

DEP SPECIFICATION

WELDING OF METALS, BASED ON ISO STANDARDS

DEP 30.10.60.32-Gen.

February 2019

DESIGN AND ENGINEERING PRACTICE

DEM1



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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for organising and managing quality assurance (QA) and quality control (QC) for welding of metals, based on ISO standards.

This DEP is a counterpart to DEP 30.10.60.18-Gen., which is based on API RP 582.

This DEP is written in accordance with the latest regulations in force within the European economic area including the European Pressure Equipment Directive (PED) 2014/68/EU and is based on the referenced standards, which cover all aspects of the design and fabrication of pressure equipment.

This DEP recognises and builds on the expertise and good practices developed in previous Shell specifications.

The scope of this DEP does not include pipeline or civil structural welding.

DEP 61.40.20.30-Gen., DEP 37.81.40.31-Gen. and DEP 30.10.60.30-Gen. cover pipeline welding, and DEP 37.81.10.34-Gen. covers civil structural welding.

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 2017; 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 Fabricators nominated by them. Any authorised access to DEPs does not for that reason constitute an authorisation 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 **Fabricator** is the party that manufactures or fabricates the equipment and provides services to perform the duties specified by the Contractor.

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 Abbreviations

Term	Definition
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
B	Maximum nominal pipe wall thickness for “as-welded” application
CI	Confidence Interval
CMn	Carbon Manganese
CSWIP	Certification Scheme of Welding Inspection Personnel
EWf	European Federation for Welding, Joining and Cutting
FCAW	Flux Core Arc Welding
GMAW	Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
HAZ	Heat Affected Zone
IIW	International Institute of Welding
ITP	Inspection and Test Plan
IVB	Independent Verification Body
MT	Magnetic Particle Inspection
NDE	Non-destructive Examination (also known as NDT)
NOBO	Notified Body
OD	Outside Diameter
PED	(European)Pressure Equipment Directive
PRE(N)	Pitting Resistance Equivalent (including nitrogen)
PT	Liquid Penetrant Examination
PWHT	Post Weld Heat Treatment

Term	Definition
RT	Radiographic Testing
SAW	Submerged Arc Welding
SMAW	Shielded Metal Arc Welding
t	Nominal Pipe Wall Thickness
TMCR	Thermo-Mechanically Controlled Rolled
TOFD	Time of Flight Diffraction
UT	Ultrasonic Testing
VT	Visual Testing
WPQR	Welding Procedure Qualification Record
WPS	Welding Procedure Specification

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 (11).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a full revision of the DEP of the same number dated February 2017. The following are the main, non-editorial changes.

Section/Clause	Change
All	Restructured and clarified requirements, enforced use of shall/should/may for normative statements.

1.6 COMMENTS ON THIS DEP

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

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

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

1.7 DUAL UNITS

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

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.

1.9 PRECEDENCE OF DOCUMENTS

1. In case of conflict between documents the following precedence of documents shall apply:
 - a. First level - statutory laws and regulations;
 - b. Second level - this DEP;
 - c. Third level - cross-referenced documents;
 - d. Fourth level - International codes and standards.

2. QUALITY PROGRAM

2.1 GENERAL

1. Welding QA/QC of equipment and piping components shall be implemented under a Fabricator quality management system that conforms to ISO 9001 and ISO 3834 and certified by an IVB.
2. Fabricator shall develop and maintain its quality system for welding activities based on ISO 3834-6.
3. A welding procedure specification (WPS) shall be considered an engineering document and is part of the detailed design of a component.
4. The applicable requirements specified in ISO 3834-5 shall be applied.

2.2 PERSONNEL COMPETENCIES

1. The Welding Coordinator, as defined in ISO 3834-2, shall be a EWF / IIW International Welding Engineer or International Welding Technologist in accordance with ISO 14731.
 - a. The certified level of active experience of the Welding Coordinator, according to the International Institute of Welding, shall be a minimum of three years, based on evidence.
2. Welding inspection personnel shall hold a valid welding inspection qualification and certificate in accordance with Table 1 or an alternative qualification approved by the Principal.

