impact test results as an average of three tests of at least 33 J for standard size specimens (10 mm (3/8 in) x 10 mm (3/8 in)),
 - ii. Only one result may be lower than 33 J, but not lower than 26 J,
 - iii. A multiplication factor of 1.83 applies to impact values for sub-size specimens, as defined in Table 4 of ASTM A333.

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

1. 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.
2. 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

3. Low hydrogen welding consumables, including fluxes, having a maximum of 8 ml (0.27 oz) of diffusible hydrogen for every 100 g (0.22 lbs) of weld metal, per AWS A4.3, shall be used.
 - a. 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.).
4. For all services, proposed welding procedure specifications and welding procedure qualifications shall be reviewed and approved by the Principal.

3.4.2.3 Welding of (super) duplex stainless steel piping systems

1. Welding of (super) duplex stainless steel piping systems shall be performed in accordance with DEP 30.10.02.35-Gen. and with DEP 30.10.60.18-Gen. or DEP 30.10.60.32-Gen.
2. (Super) Duplex welding procedure qualification SHALL [PS] be impact tested using Charpy V notch testing of the weld metal and HAZ, three specimens for each location, and achieve the following values for full-size specimens:
 - a. Weld Metal/HAZ: 50 J (37 ft-lbs) average and 40 J (30 ft-lbs) minimum at -50 °C (-60 °F)
3. For Charpy V notch impact tests three specimens, of both the weld metal and the HAZ shall be within the specified values given in DEP 30.10.60.18-Gen or DEP 30.10.60.32-Gen., as applicable.
4. The weld repair procedure shall be qualified for full penetration weld repair.

This qualification also covers partial penetration repair and cap repair.
5. The weld repair procedure shall include the following:
 - a. the method of excavation
 - b. the non-destructive examination (NDE) techniques applied to ensure removal of defects.
6. In addition to the mechanical tests for PQR validation, metallurgical tests shall be carried out on an intermetallic phase count, where the PQR is acceptable when the following are both met:
 - a. content of sigma phase does not exceed 0.5%;
 - b. total of all intermetallic phases does not exceed more than 1.0%.

3.4.3 Dissimilar weld joints

1. Dissimilar weld joints shall be designed in accordance with Appendix A of DEP 30.10.60.18-Gen. or with Clause 10.15 of DEP 30.10.60.32-Gen.
2. Dissimilar welds as defined in DEP 30.10.60.18-Gen. or DEP 30.10.60.32-Gen. may be proposed as a piping class break without Principal approval provided the following applies:
 - a. For dissimilar weld joints Class (1) and Class (3):
 - i. the thickest part of the weld or base metal does not exceed 19 mm (3/4 in) and
 - ii. P No.1 to P No.4 or P No.5 welds are stress relieved and
 - iii. stress relieving is carried in accordance with applicable piping code.
 - b. For dissimilar weld joints Class (2):
 - i. the upper design temperature does not exceed 350 °C (660 °F), and
 - ii. the effective thickness of the weldment does not exceed 19 mm (3/4 in), and
 - iii. the fluid service is non-corrosive.
3. For dissimilar weld joints (as defined in DEP 30.10.60.18-Gen. or DEP 30.10.60.32-Gen.) of Class (4) and all situations outside the limitations in (3.4.3, Item 2), prior approval by the Principal is required.

3.4.4 Repair of defects

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. This includes surface porosity, surface finish and concave surface.

1. Injurious surface defects shall be completely removed by grinding.
 - a. If defect removal results in reduction of the pipe wall below the minimum thickness, the ground-out area shall be repaired by welding
 - b. The repaired area shall be ground smooth to the pipe contour.
2. All repairs shall be executed by qualified welders according to approved welding procedures and all requirements of this DEP shall be met.
3. 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.
4. Additional weld metal to compensate for any deficiency in size shall be deposited using procedures as required in the making of the original weld.
 - a. The surfaces shall be thoroughly cleaned before depositing the additional weld metal.
 - b. 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.

5. If planar defects (cracks, lamellar tears, etc.) have to be repaired, the defects shall be prevented from propagation during their removal.
 - a. During the final stages of removal, grinding (not gouging) shall be used.
 - b. Magnetic particle/liquid penetrant examination shall be carried out to confirm the complete removal of the defect.
6. The fabricator shall not repair any repeated injurious defect without the Principal's written approval.
7. DSS and SDSS shall have repair weld procedures qualified that cover all repair scenarios.
8. (Super) duplex stainless steels shall be subject to only one weld repair, unless otherwise agreed with the Principal. See (3.4.2.3).

3.4.5 Compressor piping system spool fabrication

1. Butt-welding components shall be lined up accurately in accordance with approved fit-up procedure.
 - a. Weld roots should be ground smooth wherever possible.
2. To prevent damage to valves and compressor from welding slag, one of the following options shall be used:
 - a. Use gas tungsten arc welding (GTAW) for the root pass of welds, if it is not possible to grind the root smooth.
 - b. Alternatively, chemically clean the compressor piping system.

3.5 POST WELD HEAT TREATMENT

1. Post weld heat treatment (PWHT) methodology and procedure shall comply with the requirements of DEP 30.10.60.18-Gen. or DEP 30.10.60.32-Gen., as applicable.
2. Post weld heat treatment shall be performed for P.No.1 materials as per Table 3.1.

