

## Report

# Generic Appendix B1

This document is the new version of Appendix B1 related to welding requirement. It shall be the base for discussion with DA for the implementation on each PA.

Approval Process			
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<i>Change Log</i>			
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v3.0	Approved	13 Feb 2023	Doors version and editorial and normative changes

# Appendix B1: Welding Specification

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## 1 SCOPE

[I] This Appendix relates to welding of steel structures and steel pipes. It outlines the procedure to be adopted and documents required to be submitted to, and accepted by IO-CT.

## 2 ABBREVIATIONS

[I] The list of used abbreviations is given below:

CEN	European Committee for Standardization
DA	Domestic Agency
DR	Deviation Request
DT	Destructive Test
EBW	Electron Beam Welding
EN	European Standard
FSP	Full-Scale Prototype
IIA	Independent Inspection Authority
INC	Internal Component
IO	ITER Organisation
IO-CT	ITER Organization Central Team
ISO	International Standard Organization
IVH	ITER Vacuum Handbook
IQI	Image Quality Indicator
LBW	Laser Beam Welding
LT	Helium Leak Testing
MIP	Manufacturing and Inspection Plan
NCR	Non-Conformity Report
NDT	Non Destructive Testing
PFCs	Plasma Facing Components
PFUs	Plasma-Facing Units
PIC	Protection Important Component
PT	Liquid Penetrant Testing
PWHT	Post Weld Heat Treatment
pWDP	Preliminary Welding Data Package
QP	Quality Plan
RO	Responsible Officer
pWPS	Preliminary Welding Procedure Specification
RT	Radiographic Testing
SSS	Steel Supporting Structure
TEC	Thermal Expansion Coefficient
UT	Ultrasonic Testing
VQC	Vacuum Quality Class

VHB	Vacuum Handbook
VT	Visual Testing
VV	Vacuum Vessel
WDP	Welding data Package
WIP	Welding and Inspection Plan
WPQ	Welding Procedure Qualification
WPQR	Welding Procedure Qualification Record
WPS	Welding Procedure Specification

### 3 REFERENCED STANDARDS

[I] This chapter lists the standards to be used in the welding operations during qualification and production phases of steel structures and steel pipes. Applicable standards and reference standards are listed in two different sub-chapters.

[I] Terms:

*Applicable* standards and documents are the standards and documents applied within the scope specified in the present Appendix B1.

*Reference* standards and documents are the standards and documents intended to provide the background and supplementary information.

[I] The versions of the EN and ISO standards, their amendments and corrigendum to be used shall be those which have been approved by CEN by June 2014 (NOTE: National standards i.e. NF for France may have a later publication date).

[I] In case the same standard is referred in two different documents, the latest version of the standard applies.

[I] In case of inconsistency between requirements established in this specification and in applicable documents listed hereafter, those requirements defined in Appendix B1 prevail.

#### 3.1 *Applicable Standards and documents*

[I] The construction code used as reference for writing this appendix B1 is the standard series EN 13445, 2014 edition. The relevant provisions for the welding activities were extracted from these standards into this appendix.

[I] The normative references inside the standard series EN 13445 and lower tier ones are nevertheless applicable. In this regard, the following non-exhaustive list of applicable documents is recalled.

[1] EN ISO 3452-1:2013 Non-destructive testing – Penetrant testing – Part 1: General principles.

[2] EN ISO 5817:2014 Welding – Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) – Quality levels for imperfections.

[3] EN ISO 9606-1:2013 Qualification test of welders – Fusion welding – Part1: Steels (superseded EN 287-1:2011).

[4] EN ISO 9712:2012 Non-destructive testing – Qualification and certification of NDT personnel – General principles.

[5] EN ISO 14732:2013 Welding Personnel – Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanized and automatic welding of metallic materials.

[6] CEN ISO/TR 15608:2013, Welding – Guidelines for a metallic material grouping system (ISO/TR 15608:2013).

[7] EN ISO 15609-1:2004 Specification and qualification of welding procedures for metallic materials – Welding procedure specification – Part 1: Arc welding.

[8] EN ISO 15614-1:2004 + A1:2008 + A2:2012 Specification and qualification of welding procedures for metallic materials – Welding procedure test – Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys.

[9] EN ISO 17635:2016 Non-destructive examination of welds. General rules for metallic materials.



- [10] EN ISO 17636-1:2013 Non-destructive testing of welds – Radiographic testing – Part 1: X-and Gamma-ray techniques with film.
- [11] EN ISO 17637:2016 Non-destructive examination of fusion welds – Visual examination.
- [12] EN ISO 17639:2013 Destructive tests on welds in metallic materials. Macroscopic and microscopic examination of welds.
- [13] 17640:2010 or EN ISO 17640:2018, Non-destructive testing of welds — Ultrasonic testing — Techniques, testing levels, and assessment
- [14] EN ISO 17655:2003 Destructive tests on welds in metallic materials - Method for taking samples for delta ferrite measurement.
- [15] EN ISO 544:2011 or 2017 Welding consumables – Technical delivery conditions for filler materials and fluxes – Type of product, dimensions, tolerances and markings (ISO 544:2011).
- [16] EN ISO 8249:2000 Welding – Determination of Ferrite Number (FN) in austenitic and duplex ferritic-austenitic Cr-Ni stainless steel weld metals.
- [17] EN ISO 13185:2001 + A1:2003 Non-destructive testing — Leak testing — Tracer gas method
- [18] EN ISO 13919-1:1996 Welding – Electrons and laser beam welded joints. Guidance on quality levels for imperfections. Part 1: steel.
- [19] EN ISO 14731:2006 Welding coordination – Tasks and responsibilities.
- [20] EN ISO 15609-3:2004 Specification and qualification of welding procedures for metallic materials – Welding procedures specification – Part 3: Electron beam welding.
- [21] ISO 15609-4:2009 Specification and qualification of welding procedures for metallic materials – Welding procedure specification – Part 4: laser beam welding.
- [22] EN ISO 15613:2004 Specification and qualification of welding procedures for metallic materials – Qualification based on pre-production welding test.
- [23] EN ISO 15614-11:2002 Specification and qualification of welding procedures for metallic materials – Welding procedure test – Part 11: Electron and laser beam welding.
- [24] ISO 22825:2012 Non-destructive testing – Ultrasonic testing – Testing of welds in austenitic steel and nickel-based alloys.
- [25] ITER Vacuum Handbook - Appendix 4
- [26] 2015 ASME BPVC Section II – Materials – Part C – Specifications for Welding Rods, Electrodes, and Filler Metals.
- [27] NF EN 10204:2005 Metallic products – Types of inspection documents.
- [28] ISO 17025:2005 +AC1:2006 General requirements for the competence of testing and calibration laboratories.
- [29] EN ISO 17640:2018 Non-destructive testing of welds — Ultrasonic testing — Techniques, testing levels, and assessment
- [30] ITER\_D\_QUCYDA - Technical specification for outgassing sample. V1.2
- [31] EN ISO 6892-1:2009 Metallic materials - Tensile testing - Part 1 : method of test at room temperature
- [32] NF EN 13018:2001 + A1:2004 Non-destructive testing - Visual testing - General principles
- [33] NF EN 10228-2:2016 Non-destructive testing of steel forgings - Part 2 : penetrant testing
- [34] NF EN ISO 23277:2015 Non-destructive testing of welds - Penetrant testing - Acceptance levels
- [35] ISO 10675-1:2017 Non-destructive testing of welds - Acceptance levels for radiographic testing - Part 1: Steel, nickel, titanium and their alloys
- [36] ISO 11666:2018 Non-destructive testing of welds - Ultrasonic testing - Acceptance levels