Table 1 Competence levels for welding inspection personnel

Competence Level	Country/ Region	Applicable Standard	Inspector Position	Designation
1	UK / Europe	ISO 17637	Visual Welding Inspector	3.0
	Netherlands / Europe	ISO 17637 / 14731	International Welding inspector, Basic	IWI-B
	USA	AWS	Certified Associate Welding Inspector	CAWI
2	UK / Europe	ISO 17637	Welding Inspector	3.1
	Netherlands / Europe	ISO 17637 / 14731	International Welding inspector, Standard	IWI-S
	USA	AWS	Certified Welding Inspector	CWI
3	UK / Europe	ISO 17637	Senior Welding Inspector	3.2
	Netherlands / Europe	ISO 17637 / 14731	International Welding inspector, Comprehensive	IWI-C
	USA	AWS	Senior Certified Welding Inspector	SCWI

2.3 INSPECTION AND TEST PLAN

1. The Contractor shall submit to the Principal, for review and approval, an Inspection and Test Plan (ITP) and related method statements prior to commencement of welding work.
2. The Contractor shall review and, if deemed acceptable, approve all documents from the Fabricator prior to submission to the Principal.

2.4 DEVIATIONS

1. Any conflicts between the requirements of this DEP and other relevant documents shall be referred to the Principal for resolution.

2.5 FINAL ACCEPTANCE

1. Contractor SHALL [PS] submit the following for approval of the Principal:
 - a. Fabricator's report and record of monitoring of production welds;
 - b. Fabricator's welding inspection report.

3. GENERAL REQUIREMENTS

3.1 WELDING PROCESSES

1. All welding shall be performed with one of the processes in Table 2.

Table 2 Acceptable welding processes

Process Name	ASME Designation	EN/ISO Designation	Comment
gas tungsten arc welding	GTAW	141	Refer to (3.1, Item 2)
shielded metal arc welding	SMAW	111	
gas shielded flux cored arc welding	(GS)FCAW	136	Refer to (3.1, Item 2)
self-shielded flux cored arc welding	(SS)FCAW	114	
submerged arc welding – solid wire	SAW	121	Refer to (3.1, Item 3)
submerged arc welding – cored wire	SAW	125	Refer to (3.1, Item 3)
plasma arc welding	PAW	15	Refer to (3.1, Item 2)
gas metal arc welding (active gas)	GMAW	135	Refer to (3.1, Item 2,4)
metal-cored arc welding (active gas)	MCAW	138	Refer to (3.1, Item 2,4)

2. Gas shielded processes (GTAW, GSFCW, GMAW, MCAW, PAW) shall be used in the field only if adequate weather shielding that is approved by the Principal is provided.
3. SAW systems shall be fully mechanised (automated).

GMAW or MCAW might be allowed if the Fabricator can demonstrate to the Principal's satisfaction, adequate experience with the processes, ongoing control over the process, and the continued competence of the welders.
4. The root and second pass of all single-sided welds shall be made using one of the following methods, in order of preference:
 - a. GTAW (preferred);
 - b. Subject to review and approval by the Principal: Controlled droplet transfer (semi)-automated Pulsed GMAW welding processes such as STT (surface

tension transfer), RMD (regulated metal deposition), ESAB QSET (optimal short arc parameters setting), and CMT (cold metal transfer), provided that the Contractor can demonstrate successful prior experience (e.g., previous project listing service, material specifications and thickness ranges).

5. All GTAW machines shall be equipped with arc starting devices, e.g., high frequency starting unit, crater-eliminating, and slope-out control.
 - a. If regulations do not permit arc starting devices, alternative proposals shall be subject to the approval of the Principal.

3.2 MATERIALS

3.2.1 Grouping

1. Substrate/parent materials identified under different groupings in ISO/TR 15608 shall be defined as dissimilar metals to be welded.
2. Similar parent material welded with other grouping weld metal shall be treated as a dissimilar metal weld.

3.2.2 Parent materials certification

1. Materials used for qualification of WPSs shall be representative of materials to be used in production welding.

In this context, 'representative' is determined based on the essential variables.
2. Materials used for welding procedure qualification shall be supplied to a recognised manufacturing specification and as a minimum certified in accordance with EN10204 (ISO 10474), inspection certificate 3.1.

