

NORSOK STANDARD

STRUCTURAL STEEL FABRICATION

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FOREWORD

NORSOK (The competitive standing of the Norwegian offshore sector) is the industry initiative to add value, reduce cost and lead time and eliminate unnecessary activities in offshore field developments and operations.

The NORSOK standards are developed by the Norwegian petroleum industry as a part of the NORSOK initiative and supported by OLF (The Norwegian Oil Industry Association) and TBL (Federation of Norwegian Manufacturing Industries). NORSOK standards are administered and issued by NTS (Norwegian Technology Center).

The purpose of NORSOK standards is to contribute to meet the NORSOK goals, e.g. to develop standards that ensure adequate safety, value adding and cost effectiveness and thus are used in existing and future petroleum industry developments.

The NORSOK standards make extensive references to international standards. Where relevant, the contents of a NORSOK standard will be used to provide input to the international standardisation process. Subject to implementation into international standards, the NORSOK standard will be withdrawn.

Annex A is informative. Annexes B, C, D and E are normative.

INTRODUCTION

Revision 4 of this standard has been necessary due to regulations in new design standard N 004 and new designation of steel grades. In addition a steel grade with SMYS 690 is introduced with additional requirements to fabrication.

1 SCOPE

This standard covers the requirements for fabrication and inspection of offshore steel structures with $SMYS \leq 500$ MPa and with a minimum design temperature down to -14°C . For special application steels with SMYS up to 690 MPa may be used.

Note: For highly fatigue utilized structures, more severe requirements may apply, and these will be shown on the design drawings.

2 NORMATIVE REFERENCES

The following standards include provisions which, through reference in this text, constitute provisions of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements of the standards referenced below.

API 2B	Specification for fabricated structural steel pipe.
API RP 2X	Ultrasonic examination of offshore structural fabrications.
ASME, Section V	Non-destructive testing.
BS 7448, Part 1	Fracture mechanics toughness tests.
BS 7910	Guide on methods for assessing the acceptability of flaws in fusion welded structures.
DNV RP D404	Unstable fracture.
EN 287-1	Approval testing of welders - Fusion welding.
EN 288-series	Specification and qualification of welding procedures for metallic materials.
EN 444	NDT - General principles for radiographic examination of metallic materials by X-rays and gamma rays.
EN 462-series	NDT - Image quality of radiographs.
EN 473	Qualification and certification of NDT personnel - General principles.
EN 719	Welding coordination - Tasks and responsibilities.
EN 729-series	Quality requirements for welding - Fusion welding of metallic materials.
EN 875	Welding - Welded joints in metallic materials - Specimen location and notch orientation for impact tests.
EN 970	Welding - Visual examination of fusion welded joints.
EN 1011-series	Welding - Recommendation for welding of metallic materials, relevant parts.
EN 1289	Non destructive examination of welds - Penetrant testing of welds - Acceptance levels.
EN 1290	NDT of welds - Magnetic particle examination of welds - .

EN 1291	NDT of welds - Magnetic particle examination of welds - Acceptance levels.
EN 1418	Welding personnel - Approval testing for fully mechanised and automatic welding.
EN 1435	Non destructive examination of welds - Radiographic examination of welded joints.
EN 1597-1	Welding consumables - Test methods - Part 1: Test piece for all weld metal test specimens in steel, nickel and nickel alloys.
EN 1714	Non destructive examination of welds - Ultrasonic examination of welded joints.
EN 10204	Metallic products - Types of inspection documents.
prEN 10225	Weldable structural steels for fixed offshore structures.
EN 26847	Covered electrodes for manual metal arc welding. Deposition of a weld pad for chemical analysis.
ISO 3690	Welding - Determination of hydrogen indeposited weld metal arising from the use of covered electrodes for welding mild and low alloy steels.
ISO 5817 (=EN 25817)	Arc welded joints in steel - Guidance on quality levels for imperfections.
NORSOK M-001	Material selection
NORSOK M-120	Material data sheets for structural steel
NORSOK N-001	Structural design
NORSOK N-004	Design of steel structures
NS 477	Welding. Rules for approval of welding inspectors.

