

DEP SPECIFICATION

DEEPWATER SUBSEA CONTROLS, POWER, AND CHEMICAL DISTRIBUTION MANUFACTURING SPECIFICATION

DEP 37.80.02.37-Gen.

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DESIGN AND ENGINEERING PRACTICE



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TABLE OF CONTENTS

1.	INTRODUCTION	4
1.1	SCOPE.....	4
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	4
1.3	DEFINITIONS	4
1.4	CROSS-REFERENCES	6
1.5	SUMMARY OF MAIN CHANGES	6
1.6	COMMENTS ON THIS DEP	7
1.7	DUAL UNITS.....	7
2.	SUBSEA DISTRIBUTION LOGIC DESIGN	8
2.1	GENERAL DESCRIPTION	8
2.2	DISTRIBUTION LOGIC REQUIREMENTS	8
2.3	SUBSEA DISTRIBUTION BREAKAWAY PHILOSOPHY	11
2.4	PARKING PHILOSOPHY	11
3.	SUBSEA DISTRIBUTION HARDWARE WELDING SPECIFICATION.....	14
3.1	GENERAL DESCRIPTION	14
3.2	WELDING AND WELDER QUALIFICATION REQUIREMENTS	14
3.3	PRODUCTION WELD TEST REQUIREMENTS	22
3.4	DOCUMENTATION	24
4.	SUBSEA DISTRIBUTION HARDWARE REQUIREMENTS.....	25
4.1	UTA-MM.....	25
4.2	UTH.....	28
4.3	HDM	34
4.4	EDM	39
4.5	SFL AND ESFL	43
4.6	HFL	48
4.7	EFL.....	53
4.8	UTAJ	58
4.9	PF, IA AND SAS	63
4.10	HYDRAULIC COUPLERS	68
4.11	ELECTRICAL CONNECTORS	68
4.12	BALL, CHECK, AND BACK PRESSURE VALVES	68
5.	REFERENCES	69

1. INTRODUCTION

1.1 SCOPE

This DEP specifies the framework for controls, power, and chemical distribution equipment and gives requirements for the design and manufacture of the following equipment:

- a) Subsea distribution logic design
- b) Subsea distribution hardware welding
- c) Subsea distribution hardware equipment requirements including:
 - o Umbilical termination assembly (UTA-MM)
 - o Umbilical termination head (UTH)
- d) Hydraulic distribution manifold (HDM)
- e) Electrical distribution manifold (EDM)
 - o Steel flying lead (SFL) and Electrical steel flying lead (ESFL)
 - o Hydraulic flying lead (HFL)
 - o Electrical flying lead (EFL)
 - o Umbilical termination assembly jumper (UTAJ)
 - o Parking frame (PF) and Installation aids (IA)
 - o Hydraulic couplers
 - o Electrical connectors
 - o Ball valves and check valves

This is a revision of the DEP of the same number dated February 2011, amended February 2013; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to offshore oil and gas production. 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.

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 word **should** indicates a recommendation.

1.3.2 Abbreviations

Term	Definition
CP	Cathodic Protection
CSWIP	Certified Senior Welding Inspector
CWI	Certified Welding Inspector
DAF	Dynamic Amplification Factor
DWP	Design Working Pressure
EDM	Electrical Distribution Manifold
EFL	Electrical Flying Lead
ESFL	Electrical Steel Flying Lead
FACT	Field Assembled Cable Termination
FAT	Factory Acceptance Test
FITA	Field Installed Termination Assembly
GTAW	Gas Tungsten Arc Welding
HAZ	Heat Affected Zone
HDM	Hydraulic Distribution Manifold
HFL	Hydraulic Flying Lead
IA	Installation Aids
ID	Inner Diameter
IQI	Image Quality Indicator
LC	Logic Cap
MAOP	Maximum Allowable Operating Pressure
MBR	Minimum Bend Radius
MCS	Master Control System
MOC	Management of Change
MQC	Multi-Quick Connection
MV UTH	Medium Voltage Umbilical Termination Head
NDE	Non-Destructive Examination
OD	Outer Diameter
PF	Parking Frame
PLET	Pipeline End Termination
PQR	Procedure Qualification Record
ROV	Remotely Operated Vehicle

Term	Definition
RT	Radiology Testing
SAS	Subsea Accumulator Skid
SCM	Subsea Control Module
SCWI	Senior Certified Welding Inspector
SF	Safety Factor
SFL	Steel Flying Lead
UTA	Umbilical Termination Assembly
UTAJ	Umbilical Termination Assembly Jumper
UTA-MM	Umbilical Termination Assembly Mudmat
UTH	Umbilical Termination Head
WPQ	Welder Procedure Qualification
WPS	Weld 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 (5).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a minor revision of the DEP of the same number dated February 2011, amended February 2013. The following are the main, non-editorial changes.