3.2.3 Welding consumables

3.2.3.1 General

1. Welding consumables shall be supplied by a Manufacturer/Supplier accredited in accordance with ISO 9001 or an equivalent quality specification approved by the Principal.
2. Welding consumables shall be approved by one of the following organisations or another organization approved by the Principal:
 - a. Controlas;
 - b. Lloyds Register of Shipping;
 - c. American Bureau of Shipping;
 - d. Det Norske Veritas;
 - e. Bureau Veritas.
3. Welding consumables for new WPQRs shall be subject to the approval of Principal via the proposed WPS prior to qualification.
4. As a minimum, all welding consumables used in production welding shall produce welds with mechanical properties that are the same or better as those specified for the base metal, unless otherwise specified.
5. With the following exception, all consumables shall be identified on the WPS by their AWS or ISO classification and by their Manufacturer/Supplier's name and designation.
 - a. For solid wire electrodes (ISO 636, ISO 14171 and ISO 14341), identification solely by ISO classification may be done.

3.2.3.2 Consumable certification

1. As a minimum, welding consumables shall be delivered in accordance with their product datasheet and have certification (including chemical analysis) according to EN 10204 (ISO 10474), Type 3.1.
2. Each consumable, or consumable batch, shall have individual marking relative to its certification.
3. If batch testing of welding consumables is done, welding and testing shall be carried out in accordance with a typical WPS and certification be presented in the format of a WPQR.
 - a. Production material or an equivalent parent metal specification shall be used for such consumable certification.
4. Fluxes for SAW processes shall be delivered with certification according to EN 10204 (ISO 10474), Type 2.2.

3.2.4 Consumable handling/storage

3.2.4.1 General

1. Stored consumables shall be clearly identified with brand name, classification and batch number.
2. Consumable handling shall be controlled by a procedure subject to approval by the Principal.
 - a. Storage shall be in accordance with the Manufacturer/Suppliers' recommendations for the consumable type.
3. All non-identified, damaged, wet, partially used, rusty or otherwise contaminated consumables shall be discarded.
4. Records of consumables shall be maintained to ensure an auditable trail from receipt, through pre-treatment, their issue to operators and their return to stores so that their identity can be verified at any stage.
5. Consumables that cannot be identified to the satisfaction of the Contractor or Principal shall be discarded.
 - a. Any welds made with such consumables shall be cut out and re-welded.

3.2.4.2 Shielded metal arc welding

1. For SMAW, low hydrogen electrodes shall not be stored in heated cabinets containing electrodes of other types, such as rutile or organic type electrodes.

3.2.4.3 Gas shielding welding process (GTAW/GMAW/FCAW)

1. Each package unit (container or reel) of wire shall be labelled with the information from the supply container.
2. All bottles containing shielding gases shall have identification as per AWS 5.32.
3. Wire spools for automatic and semi-automatic processes shall be stored in original packaging.
 - a. Storage should be done using cabinets or facility with controlled conditions of temperature and humidity according to the Manufacturer's/Supplier's recommendation.
4. GTAW filler wires for CRA and non-ferrous welding shall be cleaned with a solvent immediately prior to their use.

5. Wire for automatic or semi-automatic welding, remaining coil or spool that is partially used may be reused in its original container, carefully sealed, and stored in a controlled storage on the condition that remaining welding consumable is of adequate quality to be reused.
6. FCAW wires shall be returned to a controlled storage area at the end of each shift.
7. Bare filler wire in coils or spools that have not been kept in sealed containers after use or wire that has been contaminated with rust, grease or other debris, shall not be re-used without cleaning in accordance with the wire Manufacturer/Supplier's specifications.
8. All wire that cannot be cleaned without damage to the surface, change in size, or other damage that would adversely affect its use shall be discarded.