Table 3.1 Requirements for heat treatment

Base metal P.No.	Weld metal analysis A.Number	Base metal group	Nominal wall thickness		Specified Min. Tensile strength, Base metal		Metal temperature range		Holding time		
			mm	in	MPa	ksi	°C	°F	Nominal wall		Minimum time
									min/ mm	hr/in	
1	1	Carbon steel	≤ 20	≤ ¾	All	All	None	None	...	...	...
			>20	>¾	All	All	593- 649	1100- 1200	2.4	1	1

3.6 FINISHING OF SURFACES AND MARKING OF PIPE SPOOLS

1. Post-fabrication, all welds shall be ground smooth, as and when indicated in the welding procedures or on the drawings to allow specified radiographic or ultrasonic examination, and to remove all detrimental spatters, burrs, tack welds and other marks.
2. Each pipe spool shall be clearly marked with the identification shown on the fabrication drawing.

3.7 SHIPPING AND PRESERVATION

1. Preparation for shipping is a critical operation which shall be witnessed and reported through the Contractor's quality assurance systems.
2. Protective coating shall comply with DEP 30.48.00.31-Gen.
For Upstream services, refer to DEP 39.01.10.12-Gen. for applicability of coating DEP specifications.
3. Coating requirements should be shown on the line list; see data sheet for piping, DEP 31.38.01.92-Gen.
4. Pre-fabricated pipe spools shall be protected against corrosion and damage during storage and transport to site.
5. Preservation of piping systems and components shall be in accordance with DEP 70.10.70.11-Gen., Section 4.6, with the following additions:
 - a. Flanges shall be fitted with flange protectors, including a proven protection against corrosion for the flange opening and facing.
 - i. Flange protectors in direct contact with flange faces shall not be of a porous material (e.g., wood).
 - b. Plain and bevelled pipe ends shall be provided with plastic covers.
 - i. Covers shall be designed so that they have to be removed before the piping is installed.
 - c. Threads and other machined surfaces shall be protected during surface preparation and coating so they are not coated.
 - i. 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.
 - i. When installed, plastic plugs shall not be coated, 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.
 - i. Valves DN 50 (NPS 2) and smaller shall be stored indoors.
 - ii. Tightly fitting plastic flange covers or plastic plugs are required.
6. These preservation practices shall be checked during the quality assurance audits.
7. 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, as approved by the EPC Contractor.
An example of this is to flash coat with a primer coating.
8. The use of pickling and passivation of stainless steel weldments shall be approved by the Principal.
 - a. Pickling and passivation of stainless steel weldments shall be performed in accordance with DEP 30.10.60.31-Gen.

3.8 INSTALLATION

3.8.1 Storage and handling

3.8.1.1 Storage

1. 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.
2. Stacking shall be done in a manner to avoid damage to pipes or coatings.
3. End protectors on flanges, weld bevels, threads, and socket ends shall be firmly attached.

3.8.1.2 Handling

1. All material shall be handled with care to prevent damage.
2. 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

1. Threads shall conform to the requirements of ASME B1.20.1.
2. Pipe ends shall be reamed clean after threading.
3. 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.
4. 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.
 - a. Nickel-based lubricants shall be used
 - b. Copper based lubricants may be used if approved by the Principal.
5. Austenitic stainless steel, (super) duplex stainless and nickel base alloy threaded piping joints shall not contain copper or zinc in the thread compound.
 - a. Copper in the thread compound may be used if confirmed with the Principal that there is no risk of galvanic corrosion.
6. Seal welding of threads shall comply with the requirements of ASME B31.3 and consist of 2 passes with rotating starts and stops.
7. Seal welds shall meet the following:
 - a. have a minimum welding dimension Cx in Figure 328.5.2C of ASME B31.3.
 - b. all the welding qualification requirements in ASME B31.3 for an equally sized socket weld.
8. Seal welding of threaded connections shall not be performed where subsequent heat treatment is required, other than post weld heat treatment.
9. Seal welds shall be examined by magnetic particle or liquid penetrant methods.
10. 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

1. Assembly of flanged joints shall be in accordance with (3.12).
2. Flange bolting shall be installed with lubricant compound on the threads and nut faces (except where service explicitly does not allow).
 - a. No compound or tape shall be applied to flange faces or gaskets.

3.8.2.3 Valves

1. Valve Manufacturer's installation instructions, including bolt torque for the end flanges and gland flange, shall be followed.
2. Valve handles shall be oriented as shown on the piping isometric / layout drawing.

3.8.3 Erection

1. Piping shall be erected and supported in a manner that meets the tolerances given in (3.10), so that assembly and erection will not put undue strain on pumps, compressors, tanks, vessels or other equipment.
2. 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.
 - c. If the pipe is not in correct alignment, it shall be removed and corrected.
 - d. Alignment corrections shall not be made while the pipe is connected to the equipment.
3. Piping that has been painted prior to erection shall be handled with care to avoid damage to coatings:
 - a. Slings protected with fabric or hose sleeves shall be used for lifting.
 - b. Rollers shall be used for lengths that will be pulled over supporting steel.
4. Gaskets required for service shall be used during hydrostatic pressure test.
5. Piping shall be erected in accordance with the piping isometric drawings/piping layout drawings.
6. Detailed drawings and Manufacturer's instructions shall be followed when installing expansion joints, inline instruments, valves, steam traps, and other special components.
7. Connections and hot tapping to pressurised piping or pressurised equipment shall be approved by Principal.