Section/Clause	Change
Y2.1 para 5	Wording referencing Figure 1 deleted
2.3.1.1	General requirements for SFL/ESFL was deleted
2.3.1.2	General requirements for HFL was deleted
2.3.1.3	General requirements for EFL was deleted
2.4.3, bullet 4)	Changed from MAOP to DWP
2.4.4.1	Deleted UTA in the title and first sentence
2.4.5	Added subsection Calcareous deposits mitigation
3.2.1, bullet d)	Added new first sentence
3.2.3, para 1	Added requirement "automatic welding WPQ shall be qualified in the 5G Horizontal/Verticle weld position"
Table 4	Removed formula in Acceptance Criteria, row 4
3.4, para 1	Added "for each project" and bullet j) CWI certification papers
4	This section was renumbered.
4.1	Title changed to UTA-MM
Table 11	New
Table 12 through Table 19	Previous Table 11 was renumbered Table 12, and so on. Various lines in these tables are revised.

Section/Clause	Change
5	Section 5 removed because Figure 1 Block diagram of UTA components was deleted.
5	References have been updated and are renumbered (5).

1.6 COMMENTS ON THIS DEP

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

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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.

2. SUBSEA DISTRIBUTION LOGIC DESIGN

2.1 GENERAL DESCRIPTION

Subsea production systems are monitored and controlled by the Master Control System (MCS) from which an operator can direct valve operations in subsea trees, manifolds, and flowline terminations. Sensors on these assemblies provide operators with feedback on system conditions such as pressure, temperatures, and flowrates.

Valve commands are sent from the MCS to a Subsea Control Module (SCM) where hydraulic pressure is supplied to or vented from the valve actuator. Sensors are monitored through the SCM, and data is sent to the MCS for processing and display.

Chemicals are injected at various locations within the subsea production equipment for flow assurance and operability purposes. The SCM operates chemical injection valves when commanded by the topsides operator.

Hydraulic pressure, chemical supply, and electrical power, communications, and optical signals are provided to the subsea system through an electro-hydraulic umbilical. The UTA is the main distribution point for the hydraulic, chemical, and electrical supplies to various component of the subsea production system.

The UTA includes six (6) main parts, namely the UTA foundation structure, UTH, HDM, EDM, and UTAJ.

The UTH is permanently attached to the umbilical and is installed into the UTA mudmat during installation. Hydraulic and chemical connections shall be made through multi quick connection (MQC) plates. The electrical connection shall be made through electrical connectors on EFLs. A Remotely Operated Vehicle (ROV) makes all electrical and hydraulic connections.

The production controls system shall be designed to provide full redundancy for hydraulic pressure and electrical power and communications. Redundancy shall be achieved by routing duplicate services through individual components where possible to prevent single point failure.

2.2 DISTRIBUTION LOGIC REQUIREMENTS

2.2.1 General logic requirements

General functional requirements for distribution logic are:

- a) Umbilical distribution equipment shall be designed for maximum reliability, functionality, and flexibility over the design life
- b) Spare circuits and conductors shall be accessible through ROV intervention
- c) Where possible, MQC plates known as Logic Caps shall be dedicated for logic (service) distribution by means of replacing an outboard MQC plate using an ROV to redirect services in lieu of valves
- d) Full bore ROV operated isolation valves shall be used, as a minimum, on all poppetless coupler circuits on first UTH/HDM from host
- e) Consideration shall be made during the equipment design phase to prevent seawater ingress during installation. Possible methods are:
 - i. Test caps with needle valves and hose fittings to apply pressure in a controlled method on surface to a minimum of 25% over subsea ambient pressure
 - ii. Install assembly with filled bladder compensator prior to installation

Circuits with poppetless couplers do require a precharge to verify that the lines are full of fluid. Pressure may vent on these circuits once the test cap is removed

- f) Consideration shall be made during the equipment design phase for ability to bleed trapped pressure in poppetted circuits when recovered to surface (i.e., residual operation pressure or head pressure once disconnected from system). Possible

methods are:

- i. Test caps with needle valves and hose fittings to vent pressure in a controlled method on surface
- ii. Install MQC plate with bladder compensator prior to recovery

2.2.2 MQC assembly

MQC plate assemblies shall meet the following guidelines:

- Female couplers are to be used on all Outboard MQC plates
- MQC plates shall be populated in an arrangement to provide a balanced load distribution (as close as possible) through the MQC plate when all couplers are pressurized. No couplers which allow venting during connection shall be used unless specifically approved by Principal.
- If mating assembly contains one or more blank couplers, each corresponding position in the parking plate shall use a poppetless coupler in place of a blank (i.e., blank couplers shall not be used on mating blank coupler)

2.2.3 Electrical connectors

Pin and socket configurations within electrical connections shall meet the following guidelines:

- For EDMs and EFLs female sockets shall be used on all electrical connectors where power may be present when the mating connector is removed
- Male pins shall be used in locations where retrieval of electrical connector is difficult or not possible

2.2.4 Hydraulic and electric distribution redundancy

- Dual barriers shall be used between all conductor splice or connection points and seawater
- Couplers shall have a minimum of two seal barriers to the environment when engaged
- Valves shall have a minimum of two seal barriers to the environment unless the barrier is seal welded

2.2.5 Distribution reliability

- Hydraulic and chemical tubes shall be designed and qualified in accordance with DEP 37.80.02.31-Gen.
- Tubing connections and tees shall be welded fittings and shall be kept at a minimum
- Dead legs in tubing runs shall be avoided.

