

TECHNICAL SPECIFICATION

SHOP AND FIELD FABRICATION OF PIPING

DEP 31.38.01.31-Gen.

August 2005

DESIGN AND ENGINEERING PRACTICE



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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.

This DEP is a revision of an earlier DEP of the same number dated April 2003. A summary of the changes from the previous edition is listed in (1.6).

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI and SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them.

This DEP is intended for use in oil refineries, chemical plants, gas plants and, where applicable, in exploration and production facilities and supply/marketing installations.

When DEPs are applied, a Management of Change (MOC) process should 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 may be more stringent than in this DEP the contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environment, economic and legal aspects.

In all cases the contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, 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/Vendor** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

NOTE: In the context of this DEP, the term Vendor is used to mean both the material supplier and the piping system fabricator. The term Contractor is used in the sense of a managing contractor.

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

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

hydrogen service refers to all process conditions with a hydrogen partial pressure greater than 7 bar (abs).

sour service means "sour" service and "moderate/high severity wet H₂S" 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.

1.4 ABBREVIATIONS

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

1.5 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (6).

1.6 CHANGES FROM THE PREVIOUS EDITION

The previous edition of this DEP was dated April 2003. Other than editorial changes, the following are the major changes to the previous edition.

Old Section	New Section	Change
General		
3.3	3.3	Correction on standard for material certificates.
3.6	3.6	PMI more fully specified
3.7	3.7	Material substitution simplified.
4.1	4.2	Pressure testing content moved to 4.2.
-	4.3	New section on NDE.
4.3	4.4	Hardness testing more fully specified.
Appendix 4	Appendix 4	Appendix modified with regards to inspection levels.

1.7 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the DEP Administrator at standards@shell.com.

Shell staff may also post comments on this DEP on the Surface Global Network (SGN) under the Standards/DEP 31.38.01.31-Gen. folder. The DEP Administrator and DEP Author monitor these folders on a regular basis.

2. PIPE FABRICATION

2.1 GENERAL

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, see DEP 31.38.01.13-Gen.

2.2 PREPARATION

2.2.1 Cutting and bevelling

Cutting and bevelling of pipes may be done by mechanical means: flame cutting, plasma cutting or water cutting. The following shall apply:

- For carbon steel, flame (or arc) cuts shall be reasonably smooth and all oxides shall be removed from the surface by grinding to bright metal.
- For low-alloy steel, after flame cutting a minimum of 2 mm of material shall be removed from the cut surface by grinding.
- For stainless steel, flame cutting shall not be used but plasma or water cutting may be used. The surface shall be ground to bright metal after plasma cutting.

Weld bevels for butt welds of pipes and fittings shall be in accordance with ASME B16.25.

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. Cutting oil shall be removed.

Pipes for socket weld joints shall be cut square and burrs removed.

2.2.2 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.

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

The minimum distance between the edges of two pressure-containing welds shall be twice the wall thickness of the thicker pressure part. The same requirement applies to the distance between non-pressure attachment welds and a pressure-containing weld in order to allow non-destructive inspection of the pressure-containing weld. Longitudinal welds in two adjacent pipes should be 180° apart, but in any case shall be separated by at least twice the wall thickness of the thicker pipe.

If the pipe contains a longitudinal weld, this weld shall 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 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 the welding shop accepts them for further handling.

2.3 BENDING

2.3.1 General

If economically attractive, bending of pipe spools may be considered as an alternative to using welded elbows. The application of bending and the extent of its use shall be agreed

with the Principal at an early stage of a project, and, in such cases, the piping design shall be revised to incorporate the required bending radii.

Bending radii shall be indicated on the isometric drawing. The bending radius, R_m , shall be $1.5 \times D_n$ or $5 \times D_n$ (where D_n is the nominal diameter of the pipe) and depends on the minimum remaining wall thickness, maximum deformation allowed, available space and available bending machines. Other bend radii shall be subject to the approval of the Principal.

If the pipe contains a longitudinal weld, this weld should be located in the neutral zone of the bend. If the pipe will be installed horizontally, the longitudinal weld shall be located on the top of the pipe. If one spool is bent in various planes, the longitudinal weld shall be 45° from the top of the pipe.

Pipe bending shall be carried out in pipe bending machines or presses using formers. Tolerances for thinning, flattening and wrinkling are specified in (2.6.2).

The Manufacturer shall submit bending, heat treatment and non-destructive examination procedures to the Principal for acceptance. These procedures shall, as a minimum, including the following:

- operating sequence;
- forming process and machinery used;
- production parameters, which shall at least cover:
 - width of heated band;
 - heating rate and method;
 - bending temperature range;
 - cooling rate, cooling method and coolant flow rate;
 - production bending speed;
 - method of temperature measurement and recording;
 - bend dimensions and tolerance;
 - non-destructive examination procedures;
 - post forming;
 - fabrication procedure qualification;
 - production control procedure;
 - calibration of equipment and tolerances.