[37] ISO 4063:2009 Welding and allied processes — Nomenclature of processes and reference numbers

[I] Other equivalent national or international standards may be proposed by the Supplier (the Domestic Agency) provided its implementation is preceded by an acceptance from IO processed through a deviation request DR. The justification section of the DR shall include the differences between the quoted standard of the present specification and the standard proposed.

### **3.2 Reference Standards**

[38] EN ISO 3834-2:2005 Quality requirements for fusion welding of metallic materials Part 2: Comprehensive quality requirements.

[39] EN ISO 3834-3:2005 Quality requirements for fusion welding of metallic materials Part 3: Standard quality requirements.

[40] EN 13445-1:2014 Unfired pressure vessels – Part 1: General.

[41] EN 13445-2:2014/A1:2016 Unfired pressure vessels – Part 2: Materials.

[42] EN 13445-3:2014 Unfired pressure vessels – Part 3: Design.

[43] EN 13445-4:2014 Unfired pressure vessels - Part 4: Fabrication.

[44] EN 13445-5:2014 Unfired pressure vessels – Part 5: Inspection and testing.

[45] EN 1708-1:2010 Welding – Basic weld joint details in steel – Part 1: Pressurized components.

[46] EN ISO 15607:2003 Specification and qualification of welding procedures for metallic materials – General rules.

[47] EN 1011-3/A1:2003 Welding - Recommendations for welding of metallic materials - Part 3: Arc welding of stainless steels.

[48] EN 1011-7:2004 Welding - Recommendations for welding of metallic materials - Part 3: Electron beam welding.

[49] EN 14532-1:2004 Welding consumables - Test methods and quality requirements - Part 1: Primary methods and conformity assessment of consumables for steel, nickel and nickel alloys.

[50] EN 14532-2:2004 Welding consumables - Test methods and quality requirements - Part 2: Supplementary methods and conformity assessment of consumables for steel, nickel and nickel alloys.

[51] EN ISO/IEC 17020:2012 Conformity assessment - Requirements for the operation of various types of bodies performing inspection.

[52] ISO/IEC 17024:2012 Conformity assessment - General requirements for bodies operating certification of persons.

[53] ITER Vacuum Handbook ([ITER\\_D\\_2EZ9UM v2.3](#)) and appendices (except appendix 4 which is applicable).

[54] DIN 25410:2012 Nuclear facilities - Surface cleanliness of components.

[55] Welding Journal, 76(1): 24-s to 37-s, 1997.

[56] Welding Journal, 61(11): 352-s to 361-s, 1982.

### **3.3 Exclusions and superseded sections from the code**

[I] The following tables inform about the exclusion, correspondence or replacement of requirements from EN 13445 parts 4 and 5 by requirements defined in this appendix B1.

Sections from EN 13445-4 Fabrication	Superseding sections in this Appendix B1	Remarks
3 Requirements for manufacturing and subcontracting		title
3.1 Manufacturing	6.1 General	
3.2 Subcontracting	None	See Annex A
4 Materials		title
4.1 General	None	Non-applicable
4.2 Material traceability	4.1.1 Material traceability	
4.2.1 General		title
4.2.2 Identification system	4.1.2 Identification system	
4.2.3 Visibility	4.1.2 Identification system	
4.2.4 Review of material certification and material identification	8.1 General (Production Welds)	
4.2.5 Transfer of markings	4.2.2 Transfer of markings	
5 Manufacturing tolerances		title
5.1 Surface geometry of welds	6.3.1 Surface geometry of welds	
5.2 Middle line alignment	6.3.2 Middle line alignment	
5.3 Surface alignment		title
5.3.1 Surface misalignment between parts	None	Non-applicable
5.3.2 Joining of parts of different thickness	6.3.3.1 Joining of parts of different thicknesses	
5.4 Tolerances for vessels subjected to internal pressure	None	Non-applicable
5.4.1 External diameter	None	Non-applicable
5.4.2 Out of roundness	None	Non-applicable
5.4.3 Deviation from the longitudinal axis	None	Non-applicable
5.4.4 Irregularities in profile	None	Non-applicable. Requirements covered by tolerances defined in 2D drawings.
5.4.5 Local thinning	6.3.3 Local thinning	
5.4.6 Dished ends	None	Non-applicable
5.5 Tolerances for vessels subjected to external pressure	None	Non-applicable
5.6 Structural tolerances	None	Non-applicable. Requirements covered by tolerances defined in 2D drawings.
6 Weld details		title
6.1 General	5. Weld design	
6.2 Vessels or parts made of more than one course	None	Non-applicable
6.3 Lapped joints, joggle joints, permanent backing strips	None	Non-applicable
7 Welding		title