3.2.4.4 Submerged arc welding

1. SAW fluxes shall not be left in machine hoppers for extended periods when welding is not being carried out, e.g., overnight or during non-productive shifts.
2. Recycling of flux shall only be allowed if the procedure is endorsed by the consumable Manufacturer/Supplier and by the Principal.
3. Each batch of flux and wire shall be labelled with the information from the supply container.

4. WELDING PROCEDURE PREPARATION AND QUALIFICATION

4.1 GENERAL

1. Welding procedures for all welded joints SHALL [PS] be prepared and qualified in accordance with ISO 15614, including requirements from the design code, service and client.
2. The documents described in (4.1, Item 1) shall be subject to review and approval by the Mechanical, Materials & Integrity (MMI) Technical Authority of the Principal.
3. Each Fabricator shall prepare its own WPSs and qualify its own welding procedures.
 - a. WPSs shall contain information as specified in ISO 15609 and (Appendix A).
4. The testing results for WPQR/weld test record shall be presented in a detailed format and with traceable document trail (Appendix A).
5. Unless otherwise specified, multi-pass fillet welds may be qualified by the qualified procedure for groove welds in accordance with ISO 15614,
6. Separate WPSs shall be provided for groove and fillet welds.
7. Single pass fillet welds shall be separately qualified in accordance with ISO 15614.

4.2 PREVIOUSLY QUALIFIED PROCEDURES

1. WPSs for welding procedures previously qualified by the Fabricator may be submitted for approval provided the WPSs meet the requirements of this DEP and they are supported by WPQRs that are approved by an NOBO or a recognised independent third party.
2. The ownership of WPQRs and WPSs shall be in accordance with ISO 15614-1 Section 8.2 subject to approval of the Principal.

4.3 PROCEDURE DOCUMENTATION

1. Welding procedure documentation, including the final WPS, and welder instruction cards (if adopted), shall be submitted to the Principal for final approval.
 - a. The final WPS may be modified from the original WPS within the allowable ranges given by ISO 15614 and applicable construction code according to the parameters actually used during procedure qualification.
2. As a minimum, the WPQR and weld test record documentation shall include the information specified in (Appendix A).

4.4 ESSENTIAL VARIABLES

1. Any change to a welding procedure outside the allowances to the essential variables specified in ISO 15614 and applicable construction codes shall require re-qualification of the procedure.
2. If a welding procedure includes material thicknesses above a threshold such that more stringent testing is required, the procedure qualification shall be limited to that threshold, unless the more stringent testing is performed.
3. Weaving (i.e., the width of the final bead) shall be limited to the ranges in Table 3.

Table 3 Weaving ranges

SMAW process	Three times the electrode diameter
GTAW process	Maximum equal to used cup diameter or 12 mm (1/2 in), whichever is smaller
GMAW/FCAW process	Maximum equal to used cup diameter or 15 mm (5/8 in), whichever is smaller

Weaving is restricted as quality control in addition to heat input and mitigation of air ingress to minimize risk of porosity on gas shielding welding processes.

4.5 WELDING PROCEDURE QUALIFICATION TESTING

4.5.1 General

1. Welding procedure qualification testing shall not commence without the presence of the Principal or its representative and a NOBO or recognised independent third party.
2. The Fabricator shall record all the information required for WPQRs as specified in (Appendix A).
3. Equipment, such as portable arc monitoring systems, current meters, and temperature measurement devices, shall have current and valid certificates of calibration.
4. WPQRs, inclusive of all required information and, when deemed acceptable, shall be signed as witnessed by the Fabricator and approved by the NOBO or a recognised independent third party.

Rationale: The Principal or its representative will review the final WPS/WPQR/weld test record combination and give approval to the WPS (or WPS register) before production welding starts.

5. Mechanical testing shall be performed per ISO 15614 and the additional requirements in this DEP.
6. Designated testing laboratories shall have a quality system in compliance with ISO 17025 or equivalent.

7. When PWHT is specified, it shall be carried out in accordance with (6.2) per the planned production sequence.
8. Multi-pass fillet welds may be qualified by groove weld performance testing.
9. Production weld testing of multi-pass fillet welds shall be performed to provide evidence of positive penetration of the root pass only.

