

Quality Requirement

Fabrication and Welding General Requirements

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1 SCOPE

This document covers the general requirements for Welding and Fabrication. It is the manufacturer's responsibility to comply with the specifications noted on the Purchase Order, provided drawing(s), or other NOV provided documentation. If there are discrepancies between this document and other contractual documents, the most stringent requirement shall apply.

2 REFERENCES

<u>ASME BPVC Section IX</u>	<i>Welding, Brazing and Fusing Qualifications</i>
<u>AWS D1.1</u>	<i>Structural Welding Code- Steel</i>
<u>AWS QC1</u>	<i>Specification for AWS Certification of Welding Inspectors</i>
<u>IADC</u>	<i>MRB guidance Document</i>
<u>ISO 15609</u>	<i>Specification and qualification of welding procedures for metallic materials</i>

3 ACRONYMS

CRO	Corrosion Resistant Overlay
FCAW	Flux Cored Arc Welding
GMAW	Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
PO	Purchase Order
PQR	Procedure Qualification Record
PWHT	Post Weld Heat Treatment
SAW	Submerged Arc Welding
SMAW	Shielded Metal Arc Welding
WPQ	Welder Performance Qualification
WPS	Welding Procedure Specification

4 PRE-WELD ACTIVITIES

Note that all material dimensions and sizes on the material lists in our drawings are net, post production sizes. Accordingly, all dimensions are given without deductions for bevelling or allowances for machining unless noted otherwise. The Supplier must therefore take the above into consideration when ordering materials.

4.1 Cold forming

Cold forming is defined as forming below 482°F (250°C).

Cold forming may be carried out by means of jacking, pressing or rolling tools. The use of hammering techniques is not acceptable.

Cold forming at ambient temperature may be permitted provided the bending diameter is following the steel mill recommendations, material standard and classification requirements.

The strain may be calculated according to the following formula:

Percent strain = Thickness x 100% / forming mid thickness diameter.

The strain rate percentage shall not exceed 5%, unless specifically approved by NOV engineering in writing.

If forming operations involving a higher degree of strain than 5%, a written request from supplier shall be supported by material manufacturers recommendation.

For structural steel with Chemical and Mechanical properties that fulfill the requirements of EN 10149 or ASTM A500 cold forming induced strains may be permitted to exceed 5%. Bending radiuses shall in such cases comply to the requirements of EN 10149 or ASTM A500. This is only allowed when the steel meets all chemical and mechanical properties of the standard; Bending qualification test shall be performed as required by the standard.

Cold forming is not permitted to replace mill made u-profiles, angle bars or similar items. Structures designed with two or more items that are intended to be joined by welding cannot be replaced by cold forming one item

4.2 Preparation and cutting of steel

Cutting and beveling of steel materials shall be carried out by thermal cutting or machining. Thermally cut edges shall be ground to sound metal before welding. Holes shall be machined, not cut by thermal cutting.

4.3 Fit-up assembly

Weld Inspection personnel shall visually inspect the fit up and check:

- The weld preparations for any surface defects
- The root gap and bevel geometry for compliance with WPS

- Max gap allowed between materials for fillet weld for compliance with WPS
- Alignment tolerances

4.4 Inspection of fit-up prior to welding

Weld inspection personnel shall visually inspect that all surfaces and parts that shall be welded are:

- Free from grease, oil, paint etc.
- Clean, dry and free from rust.
- No splatters or imperfections
- All areas subject to welding are accessible to be welded and there is enough access for NDE.

4.5 Material repairs and buttering

Surface defects which occur during the production, fit-up and welding process may be repaired by grinding, provided the thickness is not reduced by more than 7% of the nominal thickness, or 3 mm / 1/8", whichever the lesser.

The defective area shall be ground smooth and 100% checked with MT (magnetic particle examination) for ferromagnetic steel and PT (penetrant liquid examination) for other metallic materials

Buttering:

Excessive root gap shall be rectified by buttering according to a WPS which shall be prepared from one of the qualified main weld procedures (WPAR/PQR). The thickness of the buttering zone shall not exceed 75% of the plate thickness or 8 mm / 5/16", whichever is less. This means that maximum buttering for a groove can be 16 mm / 5/8" (8 mm / 5/16" from each side). All buttered groove welded geometries shall be considered as essential weld, i.e. extent of NDE shall be 100%.