<b>Sections from EN 13445-4 Fabrication</b>	<b>Superseding sections in this Appendix B1</b>	<b>Remarks</b>
7.1 General	8.1 General	
7.2 Welding procedure specification (WPS)	7.3.1 Welding Procedure Specification (WPS)	
7.3 Welding procedure qualification record (WPQR)	7.2 Welding Procedure Qualification (WPQ) 7.4.4 Examination and Testing 7.4.6 Welding Procedure Qualification Record (WPQR)	
7.4 Qualification of welders and welding operators	7.5 Welder and Operator Qualifications	
7.5 Filler metals and auxiliary materials	4.3.2 Delivery, Storage, use and identification of Welding Materials and Welds	
7.6 Joint preparation	8.3 Joint Preparation Examination	
7.7 Execution of welded joints	8.6 Execution of welds	
7.8 Attachments, supports and stiffeners	8.4 Fused Tack Welding and permanent attachment 8.5 Temporary Attachments and stiffeners	
7.9 Preheat	None	Non-applicable
7.10 Permanent joints other than welding	None	Non-applicable
7.10.1 General	None	Non-applicable
7.10.2 Mechanical roller expansion	None	Non-applicable
7.10.3 Brazing	None	Non-applicable
8 Manufacture and testing of welds — Production test		title
8.1 General	11.1 General 11.3 Production Test Coupon	
8.2 Reference criteria	11.2 Reference criteria	
8.3 Extent of testing	11.5 Extent of testing	
8.4 Performance of tests and acceptance criteria	11.6 Performance of tests and acceptance criteria	\
8.4.1 General	11.6.1 General	
8.4.2 Transverse tensile test	11.6.3 Transverse tensile test	
8.4.3 Longitudinal weld tensile test	None	Non-applicable
8.4.4 Impact test	11.6.4 Impact test	
8.4.5 Bend test	11.6.2 Bend test	
8.4.6 Macro examination	11.1.6.4 Macrography	
8.4.7 Micro examination	11.1.6.4 Micrography	
8.4.8 Hardness test	None	Non-applicable
8.4.9 Retests	12.1.6.7 Retests	
8.4.10 Test report	None	Non-applicable
9 Forming of pressure parts	Appendix B2 - Forming	

<b>Sections from EN 13445-4 Fabrication</b>	<b>Superseding sections in this Appendix B1</b>	<b>Remarks</b>
9.1 General	Appendix B2 - Forming	
9.2 Ratio of deformation	Appendix B2 - Forming	
9.2.1 Dished circular products	Appendix B2 - Forming	
9.2.2 Cylinders and cones made by rolling	Appendix B2 - Forming	
9.2.3 Other product types	Appendix B2 - Forming	
9.2.4 Tube bends	Appendix B2 - Forming	
9.2.5 Forming of Segments	Appendix B2 - Forming	
9.3 Forming procedures	Appendix B2 - Forming	
9.3.1 Cold forming	Appendix B2 - Forming	
9.3.2 Hot forming	Appendix B2 - Forming	
9.4 Heat treatment after forming	Appendix B2 - Forming	
9.4.1 General	Appendix B2 - Forming	
9.4.2 Heat treatment of flat products after cold forming	Appendix B2 - Forming	
9.4.3 Heat treatment of tubular products after cold forming	Appendix B2 - Forming	
9.4.4 Heat treatment of clad steels after cold forming	Appendix B2 - Forming	
9.4.5 Heat treatment after hot forming	Appendix B2 - Forming	
9.4.6 Heat treatment of clad steels after hot forming	None	Non-applicable to this appendix
9.5 Sampling of formed test coupons	Superseded	
9.5.1 Cold formed products without heat treatment	Appendix B2 - Forming	
9.5.2 Hot formed or cold formed products with heat treatment	Appendix B2 - Forming	
9.6 Tests	Appendix B2 - Forming	
9.6.1 Base material	Appendix B2 - Forming	
9.6.2 Butt welds	Appendix B2 - Forming	
9.6.3 Acceptance criteria for formed test coupons	Appendix B2 - Forming	
9.6.4 Retests of formed coupons	Appendix B2 - Forming	
9.7 Visual inspection and control of dimension	None	Non-applicable to this appendix
9.8 Marking	None	
9.9 Documentation	None	
10 Post weld heat treatment (PWHT)	9. Heat Treatment	
10.1 General	9. Heat Treatment	
10.2 Heat treatment conditions	9. Heat Treatment	
10.3 Method of PWHT	9. Heat Treatment	
10.4 PWHT procedure	9. Heat Treatment	
10.5 Mechanical properties after heat treatment	9. Heat Treatment	
10.6 Dissimilar ferritic joints	9. Heat Treatment	

<b>Sections from EN 13445-4 Fabrication</b>	<b>Superseding sections in this Appendix B1</b>	<b>Remarks</b>
10.7 Special materials	9. Heat Treatment	
10.8 Heat Treatment for reasons other than welding	9. Heat Treatment	
11 Repairs	10.8 Repair	
11.1 Repairs of surface defects in the parent metal	10.8 Repair	
11.2 Repair of weld defects	10.8 Repair	
12 Finishing operations	None	Non-applicable to this appendix
Annex A (informative) Structural tolerances	None	Non-applicable. Requirements covered by tolerances defined in 2D drawings.
Annex B (informative) Example of a sub-contractors form	None	Non-applicable.
Annex C (normative) Specification and approval of expansion procedures and operators	None	Non-applicable.

<b>Sections from EN 13445-5 Inspection and testing</b>	<b>Superseding sections in this Appendix B1</b>	<b>Remarks</b>
4 Performance of inspection and testing		title
4.1 General	None	
4.2 Inspection	10.1 NDT personnel; 10.2 Extent	
4.3 Non-destructive testing (NDT)	10.2 Extent	
5 Technical documentation	None	Non-applicable.
5.1 General	None	Non-applicable.
5.2 Information to be contained in the technical documentation	None	Non-applicable.
5.2.1 General	None	Non-applicable.
5.2.2 General description of the pressure vessel	None	Non-applicable.
5.2.3 Design and construction drawings	None	Non-applicable.
5.2.4 Descriptions and explanations necessary for an understanding of the drawings and diagrams and the operation of the pressure vessel	None	Non-applicable.
5.2.5 Results of design calculations and examinations carried out	None	Non-applicable.
5.2.6 Test reports	None	Non-applicable.
5.2.7 Technical/manufacturing schedule	None	Non-applicable.