3 DEFINITIONS AND ABBREVIATIONS

3.1 Definitions

Normative references	Shall mean normative in the application of NORSOK standards.
Informative references	Shall mean informative in the application of NORSOK standards.
Shall	Shall is an absolute requirement which shall be followed strictly in order to conform with the standard.
Should	Should is a recommendation. Alternative solutions having the same functionality and quality are acceptable.
May	May indicates a course of action that is permissible within the limits of the standard (a permission).
Can	Can is conditional and indicates a possibility open to the user of the standard.

3.2 Abbreviations

AWS	American Welding Society
BS	British Standard
CE	Carbon Equivalent equation
CTOD	Crack Tip Opening Displacement
DAC	Distance Amplitude Curve
DC	Design Class
DIN	Deutsche Institut für Normung

DNV	Det Norske Veritas
EN (pr EN)	European Standard (proposal for EN)
FCAW	Flux Cored Arc Welding
FSH	Full Screen Height
HAZ	Heat Affected Zone
H _{DM}	Hydrogen content, deposit metal
IIW	International Institute of Welding
ISO	International Organization for Standardization
NDT	Non Destructive Testing
MDS	Material Data Sheet
MSF	Module Support Frame
P _{cm}	Carbon equivalent (Parameter for crack, modified)
PWHT	Post Weld Heat Treatment
SAW	Submerged Arc Welding
SMYS	Specified Minimum Yield Strength
SQL	Steel Quality Level
WPS	Welding Procedure Specification
WPAR	Welding Procedure Approval Record

4 SELECTION OF STEELS

4.1 Design classes

The design classes will be decided by the designer and shall form the basis for selection of steel quality level (SQL). Reference is made to NORSOK standard N-004.

4.2 Selection of steel quality level

The steel quality level will be decided by the designer in compliance with N-004.

Annex B gives the correlation between the steel quality levels I, II, III and IV, and designations on equivalent steels given in NORSOK standard M-120, Material data sheets.

Selection of a better steel quality level in fabrication than the minimum required by the designer shall not lead to more stringent requirements in fabrication.

5 QUALIFICATION OF WELDING PROCEDURES AND WELDERS

5.1 Welding procedure specification (WPS)

WPS shall be established in accordance with EN 288 part 2.

5.2 Qualification of welding procedures

Welding procedures used for structures requiring steel quality level I and II for all strength levels and steel quality level III for SMYS ≥ 355 MPa shall be qualified in accordance with EN 288 part 3 and the additional requirements in this standard.

The qualification is primarily valid for the workshop performing the welding tests, and other workshops under the same technical and quality management. It may also be transferred to and used by a subcontractor, provided the principles of EN 729 part 2 are implemented and documented.

5.3 Welding procedure approval record (WPAR) - Range of approval

5.3.1 For welding of steels with SMYS ≤ 500 MPa

The WPAR is valid within the limitations specified in EN 288 part 3, with the following clarifications and modifications:

- a) Control of heat input according to EN 288 part 3, section 8.4.7, shall apply. If an approval testing have been performed at both a high and a low heat input level (with all specified mechanical testing), then all intermediate heat inputs are also qualified.
- b) When the steel to be welded has a $P_{cm} \geq 0.21$, or a carbon content $C \geq 0.13\%$, then an increase of more than 0.02 P_{cm} units or 0.03 carbon equivalent units (IIW formula) over the value on the approval test shall require a new qualification test.
- c) A change from wrought (rolled, forged) steel to cast steel or converse.
- d) A change in delivery condition (normalised, thermomechanically controlled processed or quenched and tempered).
- e) A change in microalloying element or manufacturing technique for steel with SMYS ≥ 400 MPa.
- f) A change in groove angle more than $+20$ deg./ -10 deg.
- g) A qualification of fillet welds carried out on plate thickness equal to or greater than 30 mm, applies for all plate and throat thicknesses. Single layer fillet welds qualifies multi-layer, but not the converse.
- h) CTOD testing shall be included in the qualification of welding procedures for weldments with a plate thickness above 50 mm for all strength levels for steel quality level I and II and for SMYS >400 MPa for steel quality level III. CTOD testing shall be included in the qualification of welding procedures for weldments with a plate thickness below and equal 50 mm if requested by the designer for the specified steel quality level.