Build up welding on raw or machined materials may not be considered as buttering welding. Separate evaluation or requirements will apply according to standard for overlay welding

4.6 Welding Equipment

Welding Equipment shall be capable of reproducing settings of all specified variables. This includes:

- Power Sources
- Rotating Tables
- Power Rolls

Power sources shall be equipped with calibrated voltage and amperage meters.

Process indicators shall be calibrated to the tolerance specified in the applicable standard.

5 WELDER QUALIFICATIONS

A written procedure shall be established for the qualification of welders. Welders and welding operators shall be qualified in accordance with relevant parts of ISO 9606, AWS D.1.1 or the latest revision of the applicable Industry Standard, Specification, or Code, subject to NOV's acceptance.

Qualification to prior editions must be accepted by NOV in writing.

The testing and welding of test pieces shall be witnessed by 3rd party examining body.

5.1 Welder identification

Each welder shall be assigned a unique reference number or identity code which allows traceability of welders to their welds. Welder traceability records shall be kept and, if required, submitted as part of the final documentation.

5.2 Continuity log

Supplier shall maintain a continuously updated record (log) of all welders' qualifications listing their approved processes and expiry dates according to class society rules or other regulations. The welder must be engaged in each welding process within six (6) months and have no specific reason to question a welder's ability, to remain qualified.

6 WELDING PROCEDURES QUALIFICATIONS AND CONTROL

The Supplier shall prepare qualified welding procedures in accordance relevant part of ASME IX, DNVGL, EN ISO 15614, ANSI/AWS D 1.1 or equivalent recognized subject to approval by NOV.

The manufacturer shall ensure compliance with essential welding variables and equipment monitoring.

NOV approval on the manufactures WPS/PQRs may be required prior to work commencing.

The qualification requirements are also applicable for tack welds.

The qualification is primarily valid for the workshop performing the welding test, and other workshop under the same technical and quality management. It may also be transferred to and used by a Sub-Supplier, provided the principles of EN ISO 3834-2 or equivalent standard are implemented and documented.

The WPS shall describe all of the essential, non-essential, and supplementary essential variables, including but not limited to:

- Specification with which it complies
- Welding process(es)
- Welding type(s)
- Base metal(s), P-number, Group number, Specification, EP number
- Joint details
- Position
- Filler metal
- Gas, gas composition
- Preheat
- PWHT (post weld heat treat)
- Weld technique
- Welding parameters
- Electrical characteristics
- Welding instructions
- Supporting PQRs

6.1 Weld procedure qualification

Approved welding methods by NOV are, 136/137 Flux Cored Arc Welding (FCAW), 141 Gas Tungsten Arc Welding (GTAW), 111 Shielded Metal Arc Welding (SMAW), 121 Submerged Arc Welding (SAW). Other welding methods shall requires written approval from NOV.

No welding shall be done in the downhill position for Structural equipment.

Supplier shall prepare documented welding procedures in accordance to the relevant part of the applicable Industry Standard, Specification, or Code for welding as ANSI/AWS D1.1, ASME section IX, DNVGL and EN ISO 15614.

In addition, the ASME BPVC Section II, Part C; ASME BPVC Section VIII and NACE MR0175/ISO 15156 are also to be followed when applicable and/or specified in the engineering requirements.

Relevant API product specifications shall be taken into consideration when specified by the engineering documentation.

Additional procedure testing may be required pending on classification society requirements such as ABS CDS and DNV GL OS-E101 or other applicable requirements as specified in the PO documentation package.

New qualification test is required if the carbon equivalent for the steel to be welded increase more than 0.03 carbon equivalent units (IIW formula) over the value of the existing welding procedure approval record (WPAR/PQR).

Formula for Carbon equivalent (CEQ):

$$CE = \%C + \frac{\%Mn + \%Si}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Cu + \%Ni}{15}$$

The Supplier shall record actual WPS number in Weld & NDE log and verify the compliance of the welded material.

The number and type comply with the ASME, AWS, ISO (or other) procedure being qualified.

Testing is performed at an independent laboratory.

Unless additional or prior provisions have been made, all testing methods shall comply with ASTM A370/ISO 6892 or equivalent applicable standards referenced in the qualification standard.

6.2 Weld procedure qualification review and approval

Weld Procedure Qualifications shall be documented, identify limitations and restrictions, and shall be reviewed and approved by relevant class society as ABS, DNVGL, BV or equivalent if applicable.

Class societies may have additional requirements that shall be taken into consideration when applicable.