3.9 FINAL CORRECTIONS

1. If minor adjustments are necessary to satisfy the flange parallelism tolerances specified in Appendix H., 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.
2. For detailed requirements on final corrections using pipe straightening and alignment bending, see (Appendix E).

3.10 DIMENSIONAL TOLERANCES

1. See (Appendix H) for flange face alignment.
2. Length tolerances shall be as Table 3.2:
 - a. 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 in) at 16 °C (60 °F), with no consideration for cold spring effect.
 - b. Location of branch outlets in individual fabricated spools shall have a dimensional tolerance of ± 3 mm ($\pm 1/8$ in) as measured along the length.
 - c. 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 $\pm 0.5^\circ$.

Table 3.2 Tolerances over 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		

3. For other dimensional tolerances, see ASME B16.9.

3.11 CLEANING OF PIPE SPOOLS

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

3.12 ASSEMBLY OF FLANGED JOINTS

3.12.1 General

1. The assembly of flanged joints shall meet the following requirements:
 - a. Remove foreign material and protective grease from flange faces prior to assembly.
 - b. After cleaning, visually inspect the gasket, bolting and the flange facing.
 - c. All studs and nuts shall be thoroughly cleaned before assembling joints.
 - d. Bolts and threaded studs may be re-used, but only if the stud thread and the nuts are still functional without visible damage on the thread;
 - e. Where service allows, an appropriate lubricant shall be applied.
The application of lubricants will have a substantial impact on the torque applied.
 - i. The lubrication properties vary from one lubricant to the other and shall be taken into account when torque is applied.
 - ii. Lubricants containing molybdenum disulphide shall not be used for environmental reasons and because their application can result in sulphide stress corrosion in the bolt material.
 - iii. Lubrication shall be applied on both stud bolt facing and nut.

2. Where flange faces require re-finishing, radial grooves shall be no deeper than 0.3 mm (0.012 in) and/or longer than 3 mm (0.12 in)

Refinishing may be necessary due to mechanical imperfections, damage from corrosion, in-service damage or to change the flange face finish to enable the use of a different gasket.

- a. Gaskets shall be free from any visible defects ('new' condition).
 - b. Refer ASME B.16.5 section 6.4.6, ASME PCC-1 Appendix – D and ASME PCC-2, Article 3.5.
3. 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-Gen., Section 8.3.
 - 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 depends upon bolt size, system pressure rating and system service.

1. Studs shall be long enough to show one and one-half threads outside of nuts, after full tightening.
2. Bolted flange connections may be tightened by the following methods:
 - a. Conventional spanner/wrenches
 - i. 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.
 - ii. Adjustable spanners and open end spanners shall not be used.
 - b. Torque wrenches (manual or hydraulic)
 - i. Flange bolts shall be tightened by torque wrenches, except for critical services as mentioned in hydraulic bolt tensioning (3.12.3), on all hydrocarbon systems in all pressure classes and utility systems class 300 and above.
 - ii. Bolt torque values for flanges in GRP systems and/or pipe clamp connectors (PCCs) shall be obtained from the Manufacturer.
 - iii. Flogging of bolts is not permitted because it is inaccurate and unsafe. As well as the risk of injury to personnel, there is a risk that the bolts, the flange or the gaskets are damaged.
 - c. Hydraulic bolt tensioning. See (3.12.4)

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

3.12.3 Bolt torquing

1. For guidance on bolt torque values for uncoated (lubricated) bolts, see (Appendix F).
2. Controlled torque wrenching shall be carried out using either manual or hydraulic torque wrenches.

The method chosen depends on bolt loading, access, clearance and tooling availability, which can be determined by the site personnel.

3. the bolt loading requires a torque higher than 678 Nm (500 ft- lbf.) to be applied, hydraulic bolt torquing should be used.

4. Lubricant shall be applied for the initial tightening of all types of bolts/nuts.
 - a. A friction factor of 0.16 should be used for lubricated non-coated bolts (as ASME PCC-1).
 - b. Lower friction factors shall only be used after conducting nut factor trials (size and material) under project / asset specific conditions.
5. The required bolt torques for uncoated bolts should be calculated from the bolt stress using the following approximate formula:

- a. For metric units,

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

$$F_{\text{bolt}} = A_b * \sigma_{\text{bolt}}$$

Where:

T Torque (Nm)

d_{bolt} nominal bolt diameter (mm);

F_{bolt} bolt force (N) σ_{bolt} bolt stress (MPa)

A_b bolt root area (mm²)

- b. For USC units,

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

$$F_{\text{bolt}} = A_b * \sigma_{\text{bolt}} * 1000$$

Where:

T Torque (ft-lbf)

d_{bolt} nominal bolt diameter (in);

F_{bolt} bolt force (lbf)

σ_{bolt} bolt stress (ksi)

A_b bolt root area (in.²)

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

- a. For metric units,

$$T = (0.16 * d_{\text{bolt}} * F_{\text{bolt}})/1000$$

$$F_{\text{bolt}} = A_b * \sigma_{\text{bolt}}$$

Where:

T Torque (Nm)

d_{bolt} nominal bolt diameter (mm);

F_{bolt} bolt force (N)

σ_{bolt} bolt stress (MPa)

A_b bolt root area (mm²)