Testing shall be executed from as welded and PWHT weld assemblies as applicable, covering the following combined conditions:

- Full penetration butt weld with K-, or half V -groove as deemed most representative for the actual fabrication. V and X groove are acceptable for weld metal test..
- A welding procedure representing the maximum heat input to be used in fabrication.
- Maximum joint thickness (within 10%).

Assemblies shall be made and tested for the actual combination of steel manufacturer, welding process and welding consumable (brand) used, except welding consumables used for root passes only, provided these are removed completely by gouging and grinding.

Note: The changes specified in d) and e) need not require re-qualification if HAZ properties for the material to be welded have been documented from the steel manufacturer for relevant thicknesses and heat input ranges. If sufficient documentation from the steel manufacturer is not available, a change of material shall require re-qualification of a reduced number of procedures. The number of procedures to be re-qualified shall be sufficient to verify that the HAZ properties of the new material is comparable with that used for the previous qualifications.

5.3.2 For welding of steels with SMYS >500MPa

In addition to the requirements given in 5.3.1 the following additional requirements apply for welding of steels with SMYS >500 MPa

- a) A change in steel manufacturer.
- b) CTOD testing as described in 5.3.1 h) shall be executed for thicknesses above 30 mm
- c) Stress relieving if required/specified by designer
- d) When the steel to be welded has a $P_{cm} \geq 0,21$ or a carbon content $\geq 0,13$, then an increase of more than 0,03 Pcm or 0,04 carbon equivalent units (IIW formula) over the value of the approval test shall require a new qualification test.

5.4 Examination of the test weld**5.4.1 General**

The type and number of tests shall be in accordance with table 5.1. Testing shall be performed in accordance with EN 288 and the additional requirements given below.

The test weld shall be 100% examined for both surface and volumetric defects with the relevant NDT-methods. The soundness of the weld shall comply with clause 9.

Table 5.1 Type and number of tests

Joint configuration	Joint thickness (mm)	Mechanical testing				
		Tensile test	Bend tests ¹⁾	Charpy V-notch tests	Hardness and macro ⁵⁾	CTOD
Buttwelds (Tubulars and plates)	t < 50	2	2	4 sets	1	Ref. 5.3.1h and 5.4.4
	t ≥ 50	2	2	6 sets	1	
T-joints (plates) ⁴⁾	t < 50	3)		4 sets ²⁾	2	
	t ≥ 50	3)		6 sets	2	
Tubular joints ⁴⁾	t < 50	3)		4 sets ²⁾	2	
	t ≥ 50	3)		6 sets	2	
Fillet welds	All				2	

Notes:

1. Bend tests shall consist of 1 face and 1 root bend specimen for t < 20 mm and 2 side bend specimens for t ≥ 20 mm
2. If the dimensions of the joint does not allow Charpy V-notch testing, the Charpy V-notch properties shall be documented on a butt weld joint made with the same consumable and same base material, and welding parameters and thickness within the range qualified for the joint.
3. It shall be documented on a butt weld test that the welding consumable used will have sufficient tensile strength.
4. T-joints on plates qualify for tubular joints, and vice versa.
5. For welds on submerged structures with cathodic protection, the hardness limits in NORSOK M-001 (i.e. max 350 HV10) shall apply in addition to the requirements of EN 288. For SMYS 690 MPa max 400 HV10 shall apply.

5.4.2 Charpy V-notch testing

Sampling of Charpy V-notch impact tests shall be carried out in accordance with EN 875, with the notch in the positions listed below. (All specimens shall be machined with the notch through the thickness, 2 mm below the surface of the material.) (Designation in parenthesis refers to EN 875).

- Notch in centre of weld (VWT 0/2)
- Notch in fusion line (VHT 0/2)
- Notch in HAZ, 2 mm from fusion line (VHT 2/2)
- Notch in HAZ, 5 mm from fusion line (VHT 5/2)

For welds with a joint thickness of 50 mm or more, two additional sets of Charpy V-notch tests shall be taken from the root area, with the notch in the following positions:

- Notch in centre of weld (VWT 0/b)
- Notch in fusion line (VHT 0/b)

The test temperature and energy requirements shall comply with table 5.2.