6.3 Control and storage of consumables

The Supplier shall establish and implement documented procedures for the control, storage, and maintenance of Consumables, in accordance with the applicable Industry Standard, Specification, or Code. (Example: AWS D1.1, Section 5.3 or equivalent).

- Storage ovens shall be calibrated at a minimum of every twelve (12) months. Wet consumables shall not be used, even after drying.
- Only consumables listed in DNVGL "Register of type approved products no. 2" or ABS "Approved Welding Consumables" will be accepted.
- All weld consumables (wire and electrode) used for Low alloy steel or Sour Service must be less than 1% Nickel (Ni). This information shall be verified on the applicable Mill Certificate.
- All FCAW wire, SAW flux and SMAW electrodes used for Low alloy steel must be H4 rated. This information shall be verified on the applicable Mill Certificate.
- All weld consumables which are WPS brand specific shall be verified at the time of purchase and receipt.

6.3.1 Weld Consumable Storage

6.3.1.1 Unopened weld consumable containers shall be stored in a dry area and in suitable condition for use as described below:

- Electrodes such as E6010 and E7010 shall be stored in a dry area such as 6.2.1 after removal from their sealed containers. The use of heat-controlled storage ovens is not required for these types of electrodes.
- Electrode and flux ovens shall maintain the temperature range specified in EXHIBIT A for the specific type of consumable being stored.
- All weld consumables shall have traceability to its original mill certificate. The traceability information will be required when filling out the associated weld map in the work order.
- Ovens dedicated for the drying of flux shall maintain the temperature range in conformance with the manufacturer's recommendations.
- Ovens found to be inoperative or failing to maintain the specified temperature range, shall be tagged out and removed from service.

6.3.1.2 Low Hydrogen Flux coated electrodes:

- Low hydrogen flux coated electrodes shall be controlled at all times after their storage containers are opened as described below.
- Immediately after opening the hermetically sealed containers, electrodes shall be stored in ovens held within the temperature ranges specified in Exhibit A. The electrodes shall remain in the oven until withdrawn for use.
- Electrodes may only be stored for a period of one shift in an electrode caddy maintaining applicable temperature range for the intended electrode per Exhibit A. Unused electrodes shall be returned to the appropriate oven at the end of the shift.

6.3.1.3 Approved Atmospheric time periods:

- Low-hydrogen electrodes in use shall be kept in heated electrode caddies within the temperature ranges specified in EXHIBIT A for a period not to exceed one shift.
- Electrode caddie lids will remain closed except when an electrode is being retrieved.
- Electrodes which are or have been wet shall not be used.
- Unused electrodes shall be returned to the correct temperature-controlled oven immediately

6.3.1.4 Bare Wires:

- Open spools or containers shall be covered or wrapped after each use.
- If the machine is idle or not in use with no jobs scheduled, the wire will be removed from the machine and placed in a dry, dust-free storage container.
- Prior to returning to storage, wire shall be verified to be properly tagged or marked with full traceability to its original mill certificate.

6.3.1.5 Flux Cored wires:

- Any opened flux cored wires shall be returned to the oven and kept at 100°F + 20°F at the end of the shift if time between shifts exceeds 24 hours

6.3.1.6 Flux:

- Flux shall be placed in a flux oven immediately upon opening its original package. The temperature of the flux oven shall be maintained per Exhibit A.
- When filling flux ovens never mix flux Lot/Heat numbers, old flux will be used prior to refill or discarded.
- Flux shall be at temperature per Exhibit A before use.
- Flux exposed to uncontrolled atmospheric conditions for periods longer than 8 hours or damaged flux packages will be discarded or dried per the manufacturer's recommendations.
- If the welding machine has a non-heated flux dispensing system, the operator shall remove all the leftover flux from the dispenser system by the end of the shift.
- Flux Reclamation: Used, not melted flux may be reused after recovery by vacuuming or catch pans.
- Rust, scale and other non-desirable metals and metal compounds shall be removed from the flux prior to recycle.
- A minimum of 50% new flux shall be mixed to reclaimed flux prior to usage of reclaimed flux.
- The mixture shall be returned to the oven and heated to 250°F - 350°F before being used.