Sections from EN 13445-5 Inspection and testing	Superseding sections in this Appendix B1	Remarks
5.3 Design review	None	Non-applicable.
5.3.1 General	None	Non-applicable.
5.3.2 Design review	None	Non-applicable.
6 Inspection and testing during fabrication		title
6.1 General	8.8.1 General	
6.2 Manufacturing procedures and construction drawings	8.8.2 Manufacturing procedures and manufacturing drawings	
6.3 Material traceability		title
6.3.1 General	4.1.1 Material traceability	
6.3.2 Special Conditions - Material marking	4.1.1 Material traceability	
6.4 Preparation for manufacturing processes		title
6.4.1 General	6.4.1 General	
6.4.2 Joint preparation testing	6.2 Cleanliness during manufacture	
6.4.3 Inspection of vessel supports	8.4 Fused Tack Welding and permanent attachment 8.5 Temporary Attachments and stiffeners	
6.4.4 Inspection associated with forming	None	Non-applicable.
6.4.5 Testing of areas subject to significant through thickness tensile stress	None	Non-applicable.
6.5 Welding		title
6.5.1 General	5.1 General; 11.2 Extent; 11.6 Stage of performance	
6.5.2 Verification of welder and welding operator qualification and procedures qualification	7.5.1 General; 8.7.1 General requirements	
6.5.3 Inspection of repairs	10.8.2 Repairs on welds	
6.6 Non-destructive testing of welded joints		title
6.6.1 Extent of non-destructive testing	10.2 Extent	
6.6.2 Determination of extent of non- destructive testing	10.2 Extent	
6.6.3 Performing non-destructive testing	10.4 Applicable NDT techniques	
6.6.4 Description and acceptance level of imperfections	10.4 Applicable NDT techniques	
6.6.5 Stage of performance	11.6 Stage of performance	

Sections from EN 13445-5 Inspection and testing	Superseding sections in this Appendix B1	Remarks
6.6.6 Procedure for non-destructive retesting	10.8.2 Repairs on welds	
6.6.7 Non-destructive testing documentation	10.4 Applicable NDT	
6.7 Destructive testing		title
6.7.1 Extent of destructive testing	11 Production Test Coupons	
6.7.2 Schedule for destructive testing	11 Production Test Coupons	
6.7.3 Verification of destructive tests	11 Production Test Coupons	
6.7.4 Records	11 Production Test Coupons	
6.8 Heat-treatment	9 Heat Treatment	
7 Subcontracted items		title
7.1 General	None	See Annex A
7.2 Subcontracted welding related activities	None	See Annex A
7.3 Subcontracted non-destructive testing activities		title
7.3.1 Use of contract NDT personnel at the premises of the vessel manufacturer	None	See Annex A
7.3.2 Subcontracting of NDT at a subcontractors premises	None	See Annex A
8 Miscellaneous tests	10.4 Applicable NDT techniques	
9 Calibration	None	Non-applicable
9.1 General	None	Non-applicable
9.2 Calibration procedure	None	Non-applicable
9.2.1 General	None	Non-applicable
9.2.2 Calibration	None	Non-applicable
9.2.3 Frequency	None	Non-applicable
9.3 Identification	None	Non-applicable
9.4 Registration	None	Non-applicable
10 Final assessment	None	See Annex B
10.1 General	None	See Annex B
10.2 Extent of final assessment	None	See Annex B
10.2.1 Visual and dimensional inspection	None	See Annex B
10.2.2 Review of documentation	None	See Annex B
10.2.3 Proof test	None	See Annex B
10.2.4 Post pressure test inspection	None	See Annex B



<b>Sections from EN 13445-5 Inspection and testing</b>	<b>Superseding sections in this Appendix B1</b>	<b>Remarks</b>
10.2.5 Inspection of safety accessories.	None	Non-applicable
11 Marking and declaration of compliance with the standard.	None	See Annex B
11.1 General	None	See Annex B
11.2 Marking method	None	See Annex B
11.2.1 General	None	See Annex B
11.2.2 Direct stamping	None	See Annex B
11.2.3 Nameplate	None	See Annex B
11.3 Marking units	None	See Annex B
11.4 Marking contents	None	See Annex B
11.5 Declaration of compliance with the standard	None	See Annex B
12 Documents		title
12.1 Type of documents	None	See Annex B
12.2 Control and access of documents	None	See Annex A
12.3 Retention of documents	None	See Annex A
Annex A (normative) Inspection and testing of serially produced pressure vessels	None	Non-applicable.
Annex B (normative) Detailed dimensional requirements for pressure vessels	None	Non-applicable.
Annex C (normative) Access and inspection openings, closing mechanisms and special locking elements	None	Non-applicable.
Annex D (informative) Leak Testing	None	
Annex E (informative) Acoustic emission	None	Non-applicable.
Annex F (normative) Inspection and testing of pressure vessels or parts subject to creep	None	Non-applicable.
Annex G (normative) Inspection and testing of pressure vessels subject to cyclic loads	None	Non-applicable.
Annex H (informative) Declaration of compliance with this standard	None	Non-applicable.
Annex I (informative) Specific tests during construction to assist in-service inspection	None	Non-applicable.

## 4 MATERIALS

### 4.1 General requirements

#### 4.1.1 Material traceability

**[B1-98-R]** The Manufacturer (main contractor responsible for the fabrication) shall have and maintain an identification system for materials used in fabrication (base material and welding consumables), so that all material can be traced to its origin.

#### 4.1.2 Identification system

**[B1-100-R]** The Manufacturer's identification system shall assure that all materials to be used in the component have been subjected to and satisfactorily passed the following:

- Ensure full traceability to the correct material certification as specified in the materials' specifications;
- Check of the welding consumables to ensure that the correct markings and that the correct conditions are maintained to prevent deterioration;
- All components and the main subcomponents shall be clearly marked in a permanent way and in a visible place.

**[B1-104-R]** Material traceability to the original identification markings shall be by one or more of the following methods:

- proper transfer of the original identification markings to a location where the markings will be visible on the completed component;
- identification by a coded marking traceable to the original required marking;
- recording the identification markings using material lists or as built sketches which ensure identification of each piece of material during fabrication and subsequent identification in the completed component;
- the batch numbers of welding consumables shall be recorded.

**[I]** For the Materials which cannot be stamped or which will not be visible after the component manufacturing is completed, or for small multiple parts or non-pressure boundary parts, the Manufacturer may operate a documented system which ensures material traceability for all materials in the completed component.

### 4.2 Base Material

**[I]** The base material specifications are referred to Annex B.

#### 4.2.1 Classification

**[B1-113-R]** The classification of material shall be in accordance with EN ISO 15608 table 1. The grouping applies regardless of product form, i.e. plate, forging, piping.

**[I] Notes:**

For clarification:

- a) Steels of group 8 are shown below:
- b) XM19 material is part of the group 8.3.