Table 5.2 Charpy impact test temperatures and energy requirements for welding procedure qualifications.

Material thickness mm	Steel quality level							
	I			II			III	
	SMYS ≤400	400< SMYS≤ 500	SMYS >500	SMYS ≤400	400< SMYS≤ 500	SMYS >500	355≤ SMYS ≤500	SMYS >500
$t \leq 12$	0°C	-20°C	-20°C	0°C	-0°C	-20°C	-0°C	0°C
$12 < t \leq 25$	-20°C	-40°C	-40°C	0°C	-20°C	-40°C	0°C	-20°C
$25 < t \leq 50$	-40°C	-40°C	-40°C	-20°C	-40°C	-40°C	-20°C	-40°C
$t > 50$	-40°C	-40°C	-40°C	-40°C	-40°C	-40°C	-40°C	-40°C
Energy Requirement ¹⁾	36J	42J	60J	27J	42J	60J	27J	42J
Note: 1. The minimum average value is given in the table. No individual value shall be less than 70% of the minimum average value. Reduction factors of energy requirements for subsize specimens shall be: 7,5 mm - 5/6 and 5 mm - 2/3.								

5.4.3 Transverse tensile testing

Testing shall be carried out in accordance with EN 288. The fracture shall be located outside the weld metal (i.e. max. 20% of the fracture surface shall consist of weld metal/HAZ).

5.4.4 CTOD testing

The CTOD- technique with the Bx2B through-thickness notched type specimen according to BS 7448 Part 1 should be used. Three valid test specimens shall be obtained for each test position.

CTOD-testing of welds shall be carried out with the fatigue notch tip positioned in the coarse grained region of the heat affected zone and in the weld metal. For HAZ, determination of the actual location of the fatigue crack tip shall be performed after testing. Ref. is made to prEN 10225.

Note: Test assemblies may be given hydrogen diffusion treatment prior to testing, and specimens may be precompressed.

If not specified otherwise, the test temperature for design temperature down to -14 °C shall be:

-10 °C for splash zone or above.

0 °C for submerged parts.

Other test temperature may be prescribed by the designer.

Three (3) valid test specimens shall be obtained for each notch location.

The requirement for minimum CTOD value shall be prescribed by the designer. If not specified, the requirement for minimum CTOD value shall be as for the steel purchase order.

CTOD-testing of HAZ can be omitted if relevant CTOD properties in HAZ have been documented previously in accordance with requirements in this standard, provided the requirements for the essential variables are met.

CTOD-testing of weld metal can be omitted if relevant CTOD properties in WM have been documented previously in accordance with requirements in this standard, provided the requirements for the essential variables are met.

The required fracture toughness level shall be decided in design for joints when steel quality level I and II are required. Testing is normally not requested for structures with plate thickness below 40 mm for $SMYS \leq 500$ MPa or for structures with plate thickness below 25 mm for $SMYS > 500$ MPa.

5.5 Welder and welding operators qualifications

The welders, welding operators and tack welders shall be qualified in accordance with EN 287, EN 1418 or equivalent. For tack welders, an internal test may be used.

For welding of single sided acute angled tubular joints with $\alpha < 70^\circ$, welders shall be qualified with a realistic joint, representing the minimum angle α to be used in production.

For welding of joints where steel quality level IV is selected, a certificate for welding of plates in position PE is sufficient for welding all product forms.

6 FABRICATION AND WELDING REQUIREMENTS

6.1 General

All welding work shall be according to recommendations given in relevant part of EN 1011. The manufacturer shall have a quality system, which fulfil the relevant part of EN 729 and the applicable level of EN 719.

The fabricator shall apply a weld numbering system for identification on all shop drawings and as reference in all documentation.

6.2 Forming

Cold forming of steel (i.e. forming below 250°C) shall be carried out within the deformation range recommended by the steel manufacturer. For steel quality level I and II, the deformation limit without documentation of mechanical properties is 5%.