4.5.2 Nondestructive testing

1. The NDE shall be performed for welding procedure qualification as per Table 4.

Table 4 NDE Testing

Butt Welds	Visual
	MT ferrous materials or PT for non-ferrous materials
	Radiography, (X-radiography technique)
	Ultrasonic, if specified for the material.
Fillet Welds	Visual
	MT ferrous materials or PT for non-ferrous materials

2. Visual examination of completed welds shall be conducted by both the Fabricator and the Principal, or its representative.
 - a. Cutting of a test piece for mechanical testing should not take place until it has been visually examined and accepted by the NOBO or a recognised independent third party.
 - b. If the test piece diameter be too small to allow proper examination of the weld root, then the test piece shall be cut longitudinally to facilitate examination.
 - c. For new welding procedure qualifications where alternative or additional NDE methods are proposed for production welding (e.g., time-of-flight diffraction (TOFD)), the test piece shall also be subjected to these NDE methods.
3. When NOBO witness is required, this shall be arranged by the Fabricator.
4. When acceptance criteria are not defined in the purchase specifications, the acceptance criteria shall be defined as "the design code requirements or ISO 5817 quality level B."

The NDE acceptance criteria are normally covered by the selected design code for the equipment or piping, for example PD 5500 or EN 13445.

4.5.3 Macro section examination

4.5.3.1 General

1. Macro sections shall be prepared and etched such that the whole cross section of the weld, inclusive of HAZ, and adjacent parent material and individual weld passes are visible.
2. Macro sections shall be examined under magnification between 3x and 8x.
3. WPQR documentation shall include original photographs or good quality digital images of the macro sections with the following:
 - a. any hardness survey indentations visible on the photographs;
 - b. photographs marked to indicate the magnification (scale bar).

4. For weld acceptance the examination of the macro section shall not reveal any cracks, lack of fusion (root, sidewall or inter-run) or volumetric defects (slag, porosity) that are outside the limits set by the design code or ISO 5817 quality level B.

4.5.3.2 Hardness testing

1. Hardness surveys, as specified in ISO 15614, shall be carried out on macro sections using Vickers hardness at 10 kg load.
2. Hardness testing shall be in accordance with ISO 6507-1.
3. The hardness requirements for base material, HAZ, and weld metal in Table 5 shall apply:

Table 5 Hardness requirements - base material, HAZ and weld metals

Application	Maximum Hardness
sour environments in oil and gas production facilities	Refer to DEP 39.01.10.12-Gen.
wet H ₂ S environments in petroleum refining and related processing environments	Refer to DEP 30.10.02.17-Gen.
ferritic metals in downstream process services, including H ₂ service conditions	250 HV10 for the entire weld and the HAZ
ferritic metals in non-sour service in oil and gas production	300 HV10
ferritic metals in utility services (steam, air, water, non-sour service)	300 HV10
9% Ni steels in the as-welded condition	350 HV10
9Cr-1Mo-V steel (P91, T91) in the PWHT condition	290 HV10
structural steels not directly welded to pressure containing parts	325 HV10
3.5% Ni steel with base metal thickness ≤ 9.5 mm (3/8 in)	250 HV10
3.5% Ni steel joint thickness > 9.5mm (3/8 in)	275 HV10 in the mid-thickness and cap when the hardness impression is located at least 8 mm (5/16 in) from the internal surface
duplex stainless steels	334 Hv10 for 22Cr DSS 375 HV10 for 25Cr DSS
austenitic stainless steels	250 HV10

4.5.3.3 Low temperature, impact testing

1. For impact testing, refer to ISO/TR 15608, which specifies additional material group-specific requirements.

The materials within each group have a unique response to low temperature conditions; therefore, weld qualification impact testing is group specific.