2.2.6 Umbilical Termination Head (UTH)

The functional requirements for UTH distribution logic are:

The hydraulic functional requirements for UTH distribution logic are as per the Project Scope of Work. The electrical functional requirements for UTH distribution logic are:

- Each umbilical cable shall be individually terminated at an electrical bulkhead connector
- Male pins shall be used on electrical bulkhead connectors to minimize potential failure of the UTH connectors
- These conductor colours shall be used for pairs and quads unless otherwise specified in the Project Scope of Work

- o Core insulation standard colours for a pair (per BS 5467): Red and Black
- o Core insulation standard colours for a quad (per BS 5467): Red, Yellow, Blue, and Black. The pairs shall be Red/Blue and Yellow/Black
- Connectors shall have pin assignments as per the Project Scope of Work

2.2.7 Hydraulic Distribution Manifold (HDM)

The functional requirements for HDM distribution are as per the Project Scope of Work.

2.2.8 Electrical Distribution Manifold (EDM)

The functional requirements for EDM distribution are:

- Each electrical distribution harness shall contain one spare bulkhead connector as a minimum
- Each conductor within the distribution harness shall be routed to each bulkhead connector unless designated for step out connections
- Harnesses designed to split cable conductors for step-out umbilicals, shall be configured to prevent communications errors through reflections
- These conductor colours shall be used for pairs and quads unless otherwise specified in the Project Scope of Work:
 - o Core insulation standard colours for a pair (per BS 5467): Red and Black
 - o Core insulation standard colours for a quad (per BS 5467): Red, Yellow, Blue, and Black. The pairs shall be Red/Blue and Yellow/Black

Additional project specific functional requirements for EDM distribution are as per the Project Scope of Work.

2.2.9 Logic caps

Logic caps provide the ability to redirect services by replacing an outboard MQC plate with an ROV. Logic caps provide the flexibility to modify distribution of hydraulic or chemical services due to circuit failures or changes in system requirements. Typical justification for Logic Caps (LC):

- Redistribution of circuits
- Add intensifiers
- Add flushing caps
- Add filtration modules
- Redirect spares
- Access to spare manifold

2.2.10 Steel flying lead

SFL designs are typically a direct connection between couplers on each MQC plate. Occasionally, the SFL provides circuit modifications or contains flow control devices as described below:

- Hydraulic and/or chemical circuits may split or be combined within the SFL through the use of tee fittings
- Check valves may be added to prevent backflow of chemical injection circuits
- Check valves, when used, must be installed on the downstream end of the SFL closest to the tree or manifold. Tubing between the coupler and check valve shall have a sufficient volume to prevent pressure buildup when parked on a blank coupler multiple times and/or to prevent overpressure generated from any

upstream displacement of fluid generated by the operation of the chemical injection gate valve on the tree. Check valve placement shall take into consideration the installation and parking sequence of the SFL

- SFLs shall be ROV installable and retrievable

2.2.11 Commissioning equipment

Consideration for commissioning equipment and procedures shall be made during the logic design in order to minimize ROV intervention required for removing commissioning loops and installing production equipment. The following shall be used for reference, along with project specific commissioning requirements:

- a) Commissioning caps shall be located at the tree flying lead or UTAJ locations on the UTH or the HDM tree flying lead locations
- b) Where design permits, logic caps may also serve as commissioning caps
- c) Commissioning caps can replace outboard logic caps when necessary to provide commissioning loops between umbilical services. However, as far as possible, commissioning caps shall have minimum impact on production distribution equipment (i.e. commissioning caps shall be used in positions used for SFLs during production and not logic caps or pressure caps)
- d) Hose connections shall be avoided unless otherwise approved by Principal
- e) External tubing jumpers between multiple commissioning caps shall be avoided

2.2.12 Umbilical Termination Assembly Jumper (UTAJ)

UTAJ designs are typically a direct connection between couplers on each MQC plate. Occasionally, the UTAJ provides circuit modifications as described below:

- Hydraulic and/or chemical circuits may split or be combined within the UTAJ through the use of tee fittings
- UTAJs shall be ROV accessible

2.3 SUBSEA DISTRIBUTION BREAKAWAY PHILOSOPHY

2.3.1 General requirements

The system (as a minimum) shall be designed to breakaway according to the maximum snag load.