If the deformation is more than the above given limits, either heat treatment shall be performed, or strain ageing tests shall be carried out according to the following procedure:

- The material shall be permanently strained locally to the actual deformation.
- The material shall be artificially aged at 250°C for 1 hour.
- One set of 3 impact test specimens shall be tested from the base material in the strained plus artificially aged condition. The notch shall be located within the plastically strained portion of the material, in the part of the cross section which have received the highest strain.
- The impact testing temperature shall be as specified for the actual steel grade in question.
- The Charpy-V impact value shall comply with the minimum requirements for the steel grade and shall not be more than 25% lower than the impact value for the material before deformation and strain ageing.

If forming is performed at temperature above 250°C, it shall be documented that the base material properties, weldability, weldmetal and HAZ properties satisfy the actual MDS and this standard.

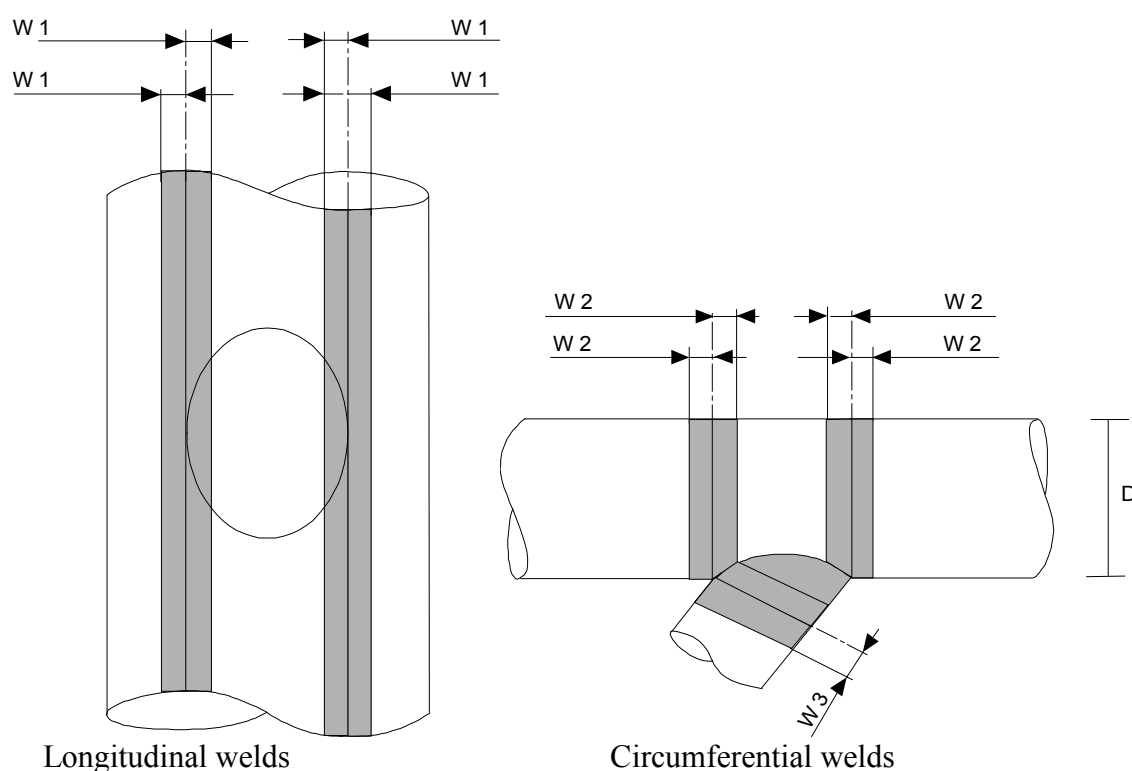
The percentage strain due to forming is defined as follows:

$$\text{Percent strain} = \frac{\text{Wall thickness}}{\text{Forming mid thickness diameter}} \times 100\%$$

6.3 Assembly

6.3.1 General

In tubular joints, circumferential and longitudinal weld joints should not be placed in the shaded areas shown in fig. 6.1, unless otherwise shown on design drawings.



W1 = 75 mm or min. 2 times chord thickness

W2 = 150 mm or min. D/4

W3 = 600 mm or min. D

Fig. 6.1 Prohibited location of welds in tubular joints. Longitudinal respectively circumferential welds shall not be located in shaded area.