8		Austenitic stainless steels, Ni $\leq$ 35 %
	8.1	Austenitic stainless steels with Cr $\leq$ 19 %
	8.2	Austenitic stainless steels with Cr $>$ 19 %
	8.3	Manganese austenitic stainless steels with 4 % $<$ Mn $\leq$ 12 %

#### 4.2.2 Transfer of markings

**[B1-115-R]** In case the original identification markings are unavoidably cut out or the material is divided into two or more pieces the markings shall be properly transferred by the manufacturer's nominated personnel prior to cutting.

**[B1-116-R]** The actual material marking shall be performed by methods, which are not harmful to the material in subsequent use/operation.

**[B1-117-R]** The transfer of markings shall take place before partitioning of the product and after verification of the marks present with the corresponding certification.

#### 4.2.3 Storage and handling

**[B1-119-R]** When storing, handling or fabricating stainless steel, the environment shall be controlled to avoid permanent breakdown of the passive layer, which gives stainless steel its good corrosion resistance.

**[B1-120-R]** Stainless steels shall be protected from contamination and surface damage during all stages of storage, fabrication and transportation.

Racking for stainless steels shall be strongly built and shall be lined in a secure manner with materials that will not contaminate stainless (e.g. dry wood or stainless steel). Unlined or painted carbon steel racking shall not be used.

**[B1-121-R]** Contact between stainless steels and other materials, (e.g. carbon steels, copper, paints, dyes and tapes), which cause a breakdown of the passive layer or other detrimental effects shall be avoided. When contact is not avoidable care shall be taken that all residues are removed.

**[B1-861-R]** Lifting grabs shall be made from or lined with a non-contaminating material.

**[B1-123-R]** Welding fixtures, earth clamps or manipulators shall be either manufactured from or lined with non-contaminating materials.

### 4.3 Welding consumables

**[I]** The Manufacturer will select the filler metal to be used for welding the component structures considering the following requirements:

- **[B1-126-R]** the welding consumables shall be suitable for use with the parent metals, the welding processes and the fabricating conditions;

- **[B1-786-R]** the prediction of ferrite content for weld joints involving XM-19, including dissimilar welds with 316LN-IG, is made before purchase of each lot and should give confidence enough to comply with the requirements established in section 7.4.4.1;
- **[B1-127-R]** the filler metal shall have cobalt content less than 0.20wt%.

**[B1-128-R]** The filler material selected by the Manufacturer shall be qualified according to EN 14532, parts 1 or 2. ASME/AWS SFA/A5.4 or ASME/AWS SFA/A5.9 is authorized for filler metal aiming to weld XM19 material.

#### 4.3.1 Determination method of ferrite content

**[I]** While the FN on the weld metal is measured by using magnetic properties of ferrite with an instrument calibrated to ISO 8249, it can also be determined from the chemical composition using several constitution diagrams. The most recent and accurate one as on date is 1992 WRC diagram. Nonetheless, Schaeffler-Delong diagram modified by Espy is more suitable for XM-19. In order to predict the ferrite content in the weld metal, the proportion (dilution) of the base material in the weld pool needs to be estimated for different processes being used.

**[I]** The following formula may be used for conversion, if needed:

$FN = (\text{vol\% ferrite}) \times [-0.025813 (\text{Fe})^2 + 5.408679 (\text{Fe}) - 102.3902]/100$
--

Where,

FN = Ferrite Number

vol% ferrite = Ferrite volume percent

(Fe) = (wt%) weight percent of Iron

#### 4.3.2 Delivery, Storage, use and Identification of Welding Consumables

**[B1-138-R]** The technical delivery conditions for welding consumables shall be in accordance with EN 544. The welding consumables and other auxiliary materials (e.g. insert) shall be identified and documented along the fabrication route, so that all welding materials can be traced to its origin.

**[B1-139-R]** The DA shall assure that the provider of the welding consumables provides inspection documents demonstrating compliance with the material specification by providing a material certification and inspection documents according to EN 10204:

- Test report "Type 2.2" for mechanical test results (or more stringent),
- and Inspection Certificate "type 3.1" for chemical composition analysis. It is required to have the ferrite content value for information in the inspection document for the XM19 filler metal (designated as ER209 in ASTM or equivalent).

**[B1-140-R]** All welding consumables shall be stored and handled with care and used in accordance with the conditions specified by the welding consumable manufacturer. Electrodes, filler wires, rods and fluxes that show signs of damage or deterioration, such as cracked or flaked coating, rusting or dirty electrode wire, shall not be used.

## 5 WELD DESIGN

### 5.1 General

**[I]** The Manufacturer when selecting an appropriate weld detail shall give consideration to:

- a. the method of manufacture;
- b. the grade and properties of metals used (weld zone shall have at minimum the same mechanical properties (which are defined by the destructive tests) as the lowest parent metal);
- c. the ability to carry out the necessary non-destructive testing required;
- d. the design requirements of welded joints given in section 5.2.

**[I]** The followings are provided as requirements:

**[B1-149-R]** a) Crossing of weld lines assembling various parts of a main component shall be avoided.

**[B1-150-R]** b) Lapped joints, joggle joints, through-wall welding (i.e. “transparent welding”), joints with permanent backing or extra lid are not allowed.

**[B1-151-R]** The followings are provided as recommendation. In case of impossibility of implementing such recommendations, an explanatory note shall be provided by the Manufacturer for IO’s acceptance.

a) The distance from the edge of a weld to the edge of another weld or the edge of a drilled hole should be greater than the smaller minimum distance of:

- twice the thickness of the thickest part to be assembled;
- 40 mm (edge to edge).

b) Welded joints should be located as far away as possible from gross shape discontinuities, in particular those assembling materials with different thermal expansion coefficients.

**[I]** Specific qualifications based on pre-production welding test according to EN ISO 15613 may be consequently requested where the shape and dimensions of the standard test pieces (e.g. those of EN ISO 15614) do not adequately represent the joint to be welded as recommended above.

### 5.2 Design requirements of welded joints

#### 5.2.1 Type of welded joint authorized

**[I]** Welded assemblies are classified into categories depending on their position on the structure, as shown in Table 5.2-1. Details of category can be found in Annex B.