Three types of bending processes are identified:

1. **Cold bending**, which is defined as bending at a temperature well below the final heat treatment temperature of both ferritic and austenitic materials. Cold bending shall not be used for piping in sodium hydroxide service.
2. **Hot bending**, which is defined as bending at a specified elevated temperature. Heat shall be applied uniformly before bending. Local heating by manually operated gas torches shall not be applied. Water cooling at any time during bending shall not be applied.
3. **High Frequency Induction Bending (HFIB)**, which is a hot bending process using machines in which the pipes are passed through an induction coil where, successively, a narrow band of pipe material is rapidly heated to the required bending temperature using the high frequency induction method. The adjacent pipe is kept cool by water and/or air jets, thus providing the necessary support for the heated area without the need for mandrels. It shall be ensured that the bending temperature is uniform over the complete circumference of the bend. An induction ring with a square profile should be used. An example of a Fabrication Procedure Qualification is attached as (Appendix 1). HFIB can be economically attractive for carbon and stainless steel. For low alloy steel this method is generally attractive only for special applications (e.g. large diameters, large wall thicknesses) where welding elbows are not readily available. It should be noted that the logistics for HFIB differ from other pipe spool production methods and

generally require a larger lay-down/stocking area because spools are in diameter/material batches rather than as required for installation in the plant.

Heat treatment shall be applied as specified in ASME B31.3 and in (2.3.2), (2.3.3) and (2.3.4) below.

Weld repairs of cracks in pipe bends shall not be permitted.

Bends intended for use in pipes that require pigging shall be checked for correct bore and radii to allow the passage of the pig.

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

2.3.2 Carbon steels, fine grain carbon steels, 0.3 Mo steels and 0.5 Mo steels

2.3.2.1 Cold bending

After cold bending, no additional heat treatment is required if the following requirements are met:

- hardness < 248 HV10;
- $R_m > 1.3 \times D_n$

where

R_m is the mean radius of the bend; and

D_n is the nominal diameter of the pipe.

If these requirements are not met, the following heat treatment shall be carried out:

- a normalising treatment for normalised steels;
- an austenising quench (oil, water) and temper treatment (Q+T) for quenched and tempered steels.

NOTE: The above heat treatments may be replaced by a stress relief heat treatment at a temperature above the post weld heat treatment temperature if it can be shown that there has been no deterioration of the mechanical and physical properties (e.g. grain growth).

2.3.2.2 Hot bending

If normalised steels are subjected to hot bending between 780 °C to 980 °C, no additional heat treatment is required. If normalised steels are subjected to bending outside these temperature limits, an additional normalising treatment shall be carried out.

For Q+T materials, a quench (oil, water) from the austenising temperature plus a temper heat treatment shall be carried out in accordance with the pipe material specification.

2.3.2.3 HFIB

After HFIB of normalised steel, a normalising heat treatment shall be carried out unless the bend test defined in (Appendix 1) shows a normalised structure with a grain size smaller than 6 (as defined in ASTM E 112) and a hardness below 248 HV10.

For Q+T materials, a quench (oil, water) from the austenising temperature plus a temper heat treatment shall be carried out in accordance with the pipe material specification.

2.3.2.4 Impact Tested Carbon Steel (ITCS)

ITCS shall be welded in a separate area from carbon steel in order to avoid mixing of pipe materials and electrodes. Colour codes shall be applied when carbon steel, ITCS and low alloy piping are handled concurrently.

2.3.3 Chromium-molybdenum steel piping

2.3.3.1 Cold bending

After cold bending, no additional heat treatment is required if the following requirements are met:

- hardness < 248 HV10;
- $R_m > 1.3 \times D_n$

where

R_m is the mean radius of the bend; and

D_n is the nominal diameter of the pipe.

If these requirements are not met, the following additional heat treatment shall be carried out:

- A stress relief treatment for normalised and Q+T steels, if it can be shown that for similar material no deterioration of the mechanical and physical properties has taken place.
- If this cannot be shown, then an austenising quench (air) and temper treatment for both normalised and Q+T steels shall be carried out. The tempering temperature shall be selected so that the specified mechanical values are met.

2.3.3.2 Hot bending/HFIB

If Q+T steels are subjected to hot bending at a temperature of 850 °C to 900 °C, an air quench from austenising temperature and a tempering treatment shall be carried out.

If normalised steels are subjected to hot bending at a temperature of 850 °C to 900 °C, a normalising heat treatment and cooling in still air shall be applied.

In all cases, the specified mechanical values of the original material specification shall be met.

HFIB of ferritic materials with 5 % Cr or more lies outside the scope of this DEP.