6.3.2 Splices

Splices shall not be located in areas, noted as restricted on design drawings.

6.3.3 Tapering

Tapering shall be in accordance with the requirements given in relevant standards or drawings. If no other requirements are specified, a tapering of 1:4 should be used.

6.3.4 Bolting connection

Bolting material shall comply with requirements in NORSOK standard M-001, Material selection. Holes shall be made by machine drilling.

6.3.5 Seal/blind-compartments.

Crevice and areas which become inaccessible after fabrication or assembly shall be sealed off from the outside atmosphere. Seal welds shall have a throat thickness of at least 3 mm. Where steel items shall be hot dip galvanised, hollow sections shall be ventilated.

6.3.6 Temporary cut-outs

Temporary cut-outs shall not be located in restricted areas as shown on design drawings. Temporary cut outs shall have a corner radius not less than 100 mm. Temporary cut-outs shall be closed by refitting the same or an equivalent plate and employing the same welding, inspection and documentation procedures and requirements that govern the structural part in question.

6.3.7 Straightening of structural members

Members distorted by welding shall be straightened according to a detailed work instruction. The base material properties shall satisfy the specified requirements after straightening.

Maximum temperature for straightening shall not exceed the temperature limit recommended by the steel manufacturer, but it shall in no case be higher than 600°C.

6.3.8 Doubler plates

All temporary attachments which shall be flame cut or welded under water shall be attached to the structure by using doubler plates.

All attachments in the splash zone shall be attached to the structure by using doubler plates.

6.4 Preparation for coatings

Edges of plates and structural shapes which are intended to be coated shall be rounded to approximately 2 mm radius, unless otherwise indicated on design drawings.

6.5 Preparation and fit-up of weld bevels

Permanent backing strips are not accepted, unless shown in design drawings.

Buttering shall be carried out in accordance with a relevant WPAR. Buttering in excess of 20 mm shall be avoided.

6.6 Welding processes

The welding processes listed in EN 288-3 are acceptable.

6.7 Welding consumables

The manufacturers shall ensure that welding consumables applied for joints where steel quality level I, II and III are required, meet the requirements for mechanical properties as specified for the welding procedure qualification, in both as welded and (where applicable) PWHT condition.

This may be achieved through (alternatively):

- Batch testing including chemical analysis and mechanical properties, see annex D.
- An established and reliable system of batch certification against accepted supplier data sheets, see annex C.
- For steels with SMYS ≥ 500 MPa Annex D is mandatory

Except for solid wires such consumables shall be classified by the supplier as extra low hydrogen, i.e. $H_{DM} \leq 5\text{ml}/100\text{g}$ weld metal. For self shielded flux cored wire $H_{DM} \leq 8\text{ml}/100\text{g}$ may be accepted, provided preheating temperature and post weld holding temperature and time is assessed to avoid hydrogen cracking. Hydrogen testing shall be according to ISO 3690 or equivalent.

For all steels with SMYS ≥ 500 MPa special precautions shall be taken to verify that selected consumables comply with hydrogen requirements. Stricter requirements than given above may be relevant. Prequalification with mock-up structures shall apply if there is a risk for high restraint in welding or erection.

Consumables for joints in steel quality level III (with SMYS $< 355\text{MPa}$) and IV and for joining stainless to carbon steel shall be selected with due consideration of base material properties, thickness and weldability, to ensure sufficient weld strength, toughness and homogeneity. Such consumables shall be delivered with EN 10204 type 2.2 certificate, as a minimum.

All welding consumables shall be individually marked.

When certification according to Annex C is used, welding consumables (except welding fluxes) shall be supplied with an inspection certificate (type 3.1B) in accordance with EN 10204, including a statement of compliance with the Welding Consumable Data Sheet and the chemical composition of the weld deposit (elements of the data sheet). Welding fluxes shall be supplied with a test report (EN 10204 type 2.2), declaring conformity with the approved product type.

6.8 Preheat and interpass temperature

Preheating above 50°C should be achieved by electric heating elements. Cutting torches are not allowed for preheating.