The breakaway mechanisms shall be designed such that the subsea tree assembly shall never be subjected to more than 50% of the calculated damage load or a maximum of 89,000 N (20,000 lbs), whichever is less. The damage load is defined as any load imparted onto the subsea tree assembly that will render the assembly or any of its major and necessary components inoperable and/or interfere with the capability to re-enter and repair the well.

2.4 PARKING PHILOSOPHY

Parking position design shall accommodate the installation of subsea distribution system equipment. Installing distribution components requires special parking arrangements because not all assets are installed/recovered simultaneously. Parking positions shall be designed to accommodate the following development scenarios:

- Subsea hardware [trees, jumpers, sleds, manifolds, pipeline end terminations (PLETs), etc., installed prior to subsea distribution system
- Multiple subsea trees installed intermittently before and during the subsea distribution system
- Subsea tree(s) installed after the subsea distribution system

Parking position design also shall accommodate for field intervention scenarios. Field interventions involve troubleshooting and remedial work that may or may not require the removal of flying leads. Parking positions shall be designed to accommodate the following:

- Interventions at the UTA will require external PFs for the outboard MQC plates, except for Logic and Commissioning caps. Logic and Commissioning caps can usually be parked on a nearby parking position
- Interventions shall utilize existing parking positions within the immediate area as the primary parking locations. External PFs can be available for assistance as needed, but shall generally be viewed as a contingency (except for parking near the UTA)
- All other subsea assets shall be designed such that for Interventions they do not require the use of external PFs
- Parking for EFLs connected to the EDM to facilitate EDM recovery

Parking position design shall accommodate the retrieval of subsea assets. Recovering subsea assets (both subsea hardware and distribution equipment) may require the removal of distribution components. Parking positions shall be designed to accommodate the following:

- Recovery of the EDM shall not require an external PF. All electrical parking positions shall be local to the EDMs position on the UTA mudmat
- Recovery of the HDM and UTH shall require the use of external, temporary PFs to park the flying leads
- Recovery of the UTAJ(s) shall require the use of the UTAJ deployment/recovery frame. UTAJs shall not be parked subsea
- Recovery of a subsea tree shall require the flying leads to utilize existing parking positions on a subsea tree/wellhead adapter base as the primary parking location. An alternative method is to use an external PF, if a wellhead adapter is not available

Recovery of other subsea hardware shall require the flying leads to utilize existing parking positions on a nearby asset as the primary parking location. An alternative method is to use an external PF.

2.4.1 General requirements

The general requirements that apply to each type of parking position are as follows:

- a) There shall be at least one parking position for each flying lead end and it shall be the correct type and style
- b) Certain applications (both electrical and MQC) shall require compensated parking positions to properly protect the flying lead
- c) The placement and location of parking positions shall allow for ROV access
- d) Parking position location shall also take into account proximity to the final operating position. The positioning shall minimize any disturbance to the "as laid" path of flying leads when moving leads between the positions
- e) Parking positions shall be mounted clear of any exposed tubing, harnesses, and other fragile components not protected from the ROV
- f) Extra parking positions may be mounted on equipment to optimize flying lead installation techniques and opportunities (such as deploying EFLs and HFLs on rigid jumpers)
- g) Extra parking positions shall also be provided to allow for intervention work without the mobilization of an external PF

- h) Parking positions shall be protected and covered by the appropriate dust cover or protective cap, depending on the application. Dust covers shall not be used during subsea deployment. Protective caps shall be stored/secured subsea for possible re-installation if needed
- i) All parked connections shall be covered by CP systems

Parking position requirements for individual equipment are listed in the following sections, but the Manufacturer/Supplier may submit alternatives subject to Principal approval.

2.4.2 Electrical parking positions

- Keyless/universal electrical parking positions are preferred to minimize the ROV effort in parking EFLs and harnesses. However, for male pin flying lead connections and parking positions that are required to be mounted in close proximity, keyed parking positions shall be used to keep the flying leads organized
- Electrical parking positions shall be mounted in similar orientation to the final operating position of the flying lead (either vertical or horizontal) to allow minimal manoeuvring by the ROV to remove and park the flying lead

2.4.3 MQC parking positions

- MQC parking positions shall be mounted in a horizontal orientation to allow minimal manoeuvring by the ROV to remove and park the flying lead
- MQC parking positions shall be designed to ensure compatibility between the mating outboard MQC
- The coupler configuration shall avoid hydraulic lock scenarios
- MQC parking plates shall protect all couplers from debris and marine growth and allow for pressure testing to DWP

2.4.4 Parking requirements on specific equipment

2.4.4.1 EDM mudmat

The EDM mudmat shall be populated with enough electrical parking positions to park all flying leads on the EDM. There shall be at least one additional electrical parking position to allow for swapping flying lead connections and parking protective covers.