2.3.4 Stainless steel piping

2.3.4.1 Cold bending

For non-corrosive and general refinery service, no additional heat treatment is required if the deformation is limited to less than 20 % for austenitic stainless steel or less than 5 % for duplex stainless steel. If the deformation exceeds these values, a final heat-treatment shall be carried out in accordance with the original pipe material specification.

For all other services, solution annealing followed by a rapid water quench shall be carried out.

2.3.4.2 Hot bending/HFIB

For non-stabilised austenitic stainless steel, e.g., grade 304 or grade 316, hot bending shall be carried out in the temperature range of 1050 °C to 1100 °C (solution annealing) followed by a rapid water quench.

For stabilised austenitic stainless steel, e.g., grade 316Ti, grade 321 or grade 347, hot bending shall be carried out at the homogenising temperature (850 °C to 950 °C) followed by cooling in still air. Alternatively, a heat treatment in the range between 1050 °C to 1150 °C, then lowering the temperature to 950 °C to 1000 °C, followed by cooling in still air, may be applied.

For duplex stainless steel, hot bending shall be carried out in the temperature range of 1050 °C to 1150 °C (solution annealing) followed by a rapid water quench.

For HFIB of austenitic and duplex stainless steel, the complete pipe subjected to bending shall be heat treated as specified above for the various grades, in order to avoid the occurrence of sensitised areas.

2.3.4.3 Contact with other alloys

Stainless steel shall not come in contact with unalloyed or low alloy steels. Stainless steels shall be fabricated in a separate work area and with tools to be used only for the fabrication of stainless steels.

Contact between stainless steel parts and zinc or zinc-containing parts (e.g. galvanised shackles, clamps and rollers) shall be prevented in order to prevent possible liquid metal embrittlement in the event of a fire. If there is any doubt, the stainless steel shall be chemically cleaned before any further work is carried out.

Stainless steel piping (particularly elbows, reducers and tees) coming from unconditioned storage shall be checked for surface contamination with chlorides caused by condensation, or covering caps. Stainless steel piping shall be cleaned by rinsing with low chloride water before painting and welding.

2.3.5 Inspection

After bending, the bent items shall be visually inspected. There shall be no cracks or linear indications.

The inspection requirements for HFIB are listed in (Appendix 2).

2.4 WELDING

2.4.1 General

In addition to the welding requirements of ASME B31.3, the following shall apply:

- The Gas Tungsten Arc Welding (GTAW) process shall be employed for root welds of all pipes and for welds of pipes, branch fittings and flanges in sizes DN 50 and smaller.
- Impact test requirements for welding procedure qualification for carbon steel and duplex stainless steel process piping operating at design temperatures below 0 °C shall be in accordance with DEP 30.10.02.31-Gen.
- 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.
- Weld connections for welded valves and steam traps shall be in accordance with (Appendix 3).

2.4.2 Welding of duplex stainless steel

The quality of duplex stainless steel welds very much depends on heat-input control. The following shall be adhered to so as to ensure that the duplex welds meet the intended quality requirements:

1. All configurations of weld geometry to be encountered shall have a Procedure Quality Record (PQR) test performed – including fillet, attachment, and longitudinal and circumferential welds.
2. Back welding to repair any mismatch (Hi/Low) is not permitted, unless the backwelding procedure is covered by a qualified PQR.
3. Repair weld procedures for half wall thickness and cap repairs also require a PQR.
4. For the qualification of fillet and attachment welds, only metallurgical and hardness testing is required, provided they are welded with the same consumables as qualified in a butt weld PQR.

5. Full mechanical tests and metallurgical tests should be performed on half wall thickness repair welds.
6. Weld cap repairs shall be subject to the same requirements as for fillet welds.
7. Attachment welds in a vibrating environment shall be designed as sweepolet.
8. In addition to the mechanical tests for PQR validation, metallurgical tests also are required on an intermetallic phase count, whereby more than 3 % intermetallic phase is not permitted and the PQR is rejected.

2.5 FINAL CORRECTIONS

If minor adjustments are necessary to satisfy the flange parallelism tolerances specified in DEP 31.38.01.11-Gen., the following correction methods are acceptable, if approved by the Principal:

1. Local heating or cooling;
2. Application of force with local heating.

The following restrictions apply to the heating, cooling and forcing of piping made from carbon steel, low alloy steel or austenitic stainless steel:

- **For carbon steel which does not require a PWHT**, the maximum temperature during alignment corrections shall be 600 °C. Temperature-indicating crayons or contact thermometers shall be used to measure the maximum temperature. If temperature-indicating crayons are used, a margin of 50 °C shall be taken to allow for measurement inaccuracy, i.e., the reading with the crayon shall not exceed 550 °C. Forcing may be applied if necessary. Cooling in still air shall be applied.
- **For carbon steel which requires a PWHT**, the maximum temperature during alignment corrections shall be the maximum PWHT temperature. Temperature-indicating crayons or contact thermometers shall be used to measure the maximum temperature. If temperature-indicating crayons are used, a margin of 50 °C shall be taken to allow for measurement inaccuracy, i.e., the reading with the crayon shall not exceed the maximum PWHT temperature minus 50 °C. Only heating with application of local force shall be used and no quenching shall be used. The area shall either be heated in full compliance with the PWHT procedure or the area which is heated (and corrected) shall be post weld heat-treated.
- **For 0.5 Mo and Cr-Mo steels**, the maximum temperature during alignment corrections shall be the maximum PWHT temperature. Preferably, contact thermometers shall be used to measure the maximum temperature, but temperature-indicating crayons may also be used. If temperature-indicating crayons are used, a margin of 50 °C shall be taken to allow for measurement inaccuracy, i.e., the reading with the crayon shall not exceed the maximum PWHT temperature minus 50 °C. Forcing may be applied if necessary. Cooling in still air shall be applied. Random hardness measurements shall be taken and the hardness shall not exceed 248 HV10.
- **For austenitic stainless steel**, the maximum temperature during alignment corrections shall be 650 °C. Temperature-indicating crayons or contact thermometers shall be used to measure the maximum temperature. If temperature-indicating crayons are used, a margin of 50 °C shall be taken to allow for measurement inaccuracy, i.e., the reading with the crayon shall not exceed 600 °C. The duration of heating shall be kept as short as possible and no forcing shall be applied.

2.6 TOLERANCES

The following dimensional tolerances shall apply:

2.6.1 Length

Length	< 1.5 m	≥ 1.5 m
distance of any two parallel or crossing centre lines	± 1.5 mm	± 3 mm
Centre to flange face		
Flange face to flange face		

2.6.2 Thinning, flattening and wrinkling of bends

The wall thickness after bending shall be at least that specified by ASME B31.3, including the specified corrosion allowance.

NOTE: Because pipe schedules have standard thicknesses, in many cases the pipe selected from a pipe class is thicker than that specified in ASME B31.3.

For flattening tolerances, see ASME B31.3.

Wrinkling tolerances shall be as follows:

- all wave shapes shall blend into the pipe surface in a gradual manner;
- the maximum vertical height of any wave, measured from the average height of two adjoining crests to the valley, shall not exceed 3 % of the nominal pipe size;
- the minimum ratio of the distance between crests as compared to the height between crests and the valley in between shall be 12 to 1.

2.6.3 Flange face alignment

See DEP 31.38 01.11-Gen.

2.6.4 Other dimensional tolerances

For other dimensional tolerances, see ASME B16.9.

3. MATERIAL CERTIFICATION, COLOUR CODING AND TRACEABILITY

3.1 INTRODUCTION

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

3.2 RESPONSIBILITY

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

3.3 GENERAL REQUIREMENTS FOR CERTIFICATION

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

- Material certificates shall comply with ISO 10474 or EN 10204.
- 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.
- 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.
- Certificates issued by material stockists or agents are not acceptable.

3.4 COLOUR CODING OF PIPING BULK MATERIALS

3.4.1 General

Colour coding is intended to supplement, not replace, the normal identification requirements of the specification (for example, ASME, ASTM, MSS, etc.) to which the pipe was purchased.

3.4.2 Colour standard

BS 381C colour standard shall be used.

Paint shall be resistant to salt water atmosphere and tropical climate, and be durable and of a distinctive identifying colour. It shall not cause corrosion of the material to which it is applied, neither during storage and construction, nor during operation of the equipment.

Paints containing sulphur, lead, zinc or other metals are not acceptable.

3.4.3 Method of identification

The following colour codes for Bulk Piping Materials shall be applied.

MATERIAL	COLOUR	BS 381C
Plain Carbon Steel (pipe, flanges, fittings and valves)	None	
Plain Carbon Steel Plate	None	
Fine Grain Carbon Steel for Low Temperature Service (all items, including valves)	Yellow	363
Fine Grain Carbon Steel for Low Temperature Services (Valves specified as ASTM A 353-LCC only)	Green	262
Stainless Steel Type 304 (all items, excluding valves)	None	
Stainless Steel Type 304L (all items)	Red	537
Stainless Steel Type 316 (all items, excluding valves)	Brown	320
Stainless Steel Type 316 (valves)	None	
Stainless Steel Type 316L (all items, including valves)	Blue	166
Ductile Iron (valves)	Light Orange	557
Bronze (valves)	None	
ASTM A 193 Grade B7 (Stud bolts)	White	
ASTM A 193 Grade B8 (Stud bolts)	None	
ASTM A 320 Grade L7 (Stud bolts)	None	

3.4.4 Pipe

Each length of pipe shall be painted over the entire length with a 12 mm to a 40 mm wide stripe, depending on pipe size.