The minimum interpass temperature shall not drop below the minimum required preheat temperature. If not otherwise stated in the WPS, and qualified by the WPAR, the maximum interpass temperature shall not exceed 250°C measured at the edge of the groove. For C- and C/Mn-steels, a maximum interpass temperature of 250°C may be used, even if a lower temperature was recorded on the WPAR.

The preheat temperatures used during repair welding should be minimum 50°C higher than the preheat used for the original weld.

Note: Production welding of high strength steels with SMYS > 500 MPa is normally more sensitive to hydrogen cracking than experienced during welding for qualification. Special precautions, including preheating temperature, minimum holding temperature and extended post weld holding temperature for 24 hours or more, shall be taken into consideration.

6.9 Production welding

6.9.1 General

Welding shall be carried out in accordance with the WPS and applicable drawings.

Butt welds in joints where steel quality level I and II for all strength levels, or steel quality level III for SMYS > 400 MPa are required shall, whenever possible, be welded from both sides.

If any welding is conducted after PWHT, the PWHT shall be repeated.

For joints in inspection category A, the "straight" edges of K- and $\frac{1}{2}$ V-butt weld grooves shall have a groove angle of at least 10° , unless it is documented that possible defects can be detected by the UT technique used. (For K-grooves, the 10° should be machined from the root to each plate surface.)

Any occurrence of cracking during production welding shall be investigated. Welding should be suspended until the cause of cracks and defects has been identified and measures taken to prevent their reoccurrence. Cracks or other persistent weld defects may lead to revision and requalification of the WPS.

6.9.2 Attachments

Temporary attachments as lifting lugs, lugs for scaffolding and assembly, supports for cables, equipment, ladders or other fabrication and erection aids should be removed. If indicated on design drawings that removal (full or partial) is not required, the temporary attachments may be left as is, or removed only partially.

All welding of attachments shall comply with the requirements for the structure to which they are attached. Temporary attachments shall be cut minimum 3 mm from the base metal and ground. The ground area shall be visually examined and magnetic particle/penetrant tested (as relevant) in accordance with the inspection category in question.

6.9.3 Stainless steel components

Permanent or temporary structural elements, attachments or penetration sleeves in stainless steel materials may be selected for various purposes.

Requirements for welding and testing of stainless outfitting structures shall follow similar classification principles as for other structural steel elements. All welding and testing of welds to carbon steel structures shall as a minimum comply with the requirements for the structure to which they are attached.

Unless other requirements apply higher alloyed consumables than given for the relevant stainless component shall be selected for tacking and final welding.

6.10 Post weld heat treatment (PWHT)

PWHT shall be required for structural welds in steel quality level I or II, or quality level III with $R_e > 400 \text{ MPa}$, when the nominal thickness (as defined in EN 288-3, section 8.3.2.1) exceeds 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 thicknesses, independent of steel quality level.

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

- Heating rate.
- Cooling rate.
- Soaking 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 time and temperature shall be as recommended by the steel manufacturer

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

The temperatures shall be continuously and automatically recorded on a chart.

6.11 Grinding

When grinding is specified on design drawings or is instructed as a corrective action, the grinding shall be performed according to a detailed procedure. Grinding tools, direction, surface roughness and final profile shall be specified. Reference samples for typical joints and sections may be prepared and used for acceptance of treated welds. Typical examples for requirements for grinding of joints are given in Annex A.

6.12 Peening

Weld improvement by peening shall be performed in accordance with detailed procedures. Normally pregrinding of a groove will be required to assure correct location of peening area. Tools for grinding and peening, surface roughness and profile of grinding as well as peening shall be specified. Tools for check and measurements shall be described and shall be available during operations. Documentation of correct performance shall include macrophotography. Typical examples of requirements for peening of joints are given in Annex A.

7 PRODUCTION TESTS

Production tests shall be selected on weldments in critical regions to verify that the specified requirements have been met. Minimum one test coupon is required from each applied welding process.

Test coupons shall be welded in a manner which realistically simulates the actual production welding, normally as extension of the production weld, and meet the requirements for welding procedure approval tests.

CTOD testing is not required for production testing.

If a production test fails, the reason for the failure shall be determined and remedial action implemented.