6.3.1.7 Exhibit A – Storage temperature requirements for open weld consumables

WELD CONSUMABLE	OVEN TEMPERATURE
E10018-D2 Thyssen Ni Mo100	250°F - 350°F
E7018, E7018-1	250°F - 350°F
E347, E2209, E2594-16, E410	250°F - 350°F
E316L-17, E309L-16	250°F - 350°F
E4130 LN	250°F - 350°F
E410-16-31F, E410-16-24F	250°F - 350°F
E10018-D2	250°F - 350°F
E11018, E12018	250°F - 350°F
IN 12 ENiCrMo-3	250°F - 350°F
E8018-B2, E8018-C3	250°F - 350°F
E8018G 8018SR	250°F - 350°F
Flux	250°F - 350°F

6.4 Welding machine calibration

Welding Machines, instruments and inspection gages shall be calibrated at a minimum of every 12 months according to recognized industry standard; repairs to these instruments shall be per supplier’s documented procedure or industry standards. Weld inspection gages shall be available on the shop floor.

7 WELDING

It is the Supplier's responsibility to comply with the specifications noted on the Purchase Order, provided drawing(s), or other NOV provided documentation. If there are discrepancies between this document and other contractual documents, the most stringent requirement shall apply.

The applicable product realization documentation (WPS or PQR procedures / requirements) shall be available to welders in the area where the work is performed.

Supplier shall establish a unique weld numbering system with traceability to each individual drawing. All welds shall be identified, recorded, and made part of the MRB.

Weld Procedures Qualification Records:

All weld procedures should be listed in the form of a matrix included in the MRB which will detail all:

- WPQR/PQR's and process
- Positions
- Consumables
- Materials
- Weld Types

Contractor shall record actual WPS/PQR number in Weld and NDE log.

Weld Procedure Qualifications shall be documented, identify limitations and restrictions, and shall be reviewed, approved, and stamped by NOV.

Inspection shall include essential variables prior to and during welding.

Final Inspection shall be done after all welding to ensure weld distortion was satisfactorily controlled.

Base material shall be free of all foreign substance within 2" of the weld zone. This includes, but limited to, oil, grease, mill scale, and rust.

If not specified otherwise, fillet weld dimensions on drawings shall be understood as:

a – throat thickness
z- leg dimension.

7.1 Pre-heating

The parent material surface shall be dry and have a temperature according to WPS before start of welding. Preheating $\geq 212^{\circ}\text{F}$ (100°C) shall be achieved by electric heating elements. For preheating $< 212^{\circ}\text{F}$ (100°C) Oxygen/Acetylene and Propane heating burners may be used. Cutting torches are forbidden.

The manufacturers written procedure shall include applicable information such as temperature controls, heating methods, stand-off distances, and flame type.

The minimum interpass temperature shall not drop below the minimum required preheat temperature.

If not otherwise stated in the WPS, the maximum interpass temperature shall not exceed 480°F (250°C) measured at the edge of the groove or the maximum qualified interpass temperature of the applicable WPS/PQR

For C- and C/Mn - steels, a maximum interpass temperature up to 480°F (250°C) may be used, even if a lower temperature was recorded on the WPAR/ PQR.

7.2 Splice material

Material splices shall be reported in the “as built” section in the FRB. Material splices not shown on the drawing shall be welded with full penetration welds and have 100% volumetric and surface NDE examination to verify the quality. If plate formats necessitate splicing of sections (i.e. Crane jibs, columns, and primary load carrying members in general) the splice shall be staggered by at least 12 inches / 300 mm offset between web and flange or top/bottom - and side-plates respectively.

Any material splice not shown on a drawing must be approved by NOV in writing prior to release of the product to NOV

7.3 Thermal straightening of welded carbon steel structures

Out of tolerance members can be straightened by locally applied heat. Heating shall be carried out under strict controlled conditions to prevent degradation of the steel properties.

The heating shall be performed by means of special heating torches/burners suitable for the purpose; cutting torches shall not be used.

The temperature of heated areas shall be checked by the operator using temp sticks, contact Pyrometer, Resistance Coil, or other suitable means during the heating process.

For structural steel, the temperature shall normally not exceed 1100°F (590°C) except when being qualified by a separate procedure.

The parts to be heated for straightening shall be free of stress and external forces, except stresses resulting from mechanical means used in conjunction with the application of heat.

The straightened areas shall be subject to 100% Magnetic Particle Inspection after complete cooling in still air.

Thermal straightening process may be repeated a maximum of two times at the same place. A non-conformance report shall be used to disposition parts out of tolerances.

For thermal straightening temperature above 1100°F (590°C) a qualified procedure shall include calculation of the lower transformation temperature (A1) for the actual steel shall be approved by NOV.