2.4.4.2 UTA

MQC parking positions are not required on the UTA and mudmat in order to reduce the size and complexity of the assembly. As an alternative, external-PFs may be used to park SFL/ESFL outboard MQCs at the UTA.

2.4.4.3 Subsea hardware

Subsea hardware includes subsea trees, manifolds, PLETs, jumpers, flowline sleds, and all other types of large production equipment. Subsea hardware shall have parking positions for each SFL/ESFL/HFL and all EFLs and harnesses. There may be at least one extra parking position (both electrical and MQC) to allow for temporary parking and manoeuvring of flying leads.

2.4.5 Calcareous deposits mitigation

Contractor shall advise the Principal if calcareous deposits could be an issue in waters where the SDH is to be installed. Contractor should provide method to mitigate the issue, which is subject to Principal review and approval.

3. SUBSEA DISTRIBUTION HARDWARE WELDING SPECIFICATION

Project specific variables pertinent to this specification shall be listed in the Project Scope of Work.

Note that for all subsea distribution system equipment Manufacturer/Supplier shall be solely responsible for providing a complete and operable system in full compliance with all applicable Government regulations, applicable Principal specifications, and applicable industry codes and standards.

3.1 GENERAL DESCRIPTION

This specification details the minimum Principal requirements for all pressure containing welds on subsea distribution system equipment. These requirements encompass both girth and socket welds for super duplex tube to super duplex tube, and super duplex tube to other corrosion resistant alloy components. Specifically, it addresses the following:

- Welding of super duplex tubing to super duplex tubing (UNS-S39274, UNS-S32750, or UNS-S32760)
- Welding of super duplex tubing to super duplex (or other corrosion resistant alloy materials approved by Principal) forged or mechanical fittings
- Welding of super duplex tubing to other corrosion resistant alloy materials approved by Principal

The document also specifies the requirements for Welding Procedure Specification (WPS), Procedure Qualification Record (PQR), the Welder Performance Qualification (WPQ) records, as well as the Non-Destructive Examination (NDE) requirements for these welds. The format used to present these requirements is that contained in the ASME Boiler and Pressure Vessel Code, Sections V, VIII and IX. Should Manufacturer/Supplier note any conflicts/differences between this text and the referenced Codes or other referenced documents, Manufacturer/Supplier shall regard this specification as governing.

Any Manufacturer/Supplier clarifications resulting in Principal agreed upon concessions or changes to this specification during tender clarifications shall be listed in the Contract. Requests thereafter shall be in the form of a Technical Deviation Request, submitted in writing to the Principal in accordance with Principal Specifications or Principal approved equivalent.

3.2 WELDING AND WELDER QUALIFICATION REQUIREMENTS

All pressure-containing welds are critical to personnel safety, protection of the environment, and the overall safe operation of the system.

Material and manufacturing requirements for the super-duplex tubing materials covered in this specification shall be as per DEP 37.80.02.31-Gen. The weld requirements detailed in this specification will vary depending on the weld type and material used. Pressure containing welds include both girth (tube-to-tube type) and socket (tube to socket/coupler type) welds. The requirements for each type are listed in the following sections.

3.2.1 General qualification requirements for all pressure containing welds

- a) All welds shall be made with filler metal using the gas tungsten arc welding (GTAW) process. Principal prefers that the welding process be performed with automatic equipment wherever possible. However, use of manual process welding for socket welds and girth tube-to-tube welds may be necessary due to access or geometry constraints. Principal considers manual welding vs. automatic welding to be an essential variable in the process and, as such, will require a separate WPS, PQR and WPQ.
- b) All welders shall be qualified or renewed for each purchase order as detailed in this paragraph. New or expired welders and weld operators shall be qualified in accordance with the WPQ requirements of this specification. Previously qualified welders and weld operators who have performed welding with GTAW, inclusive of the significant variables, within six months and performed welding according to Principal approved WPS for

appropriate tube size within 12 months (with a documented record) may renew their WPQ at the start of the Contract work through radiography and data logging only. All welder qualifications and renewals shall be performed in advance of production welding.