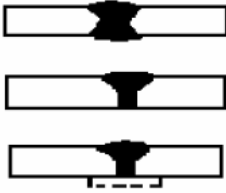
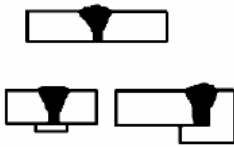
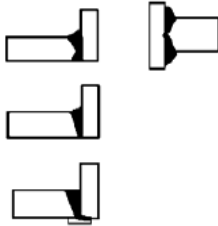
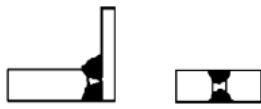


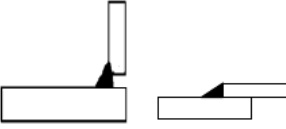
**Table 5.2-1 Welded assemblies categorization**

Category	Description	Applicability
Category 1	Structural welds of nuclear confinement barriers, Pressure boundary of Nuclear pressure vessel or Conventional pressure vessel Pressure boundary of a PIC component	NA
Category 2	Structural welds, Pressure boundary of non- Nuclear pressure vessel or non-Conventional pressure vessel Pressure boundary of a non PIC component	All boundary welds
Category 3	Others loaded welds	
Category 4	Non loaded welds	

**[B1-162-R]** For each of these categories, the various types of joints which can be used are given in Table 5.2-2 and Table 5.2-3.

**[I]** Additionally, the following weld design requirements specified in Annex A of EN 13445-3 are applicable for categories 2 and 3: M1, M2, M3, M4, M5, M6, M7, M8, M10, M12, E1, E2, E3, E4, E14, E15, S1, S2, and N6..

Table 5.2-2 Definition of type of welded joints

Examples	Definition of types welded joints				
	I.1	butt welding	full penetration	two sides accessible	back welding
	I.2	butt welding	full penetration	two sides accessible	gaseous back protection with or without insert
	I.3	butt welding	full penetration	two sides accessible	on temporary backing strip can be inspected after removal of the strip
	II.1	butt welding	full penetration	back side inaccessible	gaseous protection with or without insert
	II.2	butt welding	full penetration	back side inaccessible	permanent backing strip
	III.1	fillet or T	full penetration	two sides accessible	back weld or back machining
	III.2	fillet or T	full penetration	back side inaccessible	gaseous back protection
	III.3	fillet or T	full penetration	back side inaccessible	permanent backing strip
	IV.1	fillet or T	partial penetration	double opening preparation	double bead
	IV.2	butt welding	partial penetration	double opening preparation	double bead
	V	fillet or T	partial penetration or no penetration	straight edges or single opening preparation	double bead
	VI	fillet or T butt welding	partial penetration	single opening preparation	single bead
	VII	fillet or T	no penetration	straight edges preparation	single bead

[I] Other weld details may be proposed by the DA and accepted by the IO.

[I] It is recommended to use basic weld details given in EN 1708-1 for weld bevel preparation.

Table 5.2-3 Weld joints category-Type of welded joint authorized

Welded assembly category	Types of Welded joint authorized					
1	I.1	I.2	I.3	II.1	III.1	
2	I.1	I.2	I.3	II.1	III.1	III.2
3	I.1	I.2	I.3	II.1	III.1	III.2
4	I.1	I.2	I.3	II.1	III.1	III.2
	IV.2	V	VI	VII		

**[B1-170-R]** Unless differently specified in the 2D drawings, all welds shall be full-penetration welds and shall be qualified according to the procedure described in section 7, with the exception of the welds and joints for the water displacer in the HVT water box, which do not require qualification.

## 6 MANUFACTURING

### 6.1 General

[I] The manufacturer shall ensure that:

[B1-174-R] a) the organization for the control of manufacturing operations which includes special processes, such as welding, shall be clearly defined by the manufacturer; A dedicated organization chart shall be provided in accordance with ISO 3834-3 or equivalent national standard;

[B1-175-R] b) the manufacturing procedures such as welding and other associated processes are adequate for the purpose and meet the requirements of this appendix;

[B1-176-R] c) Where specific requirements are associated with materials these shall be taken into account;

[B1-177-R] d) the manufacturing equipment is adequate for fabrication;

[B1-178-R] e) the staff is adequate for the assigned tasks.

#### 6.1.1 Sub-contracting

[I] When the Manufacturer intends to use the sub-contracted services or activities (e.g. welding, inspection, non-destructive testing, heat treatment), then the information which is necessary to correspond to the applicable requirements shall be supplied by the Manufacturer to the Subcontractor. The Subcontractor shall provide the records and documentation of its work specified by the Manufacturer.

[I] The Subcontractor shall work under the order and responsibility of the Manufacturer and shall fully comply with the relevant requirements of the standard ISO 3834. The Manufacturer shall ensure that the Subcontractor can comply with the specified quality requirements.

[I] The information to be provided by the Manufacturer to the Subcontractor shall include all relevant data from the review of requirements (see Section 5.2 of the standard ISO 3834-3) and the technical review (see Section 5.3 of the standard ISO 3834-3). If necessary, the additional requirements may be specified to ensure that the Subcontractor complies with the technical requirements.

### 6.2 Cleanliness during manufacture

[B1-180-R] Facilities for fabrication of stainless steels shall be segregated from other works and kept free of all possible contaminating materials such as lead, zinc, copper, copper alloys or carbon steels.

[B1-181-R] Forming tools shall be cleaned thoroughly before use to avoid cross contamination. All lubricants used in the forming operations shall be removed from the workpiece. Only tools dedicated to stainless steel shall be employed; this particularly applies to grinding wheels and wire brushes.

[B1-182-R] Welding heats up the parent metal which causes formation of oxide films both on the weld metal and on the surrounding areas of the weld. These oxides as well as slags produced by covered electrodes, flux cored wires and submerged arc welding, shall be removed.

[B1-183-R] When preparing fusion faces (bevel), oxidation, hardened material shearing cracks and general contamination from thermal cutting processes shall be eliminated by machining or grinding to a sufficient depth from the cut face.

[B1-184-R] The acceptance of joint preparation testing shall be evidenced in the control plan (MIP) or in a visual testing report.

[B1-185-R] Where cut edges do not form fusion faces, care should be taken to ensure that the shearing or thermal cutting does not adversely affect the performance of the fabrication.

It shall be reported in manufacturing description document.



**[B1-186-R]** Hard stamping is only permitted on further machined areas provided that hard stamping zone is completely removed. Indentations (permanent marking on the surface of component) used for marking in radiographic examination are not allowed.

**[I]** Welds which are to be inspected and approved should not be painted or otherwise treated until they have been accepted.