8 FABRICATION TOLERANCES

Fabrication tolerances shall be in accordance with Annex E, unless otherwise specified on drawings.

9 NON-DESTRUCTIVE TESTING (NDT)

9.1 General

The inspection category shall be decided by the designer in accordance with NORSOK N-004, and shall be specified on the design drawings.

Final inspection and NDT of structural steel welds shall not be carried out before 48 hours after completion except where PWHT is required. The time delay may be reduced to 24 hours for steel grades with SMYS of 355MPa or lower, and for steel grades with SMYS of 420MPa or lower for plate thicknesses below 40 mm, provided delayed cracking have not been observed for the materials and/or welding consumables in question.

When PWHT is performed, the final NDT shall be carried out when all heat treatment have been completed.

Prior to fabrication start-up, contractor shall implement a system for recording of weld defect rates. The defect rates shall be recorded on a weekly basis from each production area (geographically split in production areas at the same yard) and shall be reported together with the accumulated defect rate. The defect rate statistics shall be used as a tool in weld quality control. Causes for defects shall immediately be investigated and corrective actions shall be taken to prevent further occurrence. Cracks detected with any NDT method shall require documented investigation/action by the responsible welding engineer.

At a weekly high defect rate or at repeated occurrence of planar defects, two trigger levels apply for extended NDT for welds in inspection category B, C and D. Two steps of actions apply within trigger level 2.

Trigger level 1

If a defect rate for any method exceed 10 % for a single week the extent shall be increased to 100 % for all welds in question irrelevant of the required inspection category for the welds.

Trigger level 2

If a defect rate for any method of 5 - 10 % for a single week is observed the following two steps of extended NDT shall apply:

Step 1.

A defect rate for any NDT method exceeding 5 % (1% for MT) for a single week require doubling of the extent of NDT according to the inspection category. Spot extent shall be increased to 20 %.

Step 2.

If the defect rate for the weld length where the extended NDT is taken in accordance with Step 1 above exceed 5 %, the extent shall be increased to 100 % for all welds in question irrelevant of the required inspection category for the welds.

The increased NDT extent shall cover welds of the same inspection categories, welded in the same period of time when the high defect rate was produced, to assure that the weld quality is maintained also with the lower extent of NDT. Unless the causes for defects found leads to immediate and documented preventive actions, the higher level of extent of NDT shall be maintained until the weekly defect rate is well below 5 %.

Generally, if the defect rate approaches 10 % during any stage in production welding, further welding should be held until investigations are completed and corrective actions implemented.

A low defect rate may be used as basis for a reduction in the extent of NDT for inspection categories B, C and D, provided that a correct defect rate identification is prepared for each weld method, each NDT method and each production area. See Note 2 in Table 9.1.

The defect rate is defined as :
$$\frac{(\text{Defect length} \times 100\%)}{(\text{Length of tested parts of welds})^1}$$

Note 1: "Tested part of welds" means the part that is tested with the same NDT method.

NDT after repair shall not be included when calculating the defect rate.

9.2 Qualification of inspectors and NDT-operators

Personnel responsible for welding inspection - welding inspectors - shall be qualified in accordance with NS 477 or equivalent scheme.

Personnel performing visual inspections of welded joints shall be qualified in accordance with relevant part of EN 473/NORDTEST.

Personnel responsible for all NDT activities shall be qualified according to EN 473/NORDTEST Level 3 or equivalent.

The NDT operators shall be qualified according to EN 473/NORDTEST Level 2 or equivalent.

Operators simply producing radiographs and not performing evaluation, do not require level 2, but shall have sufficient training.

In undertaking testing of castings or forgings the NDT operator should also document experience with forged and cast products.

9.3 Extent of visual examination and NDT

The required minimum extent of examination/testing is given in table 9.1. Design drawings may show areas of welds where testing is mandatory.

Testing performed shall be representative for the weld quality. Partial NDT shall normally be planned for on all shop drawings.

Ultrasonic testing to reveal the presence of possible weld metal transverse cracking shall be included for butt welds with thickness more than 25 mm. The testing shall be performed on minimum 5% of welds in inspection category A and B for SAW (12) and FCAW (131 and 136)