- b. For USC units,

$$T = (0.16 * d_{\text{bolt}} * F_{\text{bolt}})/12$$

$$F_{\text{bolt}} = A_b * \sigma_{\text{bolt}} * 1000$$

Where:

T Torque (ft-lbf)

d_{bolt} nominal bolt diameter (in);
 F_{bolt} bolt force (lbf)
 σ_{bolt} bolt stress (ksi)
 A_b bolt root area (in.²)

7. To achieve joint tightness, the following procedure shall be adhered to:
 - a. Tighten the bolts in three stages representing 30%, 60% and 100% of the torque values (calculated to achieve the relevant bolt stress in Appendix F).
 - b. At each stage, tighten the bolts in a controlled sequence. See Table 3.3 for a recommended method. Other cross pattern tightening methods may be used if approved by the Principal.
 - c. Finally, chase the bolts round using the 100% torque value (calculated per Appendix F), until no nut movement occurs.
8. The recommended bolt values in Appendix F are valid only for standard piping flanges (ASME B16.5 and ASME B16.47). For non-standard equipment flanges, the required bolt loads shall be determined (calculated) on an individual basis.
9. In line with ASME PCC-1, 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 80% of the respective torque values reported in (Appendix F).
10. As an alternative method, a more detailed approach may be considered for calculating the 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.
11. Alternatively, proven bolt tightening practice (e.g., ASME PCC-1) may be used, subject to approval by the Principal.

Table 3.3 Flange bolt tightening sequence

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, 3, 15, 9, 21, 6, 18, 12, 24.
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.

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.

1. method approved by the Principal that can ensure controlled elongation of bolt, 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 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.

An alternative method is torque with UT extensiometer verification.

2. Hydraulic bolt tensioning shall be applied in the cases defined in Table 3.4.

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.

3. Hydraulic bolt tensioning outside of Table 3.4 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.

Extended bolts required for hydraulic bolt tensioning are specified in the piping classes according to Table 3.4.

4. 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.

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

Table 3.4 Application of controlled bolt extension (e.g., hydraulic tension)

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). ^{1) 2)}	All	≥ 1
<i>Note 1: For critical applications selection, see Appendix J, Table J.2 of DEP 31.38.01.11-Gen.</i> <i>Note 2: For critical applications where tensioning is required for bolt diameters between 1 in and 1 ½ in, the stud bolt lengths are not included in piping classes but an equivalent bolt with extended length may be found in the MESC catalogue.</i>		

4. INSPECTION, TESTING AND CLEANING

4.1 GENERAL

1. 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.
2. 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 provide the following information:
 - a. Piping system to be inspected
 - b. Inspection activity to be performed
 - c. Reference to applicable specification acceptance criteria
 - d. Types of inspection verifying document provided
 - e. Contractor's mandatory and surveillance inspection points
 - f. Principal's required 'Hold', 'Witness' and 'Review points'.

For ITP example, see Appendix C of DEP 30.10.60.32-Gen.
3. The Principal shall approve the ITP.
4. All dimensions shall be checked to ensure that the fabrication meets the requirements of the isometric drawings within the specified tolerances.
 - a. Inspection shall be carried out before any paint, coating, or lining is applied.
5. All visual inspection of completed welds shall be carried out as soon as practical after the item has cooled down to ambient temperature.
6. 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.
7. Delayed NDE shall be applied for the following steels whenever postheating for dehydrogenization is not implemented before cooling down, or when a weld will reach a temperature below 93°C (200°F) before PWHT:
 - a. CrMo steels;
 - b. low alloy air hardenable steels;
 - c. martensitic or ferritic stainless steels;
 - d. carbon steels ($CE \geq 0.45\%$ and thicker than 19 mm (0.75 in))
 - e. carbon steels with $UTS \geq 480$ MPa (70 Ksi))
8. Delayed NDE shall be carried out no sooner than 48 hours after completion of welding.
 - a. Exception may be allowed if the recommendations for the avoidance of hydrogen cracking in accordance with EN 1011-2 Annex C.2 have been implemented, and subject to approval by the Principal.

General guidance on the selection of the appropriate hydrogen scale for various welding processes is given in C.2.3.3 of EN 1011-2.
9. Inspection of welds, as a minimum SHALL [PS] be carried out in accordance with Table D.2 and Table D.3 of (Appendix D) using the inspection classes as defined in Table D.1.
10. If the piping will be pneumatically tested, see (5).

11. The criteria and progressive examination to be employed for inspection, the acceptance criteria for welds, and the progressive examination SHALL [PS] be in accordance with Clause 341.3, ASME B31.3.
12. For Material identification, see (2.6).
13. Inspection shall be recorded in a form which clearly identifies the work and the area of inspection, methods and procedure(s), and the acceptability of the item inspected.
14. References used for reporting weld inspections shall be clearly marked on the work in paint, such that it is possible to exactly relocate any weld defects reported.
15. The Contractor shall establish a system to provide traceability between documentation and weld testing before fabrication starts.