2. Tables 6a and 6b shall be used in lieu of Tables 3 and 4 in ISO 15614-1 for range of qualification for materials.

Table 6a Range of qualification for steel groups and sub-groups

Material (sub-) group of test pieces	Range of qualification
1-1	1 ^a -1
2-2	2 ^a -2
3-3	3 ^c -3 ^c
4-4	4 ^b -4
5-5	5 ^c -5 ^c
6-6	6 ^c -6 ^c
7-7	7 ^c -7 ^c
8-8	8 ^c -8 ^c , except that UNS No is essential variable where Mo > 4%
9-9	9 ^c -9 ^c
10-10	10 ^c -10 ^c , except that UNS No is essential variable
a. Covers the equal or lower specified yield strength steels of the same group. b. Covers steels in the same sub-group and any lower sub-group within the same group. c. Covers steels in the same sub-group.	

Table 6b Range of qualification for nickel alloy and nickel alloy/steel groups

Material group of test pieces	Range of qualification
41-41	41-41
42-42	42-42
43-43	43-43
44-44	44-44
45-45	45-45
46-46	46-46
47-47	47-47
48-48	48-48

4.5.4 Tube-to-tubesheet welding

1. Welded tube-to-tubesheet joints shall be full-strength welded and qualified in accordance with the requirements of ISO 15614-8.

2. Acceptance criteria shall be all of the following:
 - a. no cracks;
 - b. no lack of fusion;
 - c. no lack of penetration;
 - d. no porosity.
3. The allowable expansion at tube-to-tubesheet joints shall be agreed between the Fabricator and the Contractor, with consideration of the tube and tubesheet materials, hardness, and potential for work hardening during the expansion process.
4. All mechanical testing shall take place after expansion.
5. A minimum of three tensile pull-tests shall be performed on a qualification test coupon.
6. For wet hydrogen sulphide or sour services, a micro-hardness survey for weld metal, HAZs, and base metals shall be performed in accordance with ISO 15156.
7. Autogenous seal welds shall not be applied as per ISO 16812.

4.5.5 Repair welding procedure

1. Dedicated WPSs, including all of the following, shall be prepared for repair welding:
 - a. the method of defect excavation;
 - b. the shape and size of excavation prior to re-welding;
 - c. all inspections required prior to re-welding;
 - d. the WPQR, if different from those used for the original weld.
2. Repair welding should be carried out to the same procedure as the original welding.
3. Where a different welding procedure (i.e., a change of process or other essential variable) is to be used for repair welding, the repair WPS shall be qualified in accordance with this DEP.
 - a. Qualification shall require the reproduction of a typical production repair.
4. Full penetration and partial penetration excavations shall be qualified separately.
5. For partial wall excavations, the remaining ligament adopted for the test weld shall be the smallest allowed in production.
6. Where impact testing is specified for the original weld, impact testing of the repair weld metal and the adjacent HAZs, both in the parent material and the original weld metal, shall be carried out at the test temperature of the original weld.
7. When a separate repair WPQR is required by the relevant material specific section, and where the repair welding is performed using essentially the same procedure as the original weld, tensile and bend tests are not required for the repair WPQR.
 - a. All other test requirements shall be met as specified.

5. WELDER QUALIFICATION

5.1 GENERAL

1. All welders shall be qualified in accordance with ISO 9606.
2. All welding operators shall be qualified in accordance with ISO 14732.

5.2 WELDER IDENTIFICATION

1. Whilst on site, the welders and welding operators shall be identifiable.
2. The Fabricator shall maintain a report of welder IDs including name, photograph, and welder identification number.
3. In the event that a welder leaves the work, the associated welder number shall not be assigned to another welder employed on the work.

5.3 WELDER PRE-QUALIFICATION

1. Welders qualified on work other than for the Principal may be accepted by the Contractor provided the following is satisfied:
 - a. their qualification has been carried out in accordance with ISO 9606 and the requirements of this DEP;
 - b. their qualification testing has been witnessed by a NOBO or independent third party acceptable to the Principal, and the certificate of qualification is endorsed accordingly;
 - c. the Fabricator can provide proof that the welder has been continuously employed by the Fabricator for the previous six months and has been welding with reasonable continuity during that time, to the same, or similar, procedures with satisfactory results.

5.4 QUALIFICATION DOCUMENTATION

1. Prior to commencement of work, the Fabricator shall submit the following:
 - a. a register of the welders to be used on the work, listing the procedures, positions and thickness ranges in which they are qualified, together with the identity number for each welder;
 - b. all weld performance qualification certificates, including relevant back-up documentation, such as NDE and mechanical test certificates.