### **6.3     *Manufacturing tolerances***

#### **6.3.1       Surface geometry of welds**

**[B1-189-R]** The surface geometry of all welded joints shall meet the requirements given in EN ISO 5817 level B or EN ISO 13919 unless the drawing specifies more stringent requirements.

#### **6.3.2       Misalignment**

**[B1-191-R]** The misalignment tolerances of the base materials after welding shall meet the requirements given in table 1 part 3 of EN ISO 5817 level B or EN ISO 13919-1 unless the drawing specifies more stringent requirements.

#### **6.3.3       Local thinning**

**[B1-193-R]** Parent metal local areas of thickness below the minimum allowed thickness defined in the 2D drawings of the component are not acceptable. Non-acceptable areas according with this criterion shall be assessed through a NCR.

### **6.4     *Preparation of component and parts***

#### **6.4.1       General**

**[B1-196-R]** Material shall be cut to size and shape by any mechanical or thermal cutting process or by a combination of both.

**[B1-197-R]** Where thermal cutting is employed precautions shall be taken to ensure that the edges are not adversely influenced by hardening. Minimum distance from cutting surface to bevel surface shall be at least 5 mm.

**[I]** Shearing of plates is permitted.

**[B1-199-R]** Weld edges may be prepared by shearing provided that the provision given above is respected. However, for plates less than 10 mm in thickness, it is sufficient that cross-sections of the welding procedure test joint demonstrate that the strain hardened zone has been eliminated.

#### **6.4.2       Precaution to be taken with austenitic stainless steels and nickel base alloys**

##### **6.4.2.1   Tools**

**[B1-202-R] Cutting tools:** tungsten carbide tools shall be used.

**[B1-203-R] Brushes:** brushes shall be made from stainless steel or nylon and used only for brushing austenitic stainless steels and nickel-base alloys.

**[B1-204-R] Grinding wheels:** grinding wheels shall be in accordance with section 24.3 of ITER *Vacuum Handbook*.

#### 6.4.2.2 Abrasive blasting

**[B1-206-R]** When silica sand is used for sand blasting, the operation shall be followed by nitric hydrofluoric acid pickling (it is preferable to use zirconia or alumina sand).

**[B1-207-R]** The sand shall be free from iron. It must not have been used previously for treating cast iron, carbon steel or low-alloy steel surfaces.

**[B1-208-R]** Only high-alloy steel shot shall be used for shot blasting.

**[B1-209-R]** All dust shall be removed from blasted surfaces.

#### 6.4.3 Precaution to be taken with vacuum boundaries

##### 6.4.3.1 Use of material and fluids

**[B1-212-R]** All material, fluids, tapes, markers, grinding wheels etc. used on the component (including during welding and NDT operations) shall be in accordance with VHB for use on VQC-1A components.

**[B1-213-R]** The requirements pertaining to cutting fluids, cleaning fluids, marker pens and UT couplants shall apply to all applications where any final surface of the component is exposed or machined.

**[B1-214-R]** The requirements pertaining to the use of Liquid Dye Penetrant shall apply at all stages of manufacture.

##### 6.4.3.2 Mechanical Processes on Vacuum Surfaces

**[B1-216-R]** Abrasive techniques to clean or to attempt to improve the appearance of the surfaces of vacuum components should be kept to an absolute minimum and are preferably avoided. The use of grinding wheels, wire brushes, files, harsh abrasives, sand, shot or dry bead blasting, polishing pastes are prohibited without prior acceptance by the IO. Grinding wheels and brushes used for the final surfaces, shall be described in a document accepted by IO before use.

**[I]** Accepted techniques for manufacturing are:

- slurry blasting with alumina or glass beads in a water jet;
- gentle hand use of a dry fine stone or a fine stone lubricated with isopropyl alcohol or ethanol;
- hand polishing using fine mesh alumina in an isopropyl alcohol or ethanol carrier on a lint free cloth;
- hand polishing with suitable pad.

**[B1-218-R]** If any such surface finish technique is employed, care must be taken that any powder or other residues are removed by washing in hot water.

#### 6.4.3.3 *Fluids not on the Accepted List*

**[B1-220-R]** Fluids which are not on the accepted list of Appendix 4 of the ITER *Vacuum Handbook* may be proposed for use. If the vacuum related properties of the fluid are not sufficiently well documented for an *assessment* to be carried out by IO, a programme of measurement of the relevant properties shall be agreed between the proposer and the designated ITER Vacuum RO.

Details of fluids to be considered for acceptance shall be submitted to the ITER Vacuum RO using the Fluid Acceptance Request Form.

The proposer shall follow a qualification procedure agreed in advance with the ITER Vacuum RO which containing a plan detailing the type and method of testing to qualify the material for use. The procedure for the qualification of new Liquid Dye Penetrant Product(s) is detailed in Section 10.4.2.

The Fluid Acceptance Request Form along with the test data, report and supporting documentation, including any manufacturer's data (Certificates of Conformity, etc.) and test pieces, shall be submitted by the DA to IO for approval.

**[I]** Fluids qualified in this way may be added to the *accepted* list. The *accepted* list and a template Fluid Acceptance Form is to be found in Appendix 4 of the ITER *Vacuum Handbook*.

## 7 REQUIREMENTS ON WELDING QUALIFICATION PROCEDURES AND DOCUMENTATION

### 7.1 *Preliminary Welding data package (pWDP)*

**[B1-379-R]** During the preparation of the documentation before production starts, the Manufacturer shall present a preliminary version of this welding data package before welding qualification activity for IO acceptance. The preliminary welding data package (pWDP) gathers together all the essential elements below, preliminarily defining the welding operations for components:

- Welding Map (general drawing(s) identifying position and providing details on typology of all welds);
- A preliminary WIP of all joints including preliminary Welding Procedure Specifications (pWPS);
- Plan of welding procedure qualification tests;
- Certificates from welding consumables planned to be used in the welding qualifications;
- Prediction of ferrite content for welds involving XM19
- Preliminary NDT protocols
- NDT qualification plan (for UT and RT, if applicable);

Note:

The NDT Qualification Plan for UT is the Preliminary UT procedure with the included reference blocks and the demonstration blocks;

- Welders/operators qualifications and/or a plan of welder qualifications tests;
- List NDT personnel qualifications and plan of qualifications tests, if any;
- Procedure of dimensional stabilization treatment and template of record
- A list of Production Test Coupons defined for the series production according to section 11.