- c) Super duplex filler metal shall be used in all welds, including socket welds. The PRE for this filler material shall be ≥ 42.5 where/when possible. Filler metal with PRE < 42.5 may be used with written permission by Principal, but the weld shall be required to pass all testing as per this specification. All production welds shall be performed using filler wire with PRE $\geq$ qualification wire PRE value.
- d) Socket welding to be used only with written permission from Principal. Socket welding configuration shall meet the requirements of ASME B31.3, Figures 328.5.2A and 328.5.2C. Socket fittings shall be made from super duplex material and shall have a PRE number ≥ 42.5 where/when possible. Socket fittings with PRE < 42.5 may be used with written permission by Principal, but the fitting shall be required to pass all testing as per this specification. Additionally, socket fittings for super duplex to couplers and for super duplex to other corrosion resistant alloy materials shall be made from appropriate materials intended for use (e.g., Nitronic 50 and 60 for super duplex to coupler welds etc.). Tubes inserted into sockets for welding shall not be allowed to completely seat in the bottom of the socket.
- e) Manufacturer/Supplier shall endeavour to maintain a minimum distance between welds in any given tubing run sufficient to allow for inboard coupler "float" in the subsea hardware.
- f) During qualification weld testing, calibrated equipment for measuring the following variables shall be available at all times:
 - i. Welding current (amperage)
 - ii. Arc voltage
 - iii. Interpass temperatures (digital)
 - iv. Oxygen and other potential contaminate levels of backing gas (maximum 500ppm oxygen level) which shall be measured with an instrument capable of measuring in ppm (parts per million) to within an accuracy limit of ± 1 ppm
 - v. Wire feed speed (for automatic welding)
 - vi. Welding head travel speed (for automatic and manual welding)
 - vii. Shielding and backing gas flow rate
- g) The G-48A Corrosion test is only required to qualify automatic and manual super duplex to super duplex tube girth weld PQRs and WPQs.

3.2.2 Welding procedure specification requirements

The WPS shall be supplied by Manufacturer/Supplier to Principal. To ensure that the WPS is documented consistently, Principal requests that the welding process be fully defined in accordance with ASME Section IX, QW-251 using ASME Form QW-482 for documentation. All essential variables for welding shall be listed in the ASME Form QW-482, including any "other" significant variables as defined in this specification, such as pre-weld and/or post-weld preparation. The WPS shall require qualification to a low and high heat input. Position is an essential variable of the WPS. The WPS shall clearly specify the cleanliness standard and the cleanliness procedure for the welds, i.e., pickling and/or passivation. Welds prepared for the PQR shall be cleaned according to this cleanliness procedure to the visible standard and the standard maintained throughout the course of production welding. The residual oxide layer (visible heat tint) shall be removed from each weld pass.

3.2.3 Procedure qualification record and welder procedure qualification requirements

The WPS defined in (3.2.2) shall be qualified by a Procedure PQR in accordance with ASME Section IX, QW-401.1, and QW-403.1 (**note that Principal requires that the automatic welding WPQ shall be qualified in the 5G Horizontal/Verticle weld position and that the manual WPQ shall be qualified in the 6G position**). ASME Form QW-483

shall be used for formatting and is required for documentation. Subsequent to the PQR, all welders who perform work on subsea distribution equipment for Principal shall be qualified by a WPQ Record in accordance with ASME Section IX, QW-301, and QW-302. Form QW-484 shall be used for formatting and is required for documentation. Manufacturer/Supplier shall make every effort to qualify the PQR and WPQ on the actual production material(s) and sizes to be used for the project. Backing gas shall be injected into the tubing such that no material contamination is present during any welding activity, and WPS and PQR procedure development shall demonstrate representative conditions, e.g., actual welding unit to be used, representative tube length on each side of the weld, fluid filled tubing, etc.

Should actual production materials not be available, similar substitute materials of the same Manufacturer, same PRE value, same grade, sizes and wall thickness may be used for qualification with written permission from Principal. Only welders who are documented as qualified per the required set of tests are regarded as approved for production welding. It shall also be noted that welders qualified for an automatic process are not, then, automatically qualified for manual welding procedures, and vice versa. As outlined in (3.2.1.a), manual welding versus automatic welding is considered by Principal to be an essential variable and as such requires a new WPS, PQR, and WPQ qualification. Manufacturer/Supplier shall maintain a register of all "qualified" welders to be provided to Principal prior to the start of any production welding, differentiating between significant variables as necessary.

As a minimum, the PQR for the WPS and all WPQs shall be comprised of the following set of tests for each material combination and/or geometric configuration:

Table 1 Table Suite for PQR and WPQ

Weld Type	Automatic Girth Welds	Manual Girth Welds	Sockets Welds
Weld Test Type	PQR/WPQ	PQR/WPQ	PQR/WPQ
Destructive Tests			
Tensile Test (ASME QW-150)	2	2	
Bend Test at Root (ASME QW-160)	2	2	
Bend Test at Face (ASME QW-160)	2	2	
Macrosection and Hardness at 0°	1	1	1
Macrosection and Hardness at 180°	1	1	1
G48A Corrosion Test ⁽¹⁾	2	2	
Ferrite and Microstructure at 0°	1	1	1
Ferrite and Microstructure at 180°	1	1	1
Weld penetration at 0°			2
Weld penetration at 180°			2
Cap Height and Root Protrusion	1	1	
Leg, Throat and Gap Measurement			2
Non-Destructive Tests	PQR/WPQ	PQR/WPQ	PQR/WPQ
Liquid Dye Penetrant			All
X-Ray Examination ⁽²⁾	All	All	
Visual Examination	All	All	All
Data Logging ⁽³⁾	All	All	All

- NOTES:
1. G48A corrosion tests for full weld sections shall be tested.
 2. Selenium isotopes as source energy may be acceptable with written permission of Principal.
 3. All Qualification welds shall be monitored via data logging. Weld travel speed and length, and weld amperage and voltage values shall be recorded and used to calculate and record heat input values

3.2.4 Qualification weld acceptance criteria for pressure containing welds

Principal acceptance criteria for pressure containing qualification welds are listed in the following sub-paragraphs.