4.2 NON-DESTRUCTIVE EXAMINATION

4.2.1 General

1. NDE procedures, techniques, and defect evaluation shall conform to the requirements of the applicable code or ASME B31.3 and shall be supplemented by (Appendix D).
2. The extent of examination specified in (Appendix D) is based on qualified welding inspectors being actively present on the worksites and independent audits being carried out by the Contractor. If this is not the case, additional NDE shall be specified.
3. The NDE company responsible for the final inspection of welds shall maintain a quality system in accordance with ISO/IEC 17020, or equivalent as agreed with the Principal, and be accredited by a nationally recognised body.
4. Qualification of NDE system (NDE company and NDE personnel) shall be in accordance with DEP 30.55.03.30-Gen.
 - a. In the event that the NDE company is not suitably accredited, then prior to award of work, it shall submit its NDE procedures to the Principal for review and approval.
 - b. All NDE procedures shall clearly specify the visual, surface and volumetric inspection techniques to establish that all welded joints meet the quality requirements of this DEP.
 - c. These NDE procedures shall be approved by a practitioner qualified to ASNT SNT-TC-1A or ISO 9712 Level III.
5. The Contractor shall implement a system for uniquely identifying each weld, for the control and recording of inspections (VT, MT, PT, UT and RT).
 - a. Isometric drawings, marked with the individual weld numbers should be maintained for this purpose.
6. Prior to fabrication start-up, the Contractor shall submit its identification system for approval by the Principal.
7. The causes for each identified defect shall be immediately investigated and corrective action shall be taken to prevent further occurrences.
 - a. The defects shall be reported with reference to the numbering system according to ISO 6520-1.
8. Where PWHT is required, final non-destructive acceptance testing SHALL [PS] take place after final PWHT has been completed.
9. The requirement for examination of 10% of the welds means that 10% of the production welds shall be randomly and independently selected throughout the fabrication period and fully examined.
 - a. The random selection shall be equally distributed over all welders and all type of welds, which includes welding procedure, pipe size, thickness, welding position.

10. In addition to the 10% examination requirement, the following inspection shall be carried out for each welder:
 - a. The first entire production weld circumference of at least 150 mm (6 in) length or the first four shorter production welds made by each welder shall be examined, before that welder performs any further welding.
 - b. If progressive examination of a welder's work is required on the basis of ASME B31.3, the follow up examinations shall first be made on welds made by the same welding procedure as used to make the defective weld.
11. In case any defective weld joint is repaired or replaced, and re-examined, progressive sampling shall be followed in accordance with section 341.3.4 (f) of ASME B31.3.

4.2.2 Visual examination of branch connections

1. All welds shall be visually examined.
2. Visual examination shall be performed in accordance with the ASME BPV Code, Section V, Article 9.
3. Visual examination shall be carried out on all prepared joints prior to welding, during welding (welder self-checks) and upon completed welds.
 - a. Verification checks should include the internal surface of the weld wherever possible.
 - b. The visual acceptance of each weld shall be recorded by the Contractor.
4. Supplementary to the requirements for visual examination in ASME B31.3, branch-to-run pipe welds of branch fittings or outlets of pipe-to-pipe connections shall be visually examined for correct geometry, branch fit-up and weld penetration.
 - a. The examinations shall be recorded for each branch connection.
 - b. For the purpose of internal examination of the weld penetration, the branch-to-run pipe weld should be made before the first butt weld in the branch pipe next to where the branch connection is made.
 - c. For checking geometry, branch fit-up and weld penetration, recorded visual examination may be replaced by radiography if the run pipe of the branch connection has a size no greater than DN 150 (NPS 6). This radiography does not count in the number of welds being radiographed if 10% of the welds are to be examined.
5. Examination requirements for branch connections not specified in the piping classes shall be approved by the Principal.

4.2.3 Radiography (RT)

1. The percentage of welds of a piping system subjected to radiographic examination shall be as (Appendix D).
2. All radiographs taken during fabrication shall be made available for examination by the Principal.
3. Final radiographs shall be approved by the Contractor prior to shipment (for shop fabrication) or prior to acceptance (for field fabrication).
4. Radiography of welds and of components other than castings shall be performed in accordance with the ASME BPV Code, Section V, Article 2.

5. Radiographic acceptance criteria shall be in accordance with ASME B31.3, as follows:
 - a. 100% radiography means 100% radiography requirements in accordance with ASME B31.3 para. 344.5.2;
 - b. 10% radiography means random radiography requirements in accordance with ASME B31.3 para. 344.5.2.
 - c. For linear indications, acceptance in accordance with ASME B31.3, para 341.3.2;
 - d. For rounded indications, acceptance in accordance with ASME B31.3, para 341.3.2.
6. Film quality requirements shall be as follows:
 - a. Fine grain film (Class II) for x-ray;
 - b. Ultra-fine grain film (Class I) for gamma ray;
 - c. An image quality indicator (IQI) with sensitivity better than 2% shall be achieved by means of source side location of the IQI for pipe wall thickness greater than 6.4 mm (0.25 in).
 - d. An image quality indicator (IQI) with sensitivity better than 2.64% shall be achieved by means of source side location of the IQI for pipe wall thickness less than or equal to 6.4 mm (0.25 in).
 - e. Where access only allows the use of film side IQI, the technique shall be proved by means of a representative sample with IQI set source side and film side.
7. Contour grinding of welds on the outside surface shall be performed to the extent that clarity of the radiographic examination is maintained.
8. Geometry, branch fit-up and weld penetration of branch connections with a branch fitting or outlet or pipe-to-pipe connections shall be inspected.
 - a. 5% of the branch-to-run pipe welds of branch connections with a size of the run pipe equal or less than DN 150 (NPS 6) shall be examined for this purpose by radiography.
 - b. Examination requirements for branch connections not specified in the piping classes shall be approved by the Principal.