5.5 TIME LIMITATIONS

1. Welder and welding operator qualification certificates shall be valid for six months from the date of approval and revalidated as per ISO 9606 9.3(c).

6. PREHEATING AND POSTWELD HEAT TREATMENT

6.1 PREHEATING

6.1.1 Preheat temperature

1. For carbon-manganese and low alloy steels, the minimum preheat temperature shall be as calculated in accordance with ISO/TR 17671-2 using the maximum carbon equivalent allowed for the material to be welded and the weld metal hydrogen level guaranteed by an approved consumable control procedure.
2. If higher preheat temperatures are necessary to meet the hardness values required by this DEP, particularly for sour service conditions in accordance with DEP 39.01.10.12-Gen. or DEP 30.10.02.17-Gen., as applicable, the temperature margin above the minimum required by ISO/TR 17671-2 shall be applied to all thicknesses to be welded.
3. For reinforced branch fittings, such as olets, that are to be welded, the minimum preheat temperature shall be 50 °C (90 °F) above that specified by ISO/TR 17671-2.
4. If preheat is not explicitly required by this DEP and ambient temperature is below 5 °C (41 °F), or if condensation/moisture is apparent on work surfaces, then sufficient

preheat shall be applied to ensure work surfaces are dry and remain warm to the touch.

5. For 3.5 % nickel steels, a minimum preheat temperature of 100 °C (212 °F) shall be used for welding all thicknesses.

6.1.2 Preheat application

6.1.2.1 General

1. For materials with wall thickness up to and including 19 mm (3/4 in), preheating shall be by gas torch or electrical resistance heaters.
 - a. For wall thickness above 19 mm (3/4 in), electric resistance heating mats shall be used, unless it is agreed with Principal that access or location makes it impractical.
2. Electrical resistance elements shall be controlled by thermocouples attached on or adjacent to the weld preparation.
3. Thermocouple devices shall be regularly calibrated as specified in ISO 17663 and ISO IEC 60584-1, with a maximum interval of six months.
4. Preheating with oxy/fuel gas should only be by soft flame burners designed for the purpose.
5. Handheld oxy/fuel gas burners should only be used for welds on pipes less than 168.3 mm OD (DN150 (NPS 6)) or attachment welds less than 300 mm (12 in) long.

This only applies where preheat above 20 °C (68 °F) is required.

6. The temperature of preheat implemented by non-electrical means shall be measured using contact pyrometers, temperature indicating crayons, or thermocouples.
 - a. If there is access, temperature measurement shall be taken on the surface opposite of the one being heated.
 - i. Measurement shall be taken at a location that is displaced from the source of heat by a minimum of 25 mm (1 in) in a direction parallel to the vessel, process piping, or other equipment axis.
 - ii. Measurement shall be taken after removal of the heat source.
 - b. If there is no access to the opposite surface, temperature measurement shall be taken 75 mm (3 in) from both weld toes/edges and delayed for a period not less than five seconds per mm of material thickness after removal of the heat source.
7. Temperature indicating crayons shall be certified to be free (less than 1 ppm) of lead and sulphur or any other low melting constituent.
8. Residue from crayons shall be removed from the weld surface before proceeding with the weld.
9. Thermocouples shall be installed under resistance heater mats, unless test trials prove the process will not expose the component to temperatures above the lower critical transformation temperature of the base metal alloy.

6.1.2.2 Welding interruption considerations

1. Interruption of welding with loss of specified preheat temperature shall not be permitted except for unalloyed steels (Group 1) with UTS of 450 N/mm² (65 ksi) or lower, or for steels with UTS of 490 N/mm² (70 ksi) when welded with low hydrogen consumables and with a welded thickness of less than 28 mm (1.1 in).
 - a. At least 30 % of the weld joint thickness shall have been completed prior to interrupting welding.
 - b. After interruption, the joint shall be slow cooled under insulation.