3.4.5 Fittings

Each socket weld fitting, swage or pipe nipple shall be dabbed with a spot of paint 12 mm to 25 mm in diameter.

The entire length of each butt weld fitting shall be painted on the outside surface with a 12 mm to 40 mm wide stripe, depending on size.

3.4.6 Flanges, spectacle blinds etc.

The outer peripheral edge of each flange shall be painted over the entire circumference. For flanges thicker than 25 mm, the width of the band may be limited to 25 mm.

3.4.7 Plate

A stripe shall be painted across from corner to corner.

3.4.8 Valves

Each welded or flangeless (wafer type) valve shall be dapped with a spot of paint 12 mm to 25 mm in diameter.

Each flanged valve shall have the outer peripheral edge of each flange painted over the entire circumference. For flanges thicker than 25 mm, the width of the band may be limited to 25 mm.

3.4.9 Bolting

Each stud bolt shall be dipped with a spot of paint on each end.

3.4.10 Special notes

Paint shall not be applied, in any circumstances, to the following:

- inside surfaces of pipe, flanges or fittings;
- threads;
- weld bevels;
- symbols or markings which would obliterate identification;
- gasket seating surface.

3.5 MATERIAL TRACEABILITY

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

The Vendor 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 Vendor 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 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 (3.6) of the finished products shall be performed if any of Steps 1 through Steps 5 is not followed completely.

3.6 POSITIVE MATERIAL IDENTIFICATION (PMI)

If (3.5) is not completely adhered to, 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.

An approved third party contracted by the Vendor shall carry out PMI. An action plan for PMI testing shall be submitted by the Vendor for the approval of the Principal.

Any portable X-ray emission analyser, such as Texas Nuclear analyser Model 9266 or equivalent with computerised read-out, is acceptable.

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 which occurs at the weldments in stainless steel, whether applied as solid material or as cladding, is acceptable in accordance with the criteria given in of DEP 30.10.60.31-Gen., Appendix 1.

3.7 PROCEDURE FOR CONCESSION REQUEST / MATERIAL SUBSTITUTION

If the Vendor intends to deviate from the originally specified requirements, it shall provide in its written proposal to the Contractor a detailed list of the items so proposed with a copy of a full description, along 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.

4. INSPECTION

4.1 GENERAL

All inspection and testing is the responsibility of the Vendor. 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.

Inspection of welds shall be carried out after final heat treatment in accordance with (Appendix 4). The methods to be employed for inspection, the acceptance criteria for welds, and the progressive examination shall all be in accordance with ASME B31.3. Positive Material Identification (PMI) shall be carried out in accordance with (Appendix 4).

4.2 PRESSURE TESTING

Test pressures shall be as stated on the isometric drawings, see (2.1). For pressure test procedures, see DEP 61.10.08.11-Gen.

Pressure testing may be performed on fully painted piping spools (including welds) provided that:

- 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;
- the test is not considered to be a sensitive leak test in accordance with ASME B31.3;
- the piping spool has been fully inspected (visual examination, non-destructive examination and positive material identification, where specified) and released for pressure test.

4.3 NON-DESTRUCTIVE EXAMINATION

4.3.1 General

Non-destructive examination procedures, techniques, and defect evaluation shall conform to the requirements of the applicable Code or ASME B31.3, as supplemented by that specified in Appendix 4. The extent of examination specified in Appendix 4 is considered sufficient if qualified welding inspectors with a defined span of control are actively present on the worksites and if independent audits are carried out by the Contractor, otherwise the Principal should specify additional NDE.

The requirement for examination of 10 % of the welds shall mean that 10 % of the production welds shall be randomly and independently selected throughout the fabrication period and fully examined. The random selection shall be equally distributed over all welders and all type of welds, which includes welding procedure, pipe size, thickness, welding position, etc. The first 10 production welds made by each welder shall be examined before that welder performs any further welding. If progressive examination of a welder's work is required on the basis of ASME B31.3, the follow up examinations shall first of all be made on welds made by the same welding procedure as used to make the defective weld. The above "first 10 welds" and any progressive examinations shall be in addition to the 10 % examination requirement.

4.3.2 Visual examination of branch connections

Appendix 4 specifies that all welds shall be visually examined.

Supplementary to the requirements for visual examination in ASME B31.3, branch-to-run pipe welds of branch fittings or outlets or of pipe-to-pipe connections shall be visually examined for proper geometry, branch fit-up and weld penetration. The examinations shall be recorded for each branch connection. 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. 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. This radiography shall not be counted in the number of welds being radiographed if 10 % of the welds are to be examined.

Examination requirements for branch connections not specified in the piping classes shall be approved by the Contractor.

4.3.3 Radiography (RT)

Appendix 4 specifies the percentage of welds to be radiographically examined.