4.2.4 Ultrasonic examination

1. Ultrasonic examination (UT) may replace RT in accordance with ASME B31.3, para. 341.4.1 and B31 case 181.
2. If UT is applied, automated computer enhanced data acquisition shall be used to obtain a permanent record of the full weld to demonstrate the absence, or not, of linear type discontinuities with amplitudes exceeding the reference level.
3. UT of welds shall only be carried out where the material properties allow in accordance with ASME BPV Code, Section V, Article 4.
4. UT is limited by the local geometry near the welds. The use of UT shall not affect the random and independent selection of the welds for examination.
5. On branches, O-lets and similar geometries, scanning from the internal surface shall be carried out if practicable.
6. Acceptance criteria for UT shall be in accordance with ASME B31 case 181 or as agreed with the Principal for non-ferritic materials.

4.2.5 Liquid penetrant and magnetic particle examination

(Appendix D) gives requirement for the percentage of welds of a piping system to be subjected to be liquid penetrant examination (PT) or magnetic particle examination (MT). Note that this only includes:

- *Branch-to-run pipe welds of branch connections; and*
 - *Fillet welds of support clips, shoes, bracings and attachments.*
1. The selected welds shall be fully examined.
 2. PT and MT of welds shall include all accessible weld surfaces and a band of base metal at least 10 mm (3/8 in) wide on each side of the weld.
 3. MT of welds shall be carried out in accordance with ASME BPV Code, Section V, Article 7.
 4. PT materials shall meet the requirements for sulphur and halogen content of ASME V, Article 6, Paragraph T-644, regardless of the type of material to be examined.
 5. Contour grinding of welds on the outside surface shall be performed to the extent that clarity of the PT or MT is maintained.
 6. Additional requirements for MT:
 - a. MT areas shall be cleaned prior to inspection and be free from surface irregularities, such as weld spatter.
 - b. Magnetisation shall be by electromagnetic yoke using alternating current.
 - c. Coil or parallel conductor methods may only be used if approved by the Principal.
 - d. Only the wet method shall be employed, using either black ink on white background or ultra-violet fluorescent ink.
 7. Additional requirements for PT:
 - a. Examination areas shall be cleaned prior to inspection and shall be free from surface irregularities, such as weld spatter.
 - b. Colour contrast, solvent removable penetrant shall be used.
 8. Acceptance criteria for MT shall be in accordance with ASME BPV Code, Section VIII, Division 1, Appendix 6.
 9. Acceptance criteria for PT shall be in accordance with ASME BPV Code, Section VIII, Division 1, Appendix 8.

4.2.6 Ferrite number measurement

(Appendix D) gives requirement for the percentage of welds of a piping system to be subjected to ferrite number (FN) measurement.

1. The FN of the deposited weld metal of all austenitic stainless steel shop and field welds shall be in the range 3 FN to 8 FN.
2. For (super) duplex stainless steel the ferrite number (FN) shall be in accordance with (6.2) of DEP 30.10.02.35-Gen.
3. For detailed requirements of ferrite testing, see DEP 30.10.60.18-Gen. or DEP 30.10.60.32-Gen., as applicable
4. FNs shall be measured in accordance with ISO 8249.

4.2.7 Other NDE techniques

1. Other NDE techniques, e.g., time-of-flight diffraction (TOFD), may be used subject to approval by the Principal.

4.2.8 NDE personnel

1. NDE personnel to be used by the Contractor shall be individually approved by the Principal. The Principal reserves the option to interview operatives and, when necessary, to require a practical skill test.
2. NDE personnel shall be qualified in accordance with the requirements specified in ASNT SNT-TC-1A or ISO 9712 Level II as a minimum. Other qualifications are subject to approval by the Principal.
3. Supervisors responsible for overseeing and controlling NDE activities shall be ASNT SNT-TC-1A or ISO 9712 Level III qualified

4.3 HARDNESS TESTING

4.3.1 General

1. Each welding procedure qualification shall include hardness tests (see 4.3.2).
2. (Appendix D) specifies the percentage of production welds to be hardness tested. Those welds shall be hardness tested as follows:
 - a. At least one reading per weld on piping of size DN 100 (NPS 4) and smaller.
 - b. At least two readings per weld on piping of size DN 150 through DN 300 (NPS 6 through NPS 12).
 - c. At least one reading every 400 mm (16 in) of weld length on piping over size DN 300 (NPS 12).
3. The highest hardness for each weld shall be recorded on the spool sheets for the Principal's review and record.
4. The hardness measurement values shall be within the limits specified in DEP 30.10.60.18-Gen or in DEP 30.10.60.32-Gen., as applicable.
 - a. Brinell hardness limits in ASME B31.3 may be converted to Vickers hardness using ASTM E140.

4.3.2 Hardness measurement method

1. Hardness measurements for welding procedure qualification shall be performed by the Vickers method, with hardness traverses in accordance with API RP 582 or ISO 9015-1.
 - a. Measurements shall be taken from unaffected base material on one side, across the weld to unaffected base metal on the other side.
 - b. Three traverse measurements shall be made: one 2 mm (0.08 in) below the outer surface, one 2 mm (0.08 in) below the inner surface and one across the centre.
 - c. The distance between measurements across the weld shall not exceed 2 mm (0.08 in).
2. Traverse weld hardness testing of production welds shall be carried out by means of a portable Vickers or Rockwell tester in accordance with ASTM E110 or, if approved by the Principal, by another method capable of detecting a hard HAZ in a reliable and repeatable manner.
3. Hardness tests shall be made on smooth ground surfaces.
4. For each set of hardness measurements required, the average and maximum of three measurements on the weld and on each HAZ shall be reported.
5. Hardness measurements shall be carried out after PWHT (if any).