- c. Preheating shall be restored to the specified temperature before welding is recommenced.
2. If welding is interrupted, with associated cooling, and the completed weld ligament depth is less than 30 % of the total joint thickness, then the appropriate surface inspection (e.g., MT or PT) shall be performed to ensure freedom from deleterious defects.
3. For other materials where interruption of welding is permitted by the applicable welding code the root and second pass as a minimum shall be completed before any welding interruption

6.1.3 Interpass temperature

1. The maximum welding interpass temperature for production welding shall not exceed that measured during welding procedure qualification WPQR by more than 50 °C (90 °F).

6.2 POSTWELD HEAT TREATMENT

6.2.1 General

1. PWHT shall be in accordance with the applicable design codes and as specified in the appropriate standards included in the purchase order.

Additional guidance is given in tables 7A and 7B.

2. Refer to ISO 17663 for PWHT quality requirements.
3. Refer to DEP 30.10.02.31-Gen. for PWHT requirements in relation to engineering against low temperature embrittlement.
4. For quenched/normalised and tempered steels, the PWHT temperature shall be such that it does not cause an unacceptable decrease of mechanical properties of the parent material.
 - a. PWHT temperature shall be at least 25 °C (45 °F) below the tempering temperature used during the manufacture of the base metal component and recorded on the material certificate.
5. The PWHT cycle shall be designed in such a way as to allow for a minimum of one additional PWHT cycle in case weld repairs are required.
 - a. Where conflict between this requirement and the base material temper develops, it shall be brought to the attention of the Principal for resolution.
6. When production test coupons are requested they shall have the same PWHT conditions as the actual items in the assembly.
 - a. Total soak time and cycles for coupons shall be set according to the thickness of the coupons and equipment thickness.
 - b. Soak time on the WPQR shall not be less than what is expected for the maximum thickness range in production welding.
 - c. If additional PWHT cycles need to be applied on the material, additional production test coupons exposed to the same heat cycle are required to verify the mechanical properties stated in the WPQR are maintained.

This includes the heating method either in a furnace or local heat treatment by resistance mats or induction coils.

7. Refer to (6.2.3, Item 1) for the PHWT of dissimilar welds.
8. No welding or heating shall be carried out after final PWHT.
9. Cooling in still air may be applied below 300 °C (572 °F).

6.2.2 Piping PWHT

1. If there is no subsequent machining operation, all piping threads and gasket surfaces shall be protected from oxidation whilst the equipment is subjected to PWHT.
2. PWHT of non-ferrous and austenitic materials shall be subject to the approval by Principal.

6.2.3 PWHT procedure

1. The PWHT procedure, including all of the following, shall be subject to the approval by Principal:
 - a. name of Contractor/Subcontractor;
 - b. ruling specification;
 - c. material and item type;
 - d. method of heating;
 - e. fuel gas and method of atmosphere control (if gas-fired furnace);
 - f. size and type of electrical element (if electrical resistance);
 - g. type, location and number of thermocouples;
 - h. method of thermocouple attachment and removal;
 - i. details of loading and supporting arrangements to avoid distortion;
 - j. provisions to avoid flame impingement (if flame heated)
 - k. holding time and temperature;
 - l. heating and cooling rates;
 - m. type of recording equipment including number of channels;
 - n. chart speed;
 - o. calibration documentation.

6.2.4 Furnace PWHT

1. PWHT shall be performed in a fully enclosing furnace.
2. Fuel powered furnaces shall have adequate flame controls to prevent an oxidising furnace atmosphere or flame impingement onto PWHT items.
3. Unless otherwise specified by the applicable code, the temperature during heating and cooling shall not vary by more than 150 °C (270 °F) in any 4.5 m (15 ft) length of piping.
4. The number of thermocouples shall be sufficient to ensure that the temperature and thermal gradients of the whole of the work are within the required range.
5. One thermocouple shall be attached directly to each spool at the point of greatest wall thickness.
6. If a large number of small spools are to be treated in one batch, thermocouples may be attached to a representative number (no less than one in four) of the spools.

6.2.5 Local PWHT

1. Local PWHT may be used if size or installation restrictions prevent furnace PWHT.
2. For local PWHT, heating shall be by electrical resistance heating elements.