All radiographs taken during fabrication shall be made available for examination by the Principal. Final radiographs shall be approved by the Contractor prior to shipment (for shop fabrication) or prior to acceptance (for field fabrication). Radiographic acceptance criteria shall be in accordance with ASME B31.3, as follows:

- 100 % radiography shall be interpreted to 100 % radiography requirements in accordance with ASME B31.3 para. 344.5.2;
- 10 % radiography shall be interpreted to random radiography requirements in accordance with ASME B31.3 para. 344.5.2.

Film quality requirements shall be as follows:

- fine grain film (Class II) for x-ray;
- ultra-fine grain film (Class I) for gamma ray;
- An Image Quality Indicator (IQI) with sensitivity better than 2 % shall be achieved by means of source side location of the IQI. 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.

Contour grinding of welds on the outside surface shall be performed to the extent that clarity of the radiographic examination is maintained.

Geometry, branch fit-up and weld penetration of branch connections with a branch fitting or outlet or pipe-to-pipe connections shall be properly controlled. 5 % Of the branch-to-run pipe welds of branch connections with a size of the run pipe equal or less than DN 150 shall be examined for this purpose by radiography. Examination requirements for branch connections not specified in the piping classes shall be approved by the Contractor.

4.3.4 Ultrasonic examination (UT)

Ultrasonic examination may replace radiography in accordance with ASME B31.3, para. 341.4.1. If ultrasonic examination is applied, automated computer enhanced data acquisition is required 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.

Ultrasonic examination is limited by the local geometry near the welds. The use of ultrasonic examination shall not affect the random and independent selection of the welds for examination.

4.3.5 Liquid penetrant (PT) or magnetic particle examination (MT)

Appendix 4 specifies the percentage of welds to be examined.

Note that this only includes:

- a) branch-to-run pipe welds of branch connections; and
- b) Fillet welds of support clips, shoes, bracings and attachments.

The selected welds shall be fully examined.

Liquid penetrant and magnetic particle examination of welds shall include all accessible weld surfaces and a band of base metal at least 10 mm wide on each side of the weld.

Liquid penetrant 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.

Contour grinding of welds on the outside surface shall be performed to the extent that clarity of the liquid penetrant or magnetic particle examination is maintained.

4.3.6 Ferrite Number (FN) measurement

Appendix 4 specifies the percentage of production welds to have their Ferrite Number measured.

The Ferrite Number of the deposited weld metal of all austenitic stainless steel shop and field welds shall be in the range 3 FN to 8 FN. For duplex stainless steels, the Ferrite Number for the deposited weld metal shall be in the range 35 FN to 70 FN. Ferrite Numbers shall be measured in accordance with ISO 8249.

4.3.6 Other NDE techniques

Other NDE techniques, e.g. time-of-flight diffraction (TOFD), may be used if approved by the Principal.

4.4 HARDNESS TESTING

4.4.1 General

Each welding procedure qualification shall include hardness tests (see 4.4.2).

Appendix 4 specifies the percentage of production welds to be hardness tested. Those welds shall be hardness tested as follows:

- At least one reading per weld shall be taken on piping of size DN 100 and smaller;
- At least two readings per weld shall be taken on piping of size DN 150 through DN 300;
- at least one reading every 400 mm of weld length shall be taken on piping over size DN 300,.

The highest hardness for each weld shall be recorded on the spool sheets for the Principal's review and record.

The hardness shall not exceed 248 HV10 unless ASME B31.3 table 331.1.1 specifies a lower hardness limit. Brinell hardness limits in ASME B31.3 may be converted to Vickers hardness using ASTM E 140.

4.4.2 Hardness measurement method

Hardness measurements for welding procedure qualification shall be performed by the Vickers method, with hardness traverses in accordance with EN 1043-1. The series of readings shall extend from unaffected base material on one side, across the weld to unaffected base metal on the other side. Three traverses shall be made: one 2 mm below the outer surface, one 2 mm below the inner surface and one across the centre. The distance between measurements across the weld shall not exceed 2 mm.

Transverse weld hardness testing of production welds shall be carried out by means of a portable Vickers or Rockwell tester in accordance with ASTM E 110 or, if approved by the principal, by another method capable of detecting a hard HAZ in a reliable and repeatable manner. Hardness tests shall be made on properly ground surfaces. For each set of hardness measurements required, the average and maximum of three measurements on the weld and on each HAZ shall be reported.

Hardness measurements shall be carried out after PWHT (if any).

5. PRESERVATION

Painting shall comply with DEP 30.48.00.31-Gen. Painting requirements should be shown on the line list; see DEP 31.38.01.92-Gen.

Pre-fabricated pipe spools shall be properly protected against corrosion and damage during storage and transport to site. Flanges shall be fitted with flange protectors, including a proven protection against corrosion for the flange face. Plain and bevelled pipe ends shall be provided with plastic covers.

All stainless steel weldments required by the Principal (or the Principal's inspectors) to be pickled and passivated shall be carried out in accordance with DEP 30.10.60.31-Gen.