4.4 PRESSURE TESTING

1. Prior to installation of insulation, or otherwise prior to initial operation, all process piping shall be pressure tested in accordance to ASME B31.3, except for piping built in accordance with ASME B31.1.
 - a. Partial insulation prior to hydrotest may be accepted if all welds are exposed for hydrotest.
2. Pressure testing may be performed on fully painted piping spools (including welds) in accordance with Section 345.3.1 of ASME B31.3 under the following conditions:
 - a. The welds consist of at least two layers (root and fill run) for stainless steels, and three layers for all other materials, in accordance with a Welding Procedure Specification qualified for the application.
 - b. The test is not considered to be a sensitive leak test in accordance with Section 345.8 of ASME B31.3.
 - c. The piping spool has been fully inspected (visual examination, non-destructive examination and positive material identification, where specified) and released for pressure test.
3. Pressure testing of piping systems shall be in accordance with DEP 74.00.10.10-Gen.
4. With reference to section 345.1 (a) of ASME B31.3, service testing in line with the requirements for category D fluid service is acceptable for piping systems sizes $\leq$ DN 80 (NPS 3).
 - a. Only the following services are deemed to be category D fluid services (see Appendix M, ASME B31.3):
 - i. Utility air;
 - ii. Utility water;
 - iii. Utility nitrogen operating in non-confined areas;
 - iv. Steam, design pressure 3.5 barg (50 psig) or lower;
 - v. Steam condensate, design pressure 3.5 barg (50 psig) or lower.
5. Test pressures shall be as specified on the isometric drawings, see DEP 31.38.01.11-Gen., Appendix N.

4.5 CLEANING OF PIPING SYSTEM

1. Cleaning of piping systems shall be carried out in accordance with (Appendix G).

5. SPECIAL CRITERIA FOR SHOP FABRICATION AND INSPECTION FOR PNEUMATIC TESTING

5.1 GENERAL

1. For engineering requirements associated with pneumatic testing, reference is made to DEP 74.00.10.10-Gen.
2. Where the hydrostatic leak test is replaced by a pneumatic leak test as defined in ASME B31.3, and the Principal wishes to apply safety distances corresponding with a probability of failure of $1E-5$, during execution of the pneumatic test, criteria mentioned in (5.2) shall apply.

5.2 SPECIAL CRITERIA FOR PIPING SUBJECTED TO PNEUMATIC LEAK TEST

5.2.1 Fabrication requirements

1. For existing systems with miter bends, in addition to 100 % RT and 100 % PT/MT, the actual thickness SHALL [PS] be more than 1.2 times the minimum thickness required for the component's design pressure.
2. For fabricated branch fittings on piping subjected to pneumatic leak test, the following requirements apply:
 - a. The diameter of the branch SHALL [PS] be $<0.8 \times \text{Diameter of the run pipe}$.
 - b. Reinforcement as specified in ASME B31.3 paragraph 304.3.3 (f) is not acceptable. Instead, reinforcement SHALL [PS] be achieved through enhancing the component thickness.
 - c. The actual thickness for the area within the limits for reinforcement zone per ASME B31.3 par. 304 SHALL [PS] be more than 1.2 times the minimum thickness required for the component's design pressure.

5.2.2 Inspection and testing requirements

1. Inspection 'class -1 a' as Table D.1 SHALL [PS] be applied.
2. Branch outlet fittings SHALL [PS] have full weld size.

6. DOCUMENTATION

6.1 SHOP DETAIL DRAWINGS

1. The Contractor shall make shop drawings for all the piping fabricated showing the following:
 - a. spool number;
 - b. materials;
 - c. dimensions;
 - d. fabrication details;
 - e. the applicable code and procedures.
2. A number, consisting of the plant or unit number, commodity symbol, line number, and spool piece number, shall identify each pipe spool. Each spool shall be detailed on a separate sheet.
3. The Contractor shall prepare a complete index of all piping spool drawings, referencing each piping spool drawing to the piping drawings from which it was prepared.
4. The location of field welds between shop-fabricated spool pieces shall be shown on the piping isometric drawings.

6.2 SPOOL IDENTIFICATION

1. Spools shall be identified by a detail number comprising of the piping system line number and spool suffix, which shall be weatherproof and painted or stencilled in characters at least 50 mm (2 in) high.
2. Piping systems size DN 40 and below (NPS 1½ and below) shall be identified with stainless steel weather- and tear-resistant tags.

6.3 RECORDS AND REPORTS

1. As a minimum, the following records, fully identified with the specific material or part of the piping presented, shall be available for reference or examination by the Principal in the form of hard copy or electronic copy, as agreed with the Contractor.
 - a. Certificates attesting that all the quality control requirements of the applicable code and of the engineering design have been met.
 - b. Pyrometer charts and records of heat treatment.
 - c. Radiographic films, material test reports (MTRs) and radiograph examination reports/logs.
 - d. Results of magnetic particle and liquid penetrant examinations.
 - e. Charts or other records of hydrostatic, pneumatic and Brinell hardness tests.
 - f. Results of any other supplemental types of examination, test or analysis specified.
 - g. Welding procedure specifications (WPSs) and applicable procedure qualification records (PQRs). Operator welding qualifications test results.
 - h. Weld repair procedures.
 - i. Weld maps.
 - j. Log of identification symbols of the welders or welding operators.
 - k. Shop detail drawings.
 - l. Positive material identification records.