Manufacturer/Supplier shall provide an "on the job" full time weld inspector, qualified to Certified Senior Welding Inspector (CSWIP) Level 3, Senior Certified Welding Inspector (SCWI), or alternatively, a Certified Welding Inspector (CWI) with Principal approval, to supervise all welding and maintain weld maps, records, and logs.

3.2.4.1 Destructive Testing Requirements for Qualification Welds

3.2.4.1.1 Tensile and Bend Tests

Table 2 Tensile Test Requirements for Qualification Welds

Test	Tensile
In accordance with	ASTM A370 (see modified acceptance criteria below)
Specify	Dimensions of the test specimen, section area Strip or full section specimen For strip specimen, state from which weld sector (clock position)
Report	Rm, Tensile strength Elongation, % in 51 mm (2 in) Location of fracture (weld or base material)
Acceptance Criteria	Fracture min tensile strength $\geq$ 100% minimum ultimate tensile strength of base material Elongation = no criteria, measure and report for information
If test fails	Retest two (2) samples
Definition of retest	Two (2) samples from additional qualification welds from the same welder
If either retest fails	Change WPS to correct issue and re-test qualification

Table 3 Bend Test Requirements for Qualification Welds

Test	Bend
In accordance with	ASME IX (see modified acceptance criteria below)
Specify	Dimensions of the test specimen with weld in the centre Bend test angle Former diameter
Report	Pass/Fail
Acceptance Criteria	<u>No</u> defects or cracks in heat affected zone (HAZ) or weld metal.
If test fails	Retest two(2) samples
Definition of retest	Two (2) samples from additional qualification welds from the same welder
If either retest fails	Change WPS to correct issue and re-test qualification

3.2.4.1.2 Hardness

Rockwell macro-hardness and Vickers micro-hardness traverses shall be taken generally at the outer diameter, midwall, and the inner diameter. Three readings shall be taken in the base metal, each HAZ, and in the weld metal. The hardness criteria and proposed hardness test plan are shown in the table below:

Table 4 Hardness Test Requirements for Qualification Welds

Test		Hardness														
In accordance with		ASTM A370 Vickers Hardness Test HV10														
Specify		Dimensions of the test specimen Distance from outer diameter (OD) surface to cap line Distance from inner diameter (ID) surface to root line														
Report		Measured values, see below In the case of single pass welds with WT < 2.3 mm (0.09 in), mid line only is required														
Acceptance Criteria		All values in the range Min 230 Hv Max 330 Hv														
If test fails		Retest two (2) samples														
Definition of retest		Two (2) samples from additional qualification welds from the same welder														
If either retest fails		Change WPS to correct issue and re-test qualification														
Comments		Two sections required, 0° and 180° Three lines traversing cap, mid, root Each line split to five zones : BM, HAZ, Weld, HAZ, BM Each zone, 3 equally spaced readings														
Loc		BM	BM	BM	HZ	HZ	HZ	W	W	W	HZ	HZ	HZ	BM	BM	BM
Cap																
Mid																
Root																

3.2.4.1.3 Corrosion Resistance

Test specimens shall be prepared in accordance with G48 and tested in accordance with ASTM G48, Method A. The tests shall be conducted and conform to the acceptance parameters listed in the following table. Note that the G48 test is required for automatic and manual super duplex to super duplex girth tube welds only.

Table 5 Corrosion Resistance Test Requirements for Qualification Welds

Test		Corrosion														
In accordance with		ASTM G48A Test temperature = 40°C ± 2°C (104°F ± 3.6°F) Test Duration = 24 hours Magnification x20														
Specify		Dimensions of the test specimen to mean one inch of tube, either side of the weld														

	No blasting or etching allowed; ScotchBrite OD only Prep cut edges of sample by grinding or machining Automatic or Manual Weld process used
Report	Specimen dimensions Calculated area Measured weight pre-test Measured weight loss Calculated corrosion loss (g/m^2) Temperature profile Automatic or Manual weld process used
Acceptance Criteria	Probe for pits per G48A Perform Liquid Penetrant Examination per (3.2.4.2.1) Use microscope at x20 magnification. If the specimen weight loss is $< 4 \text{ g/m}^2$ and there is no evidence of pits, the test passes If the specimen has any evidence of pits, regardless of weight loss, the test fails If the specimen has weight loss $> 4 \text{ g/m}^2$ and there is no evidence of pitting, Manufacturer/Supplier has the option to place the sample back into the bath for another 24 hours (no cleaning of sample or probing for pits is allowed) If any pitting is discovered on the retest sample (with probing), the test fails If the total weight loss from the retest (second test weight loss) is $< 1 \text{ g/m}^2$ and there is no pitting, the test passes If the total weight loss from the retest (second test weight loss) is $> 1 \text{ g/m}^2$, the test fails
If test fails	Retest two (2) samples
Definition of retest	Two (2) samples from additional qualification welds from the same welder
If either retest fails	Change WPS to correct issue and re-test qualification
Comments	Measure pH at start and completion of each test Record temperature manually at 15 min intervals or by continuous digital chart to ensure temperature stability