6. 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 users on the SWW (Shell Wide Web) at <http://swww.shell.com/standards>.

SHELL STANDARDS

Definition of temperature, pressure and toxicity levels	DEP 01.00.01.30-Gen.
Metallic materials – selected standards	DEP 30.10.02.11-Gen.
Metallic materials – prevention of brittle fracture	DEP 30.10.02.31-Gen.
Oxidation of stainless steel weldments	DEP 30.10.60.31-Gen.
Painting and coating of new equipment	DEP 30.48.00.31-Gen.
Piping – general requirements	DEP 31.38.01.11-Gen.
Compilation of bill of material for piping isometrics	DEP 31.38.01.13-Gen.
Field inspection prior to commissioning of mechanical equipment	DEP 61.10.08.11-Gen.
Material Equipment Standards and Code	MESC

AMERICAN STANDARDS

Forged fittings, socket-welded and threaded	ASME B16.11
Buttwelding ends	ASME B16.25
Factory-made wrought buttwelding fittings	ASME B16.9
Process piping	ASME B31.3

Issued by:
American Society of Mechanical Engineers
ASME International
Three Park Avenue, M/S 10E
New York, NY 10016-5990 USA

Standard specification for alloy-steel and stainless steel bolting materials for high-temperature service	ASTM A 193
Standard specification for alloy/steel bolting materials for low-temperature service	ASTM A 320
Standard specification for pressure vessel plates, alloy steel, 9-percent nickel, double-normalized and tempered	ASTM A 353
Standard test method for indentation hardness of metallic materials by portable hardness testers	ASTM E 110
Standard test methods for determining average grain size	ASTM E 112
Standard hardness conversion tables for metals relationship among Brinell hardness, Vickers hardness, Rockwell hardness, superficial hardness, Knoop hardness, and scleroscope hardness	ASTM E 140
Standard test method for liquid penetrant examination	ASTM E 165

Standard guide for magnetic particle examination

ASTM E 709

Issued by:
American Society for Testing and Materials
ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959 USA

BRITISH STANDARDS

Specification for colours for identification, coding and special purposes

BS 381C

Issued by:
British Standards Institution
389 Chiswick High Road
London, United Kingdom W4 4AL

EUROPEAN STANDARDS

Destructive tests on welds in metallic materials -
Hardness testing – Part 1: Hardness test on arc
welded joints

EN 1043-1

Metallic products – types of inspection documents

EN 10204

Issued by:
European Committee for Standardization
Rue De Stassart 36
Bruxelles, Belgium B-1050

Copies can also be obtained from national standards organizations.

INTERNATIONAL STANDARDS

Steel and steel products - Inspection documents

ISO 10474

Issued by:
International Organization for Standardization
Case Postale 56
Geneva, Switzerland CH-1211

Copies can also be obtained from national standards organizations.

**APPENDIX 1 FABRICATION PROCEDURE QUALIFICATION FOR HIGH FREQUENCY
INDUCTION BENDING (HFIB)**

The Contractor and the laboratory in which the tests are to be performed shall be subject to approval by the Principal. The Contractor shall submit a detailed sketch indicating the location of all test specimens for approval by the Principal.

For all materials, at least two test bends per material type shall be prepared, one with the smallest outside diameter and wall thickness, and one with the largest diameter and wall thickness. For low-alloy steel, two test bends on these sizes shall be prepared for each heat.

Qualification shall include all mechanical testing and all non-destructive examinations as specified by the material specification. In addition, for the smallest low-alloy steel qualification test bend, an additional microstructure examination shall be carried out to verify the absence of micro-fissures.

There shall be no repair welding of test bends.

APPENDIX 2 INSPECTION AND TESTING OF PRODUCTION BENDS PRODUCED BY HIGH FREQUENCY INDUCTION BENDING (HFIB)

Each production bend shall be subjected to the following inspection and testing after bending and heat treatment:

- Dimensional checking for ovality, angle, etc. in accordance with ASME B16.9.
- Visual inspection of the external surface including bevels and, where possible, the internal surface.
- The surface of bends shall be free of the defects listed below:
 - any crack or suspected crack;
 - any limitation, lap or dent;
 - any excessive wrinkles as defined in (2.6.2).

For one bend of each production run, i.e., bending machine operating with same pipe size, wall thickness and material, and with all bending parameters within specified limits, the following tests shall be performed:

- An ultrasonic wall thickness measurement on the complete outer and inner radius of each bend shall be carried out to ensure that the wall thicknesses are within the required tolerances. Minimum and maximum values shall be recorded.
- Complete outside and (where accessible) inside magnetic particle examination to ASTM E 709 for carbon steel and low alloy steel. There shall be no linear indications. The method used and the results shall be shown on the material certificate.
- Complete outside and (where accessible) inside liquid penetrant surface examination to ASTM E 165 for stainless steel bends. There shall be no linear indications longer than 2 mm. The method used and the results shall be shown on the material certificate.
- Hardness tests shall be performed at 1/6, 1/2 and 5/6 of the bend angle on the outside surface with four measurements at each location, including the inner and outer radius and the neutral axis. Where possible, the same measurements shall also be taken on the inside surface of the bend.