8 WELD REPAIR

All weld repair work shall be carried out according to a documented procedure established by the Supplier and approved by NOV. The procedure shall be available to welders where the work is being performed

All weld repair work shall be documented. This includes dimensions of defect, type of defect, excavation, and NDE verification of removal.

Repair welding shall be performed using a qualified WPS and written procedure established by the manufacture and approved by NOV.

8.1 Weld repair procedure

The preheat temperatures used during repair welding shall be minimum 125°F (50°C) higher than the preheat temperature used in the original weld procedure.

All repair work shall be carried out according to a repair WPS and based on an approved WPAR/PQR established by Contractor.

The WPS shall include the method of defect location and removal, preparation of weld area and NDE before and after re-welding.

Prior to excavation, the NDE operator shall mark the exact location and depth of the defect on the metal surface. If required, additional NDE techniques shall be used to determine the exact location.

The defective material shall then be removed by grinding, machining, or by air arc gouging followed by grinding to sound metal.

After completed excavation and grinding, the affected zone shall be 100% examined by MT/PT. No repair area shall be shorter than 100 mm in the defects longitudinal plane and minimum 2 inches (50 mm) in each end of defect.

The repair weld shall be given the same weld number with the suffix R1, R2 etc. to permit traceability of NDE. It shall then be subject to 100% NDE by all applicable methods. The retested area shall be the full excavated area + 4 inches (100 mm) in each end when possible due to the nature of construction.

The same area shall not be repaired more than twice without a written acceptance from NOV

9 WELD INSPECTION AND TESTING

9.1 Weld inspection qualifications

Weld Inspection personnel performing visual inspection of welding operations and completed welds shall be qualified and documented as follows:

- ISO 9712 / AWS or equivalent Certified Welding Inspector (CWI) per AWS QC1 or recognizable equivalent standard
- ISO 9712 / AWS or equivalent Certified Associate Welding Inspector per AWS QC1 or recognizable equivalent standard, or
- A Welding Inspector qualified by the manufacturer's documented requirements

Relevant API product specifications shall be taken into consideration when specified by the engineering documentation.

9.2 Dimensional control

The Supplier shall carry out dimensional control in accordance to tolerances specified on the drawing. If nothing is specified on the drawings EN ISO 13920 Class A and E applies or recognizable equivalent standard. If a welded construction undergoes post machining activities the dimensions shall meet ISO 2768-m unless tolerances are specified on the drawing.

10 POST WELD HEAT TREATMENT

PWHT may be required for structural welds when the nominal thickness exceeds 2 inches (50 mm), unless adequate fracture toughness can be documented in the as welded conditions. For restrained joints of complicated design, PWHT may be required for smaller thickness. PWHT shall be performed when WPAR/PQR used is approved including the PWHT process.

PWHT shall be carried out in accordance with a procedure specification which shall include:

- heating rate
- cooling rate
- soak temperature and time
- heating facilities
- insulation
- control devices
- recording equipment
- configuration of structure to be PWHT or details if local PWHT shall be carried out.
- number and location of thermocouples to be used during PWHT

The holding temperature shall normally not exceed 1070°F (580°C) or as recommended by the steel manufacturer / Supplier. The soaking time shall be 5 min per 1/12" (2 mm) thickness.

The temperature difference between different parts of the structure during soaking time shall not exceed 85°F (30°C) within the heated area. Double-sided heating shall be used as far as possible.

The temperatures shall be continuously logged and automatically recorded by thermocouples in different positions and temperatures shall be plotted on a chart.

Regular calibration of thermocouples shall be minimum every 12 months.

Only pre-qualified PWHT procedures are accepted.

11 WELD DOCUMENTATION

All documentation shall be in accordance with the International Association of Drilling Contractors (IADC) MRB Guidance Document and Quality Requirements, Doc # 101444171

11.1 Procedure for identification of welds

The Supplier shall establish a unique numbering system with traceability to each individual drawing for welds in category above secondary or the lowest grade (see table 1 under 9.4). The numbering system shall be used for identification in Weld & NDE log.

Each welder shall be assigned a reference number or identity code which allows traceability of welders in the Weld & NDE log

11.2 Weld procedure qualification records

All weld procedures should be listed in the form of a matrix included in the FRB which will detail all:

- WPQR/PQR's and process
- Positions
- Consumables
- Materials
- Weld Types

Contractor shall record actual WPS/PQR number in Weld and NDE log.