3.2.4.1.4 Phase Balance and Ferrite Content

A representative specimen shall be properly prepared for metallographic examination and the ferrite content shall be measured per ASTM E562 or ASTM 923 in the weld and both HAZs. Test parameters and acceptance criteria are listed in the following table:

Table 6 Phase Balance and Ferrite Content Requirements for Qualification Welds

Test	Ferrite
In accordance with	ASTM E562/ ASTM 923 Magnification x 500-1000
Specify	Etching solution 16 point Grid size, number of fields = 30
Report	% per field Fields shall be evenly distributed

Acceptance Criteria	35% - 65% ferrite
If test fails	Retest two (2) samples
Definition of retest	Two (2) samples from additional qualification welds from the same welder
If either retest fails	Change WPS to correct issue and re-test qualification

3.2.4.1.5 Precipitate Phases

The microstructure shall be examined at a minimum magnification of 500X to 1,000X for the presence of deleterious grain boundary precipitates, such as sigma and chi. Acceptance criteria are listed in the following table:

Table 7 Acceptance Criteria for Qualification Weld Microstructure

Test	Microstructure
In accordance with	Procedure observed and approved by Principal Magnification x 500-1000
Specify	Dimensions of the test specimen Etching solution Specimen dimensions, including weld sector and clock position used
Report	Any foreign phases, if observed report characteristics of the feature, location and field maximum particle count
Acceptance Criteria	The microstructure of the base material, HAZ, and Weld Metal shows no deleterious constituents. Total deleterious content shall not exceed 0.05%
If test fails	Retest two samples
Definition of retest	Two samples from additional qualification welds from the same welder
If either retest fails	Change WPS to correct issue and re-test qualification

3.2.4.1.6 Cap Height

Table 8 Cap Height Test Requirements for Qualification Welds

Test	Cap Height
In accordance with	Principal specified values
Specify	Cap height
Report	Measured values Automatic or Manual weld process used
Acceptance Criteria	Manual Welding Maximum value can be the nominal wall thickness or 3.125 mm (0.125 in), whichever is less Automatic Welding Maximum value can be the 1/3 nominal wall thickness or 1.6 mm (0.0625 in), whichever is less
If test fails	Retest two (2) samples

Definition of retest	Two (2) samples from additional qualification welds from the same welder
If either retest fails	Change WPS to correct issue and re-test qualification

3.2.4.1.7 Root Protrusion

Table 9 Root Protrusion Test Requirements for Qualification Welds

Test	Root Protrusion
In accordance with	Principal specified values
Specify	Root Protrusion
Report	Measured values Automatic or Manual weld process used
Acceptance Criteria	Maximum value = 2.29 mm (0.090 in) for all tube sizes
If test fails	Retest two (2) samples
Definition of retest	Two (2) samples from additional qualification welds from the same welder
If either retest fails	Change WPS to correct issue and re-test qualification

3.2.4.1.8 Leg, Throat and Gap Measurements for Socket Welds

Table 10 Requirements for Leg, Throat, and Gab Measurements of Socket Welds

Test	Leg, Throat and Gap Thickness Measurement
In accordance with	ASME 31.3
Specify	Fillet weld size as per Figure 328.5.2.A Minimum welding dimension as per Figure 328.5.2.C
Report	Dimensions of the test specimen
Acceptance Criteria	Minimum Leg Length: 31.75 mm (1.25 in) x nominal wall thickness, but not less than 3.125 mm (0.125 in) Minimum Throat Length 17.96 mm (0.707 in) x leg length Minimum Gap Length: 1.6 mm (0.0625 in)
If test fails	Retest two (2) samples
Definition of retest	Two (2) samples from additional qualification welds from the same welder
If either retest fails	Change WPS to correct issue and re-test qualification

3.2.4.2 Non-Destructive Testing Requirements for Qualification Welds

Qualification welds shall be subjected to and pass the following non-destructive testing (NDT) criteria per the frequency outlined in Table 4. Should any of these NDT criteria not be met by the qualification welds modify the WPS to correct the issue and re-test the qualification. All welds shall be inspected by X-ray before the weld qualification specimens are prepared. Any flaw or defect shall be cause for rejection.