The hardness values shall be as specified in this DEP. The results shall be shown on the material certificate.

HYDROSTATIC TESTING

Hydrostatic pressure testing is not required prior to installation. The Contractor shall, however, certify that each delivered bend is capable of passing a hydrostatic test at the test pressure at which the original pipe has already been tested in the pipe mill. Hydrostatic testing of piping systems or spools including bends shall be carried out after installation at site.

APPENDIX 3 WELDING PROCEDURE FOR SOFT-SEATED WELDED VALVES

The welding of such valves shall comply with all applicable code requirements as regards quality and strength; however, the heat input shall not be so excessive as to damage the soft seats and distort the bodies of these valves.

SOCKET WELD SMALL BORE VALVES:

The welding process to be used shall be shielded metal arc, metal inert gas or gas metal arc (which should be the lower heat input high deposition (dip transfer) processes). Gas welding shall not be used because of its excessive heat input.

During welding of the valve, the closure member shall be in the open position.

The pipe shall be correctly located and aligned in the valve socket with a clearance of approximately 1.6 mm between the end of the pipe and the bottom of the socket.

The first run of weld metal shall be deposited around the pipe. Additional runs, as required, shall be deposited while ensuring that each run of weld metal is cleaned and any visible defects are removed before further weld metal is deposited. For a detailed welding configuration, see ASME B31.3.

BUTT WELDED VALVES:

For butt-welded valves, the Manufacturer's specification and limitations shall be followed.

APPENDIX 4 INSPECTION CLASSES FOR PIPING

MATERIAL	SERVICE ¹⁾	ASME RATING CLASS	Visual	RT or UT	MT or PT	Hardness	FN
			Section				
			4.3.2	4.3.3 and 4.3.4	4.3.5	4.4	4.3.6
All	Severe cyclic conditions (ASME B31.3, para 300.2)	All	100 %	100 %	100 %	100 % ²⁾	10 % ⁶⁾
Carbon and C-Mn steels with a minimum specified tensile strength $\leq 500 \text{ N/mm}^2$	All	1500 2500	100 %	10 %	100 %	10 % ³⁾	
	• Very toxic • Hydrogen Service • Sour or Wet-H₂S • Liquefied gas • Caustic, sulphuric acid, chlorine	150 300 600 900	100 %	10 %	10 %	10 % ³⁾	
	All other	150 300 600 900		5 % ⁴⁾			
Other ferritic steels, incl. Cr-Mo steels	All, with a normal operating temp > 435 °C	All	100 %	100 %	100 %	10 %	
	All other	1500 2500	100 %	100 %	100 %	10 %	
	All other	150 300 600 900	100 %	10 %	10 %	10 %	
Duplex stainless steel	All	150 300 600 900	100 %	10 %	10 % PT	10 % ⁵⁾	10 %
Austenitic stainless steels and nickel-base alloys	All, with a normal operating temp > 450 °C or with LDT < -101 °C	All	100 %	100 %	100 % PT		100 %
	All other	1500 2500	100 %	100 %	100 % PT		100 %
	• Very toxic • Hydrogen service • Sour or Wet-H₂S • Liquefied Gas • Oxygen	150 300 600 900	100 %	10 %	10 % PT		10 %
	All other	150 300 600 900		5 % ⁴⁾	10 % PT		10 %
Dissimilar metal weldments	All	All	100 %	100 %	100 % PT		

- NOTES:
- For definitions see DEP 01.00.01.30-Gen., DEP 30.10.02.31-Gen., and DEP 31.22.10.32-Gen. or DEP 31.22.20.31-Gen.
 - Applicable for:
 - Carbon and C-Mn steels with a minimum specified tensile strength $\leq 500 \text{ N/mm}^2$.
 - Hydrogen service, sour or wet-H₂S Service, or hydrofluoric acid service.
 - Other ferritic steels, including Cr-Mo steels.
 - Hydrogen service, sour or wet-H₂S Service, or hydrofluoric acid service.
 - Including branch-to-run pipe welds of branch connections in which a size of the run pipe is equal or less than DN 150, as specified in (4.3).
 - Only applicable if:
 - a) the service is sour or wet-H₂S; and
 - b) the Code or the material specification includes hardness restrictions.
 - a) Only applicable for duplex stainless steel and austenitic stainless steel.
 - b) 100 % testing shall be performed if the normal operating temp > 450 °C or if LDT < -101 °C or if the ASME rating class is 1500 or 2500.