7. REFERENCES

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

- NOTES:
1. Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.
 2. The DEPs and most referenced external standards are available to Shell staff on the SWW (Shell Wide Web) at <http://sww.shell.com/standards/>.

SHELL STANDARDS

DEP feedback form	DEP 00.00.05.80-Gen.
Definition of temperature, pressure and toxicity levels	DEP 01.00.01.30-Gen.
Metallic materials – Selected standards	DEP 30.10.02.11-Gen.
Construction materials - Metallic materials for low-temperature service	DEP 30.10.02.12-Gen.
Wet H ₂ S requirements for downstream pressure vessels and piping	DEP 30.10.02.17-Gen.
Metallic materials – Prevention of brittle fracture in new assets	DEP 30.10.02.31-Gen.
Technical Requirements for the Supply of Components in 6Mo Austenitic, 22Cr Duplex and 25Cr Super Duplex Stainless Steel	DEP 30.10.02.35-Gen.
Material Substitution Procedure – Request for material substitution (Standard form)	DEP 30.10.02.90-Gen.
Welding of metals (amendments/supplements to API RP 582)	DEP 30.10.60.18-Gen.
Welding of metals, based on ISO standards	DEP 30.10.60.32-Gen.
Oxidation of stainless steel weldments	DEP 30.10.60.31-Gen.
Protective coatings for onshore and offshore facilities	DEP 30.48.00.31-Gen.
Coating of fasteners	DEP 30.48.00.32-Gen.
Qualification of NDT for fabrication inspection	DEP 30.55.03.30-Gen.
Steam, condensate and boiler feed water systems	DEP 30.75.10.10-Gen.
Positive material identification (PMI) program	DEP 31.10.00.10-Gen.
Gaseous oxygen systems	DEP 31.10.11.31-Gen.
Unfired pressure vessels	DEP 31.22.00.31-Gen.
Piping – General requirements	DEP 31.38.01.11-Gen.
Piping classes – Refining and chemicals	DEP 31.38.01.12-Gen.
Compilation of bill of material for piping isometrics	DEP 31.38.01.13-Gen.
Piping classes – Exploration and production	DEP 31.38.01.15-Gen.
Piping – Requisition	DEP 31.38.01.92-Gen.
Pipeline engineering (amendments/supplements to ISO 13623)	DEP 31.40.00.10-Gen.
Glass-fibre reinforced plastic pipeline and piping systems	DEP 31.40.10.19-Gen.
Selection of materials for life cycle performance (upstream equipment) including H ₂ S-containing environments (amendments and supplements to ISO 15156:2009)	DEP 39.01.10.12-Gen.
Welding of pipelines and related facilities (amendments/supplements to ISO 13847:2000)	DEP 61.40.20.30-Gen.
Mechanical and electrical maintenance equipment and tools	DEP 70.08.10.11-Gen.
Preservation of new and old equipment standing idle	DEP 70.10.70.11-Gen.

Shop and field pressure testing of piping systems DEP 74.00.10.10-Gen.
Shell HSSE & SP Control Framework, Design Engineering Manual DEM1
(DEM) 1 – Application of Technical Standards

https://eu001-sp.shell.com/sites/AAAAA8432/CF/Web/Design_Engineering_Manual_1_DEM1.aspx

Material equipment standards and code MESC

AMERICAN STANDARDS

Welding guidelines for the chemical, oil, and gas industries	API RP 582
Use of duplex stainless steels in the oil refining industry	API TR 938-C
Pipe threads, general purpose (Inch)	ASME B1.20.1
Forged fittings, socket-welded and threaded	ASME B16.11
Buttwelding ends	ASME B16.25
Large diameter steel flanges – NPS 26 through NPS 60	ASME B16.47
Pipe flanges and flanged fittings – NPS ½ through NPS 24 Metric/Inch Standard	ASME B16.5
Factory-made wrought buttwelding fittings	ASME B16.9
Power piping	ASME B31.1
Process piping	ASME B31.3:2014
Welding and brazing qualifications	ASME BVPC Section IX
Non-destructive examination	ASME BVPC Section V
Rules for construction of pressure vessels	ASME BVPC Section VIII, DIV.1
Guidelines for pressure boundary bolted flange joint assembly	ASME PCC-1
Repair of pressure equipment and piping, Article 3.7: Pipe Straightening or Alignment Bending	ASME PCC-2
Recommended practice for personnel qualification and certification in nondestructive testing	ASNT SNT-TC-1A
Standard specification for carbon steel forgings for piping applications	ASTM A105/A105M
Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High - Temperature Service	ASTM A182/A182M
Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications	ASTM A193/A193M
Standard specification for carbon and alloy steel nuts for bolts for high pressure or high temperature service, or both	ASTM A194/A194M
Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service	ASTM A320/A320M
Standard specification for seamless and welded steel pipe for low-temperature service	ASTM A333
Standard specification for carbon and low-alloy steel forgings, requiring notch toughness testing for piping components	ASTM A350/A350M