**[B1-390-R]** Before to start the qualification, it is required that the Manufacturer assesses the weldability of materials in the pWDP showing:

- the use of appropriate filler metal in accordance with the base material (if any);
- the welding electrical parameters allowing to obtain the correct mechanical properties in the weld joints;
- the feasibility of the required NDTs depending on the weld configuration.

#### 7.1.1 **Preliminary Welding Procedure Specification (pWPS)**

**[B1-395-R]** For each test piece to be qualified, the Manufacturer presents a pWPS for qualification tests.

**[B1-396-R]** The pWPS shall be prepared in accordance with EN ISO 15609 –n.

**[I]** Using pWPS for any other operation than for qualification test is strictly prohibited. pWPSs will be qualified by suitable welding procedure qualification tests.

### 7.1.2 Welding Inspection Plan (WIP)

[I] The Welding Inspection Plan (WIP) is a document to be accepted by IO before starting the welding activities.

[I] The format of the Welding and Inspection Plan will be left to the DA's discretion, but must contain all the necessary information in order that the correct controls are exercised.

[B1-401-R] A Welding and Inspection Plan of all the welded joints shall include at least:

- The weld identification;
- Reference to bevel geometries according to typology defined in the weld map;
- Reference to corresponding Weld Map and/or drawing where the weld is referred;
- The applicable WPS;
- The corresponding WPQR;
- The type and extend of non-destructive examinations to be performed;

### 7.2 Welding Procedure Qualification (WPQ)

[I] The WPQ is intended to provide proof of weldability of two parts with a particular process, using the parameters stated in the pWPS.

[B1-411-R] The welded joint to which the welding procedure will relate in production shall be represented by making a standardized test piece or pieces, as specified in EN ISO 15614-1 [8] or other relevant part.

[B1-412-R] Where the production/joint geometry do not represent the standardized test pieces as shown in EN ISO 15614-n, the use of EN ISO 15613 [22] shall be required.

[B1-413-R] The WPQ shall be achieved by performing approval tests in accordance with relevant part of EN ISO 15614 or with EN ISO 15613.

[B1-414-R] The WPQR is a record of the parameters used during the WPQ. The relevant items listed for the WPS in the relevant part of EN ISO 15609 shall be included, together with the details of any testing results required in the relevant part of EN ISO 15614.

[I] Details of the execution of this WPQ are given in paragraph 8.4.

### 7.3 Welding Data Package (WDP)

[B1-417-R] The Welding Data Package shall include at least the following documents:

- An updated Welding Map;
- An updated WIP of all weld joints;
- Plan of weld identification/markings during the welding operations (Welding Map);
- Set of WPQRs resulting from the welding procedure qualifications;
- Set of WPSs covered by accepted WPQRs;
- Demonstration Report from NDT qualifications (it is the report of the NDT qualification, if it is needed to demonstrate the NDT results for the complex non-standard geometry, etc.);
- NDT procedures (including UT scan plan and RT inspection plan for each weld);
- Set of welders / Operators qualification certificates up to date;
- Procedure of dimensional stabilisation treatment and record template;

- List of NDT personnel qualifications and plan of qualifications tests, if any;
- A list of Production Test Coupons defined for the series production according to section 11.

**[B1-429-R]** This document requires IO's acceptance prior the starting of any welding activity.

### **7.3.1 Welding Procedure Specification (WPS)**

**[I]** A Welding Procedure Specification (WPS) is a document, which gives the welder or operator specific instructions on how to complete a welded joint.

**[B1-432-R]** A WPS shall contain information according to the standard EN ISO 15607 and the relevant part of EN ISO 15609.

**[B1-433-R]** WPSs to be used in production shall be qualified by reference to an appropriate WPQR.

**[B1-434-R]** A set of WPSs related to repairs shall be qualified before production welds start to be executed. This set shall cover all applicable types of geometries and shall simulate repairs on half of thickness.

## **7.4 Welding Procedure Qualification Tests**

**[B1-436-R]** Preliminary Welding Procedure Specifications (pWPS) shall be qualified by welding procedure tests according to the relevant part of EN ISO 15614 and additional requirements defined in section 7.4.4.1.

### **7.4.1 Test Specimen**

**[B1-438-R]** The dimensions of the test pieces shall be determined in accordance with:

- The welding process;
- The cut-out scheme of the test samples to be cut from the test specimens for tests and retests;
- The NDT to be performed;
- If necessary, the qualification of the repairs;
- If necessary, the simulation of heat treatment;
- As much as possible, the representativeness of the production configuration (cooling conditions, clamping....);
- Parts 6.2 and 6.3 of EN ISO 15614-1.
- 

### **7.4.2 Welding Position**

**[B1-447-R]** It is required then that the WPQ is to be completed in the most difficult position.

**[B1-448-R]** Welds produced in downward (PG) position must be covered by a WPQ in PG position.

### 7.4.3 Executing of qualification

**[B1-450-R]** Preparation and welding of the test specimens shall be carried out in accordance with the pWPS and under the general conditions of welding in production which they shall represent. If tack welds are to be fused into the production joint they shall also be included in the test piece.

**[I]** The qualification of the WPS provides proof that the defined welding process, will achieve a weld of acceptable quality.

**[B1-452-R]** The welding and testing of the test piece must be witnessed by an ITER recognised Independent Inspection Authority (IIA) or a representative accepted by IO as required in Attachment 1 of the ITER *Vacuum Handbook*. If accepted by the IIA, accredited laboratories may perform destructive and non-destructive tests for WPQ without the presence of an inspector.

**[B1-453-R]** The IIA used for the approval of WPQR shall belong to the following list:

1) The company has an ASME stamp (U, N)

In this case the company can qualify the WPQR by its own quality assurance system.

2) The company doesn't have an ASME stamp. In this case the third party used for the qualification of WPQR shall be PED Notified Bodies or recognized third parties belonging to the following list:

<http://ec.europa.eu/growth/tools-databases/nando/index.cfm?fuseaction=notifiedbody.main>

and have the following procedures covered by the accreditation for pressurized equipment:

- Approval of permanent joining personnel

- Approval of permanent joining procedures

3) A third possibility would be that the proposed third party provide evidences of their certification and experience in the field of the approval of WPQR.

**[I]** For clarification of this third option, DA and their Suppliers shall prove that the IIA company:

- has experience to perform qualification of welding and welders in accordance with EN standards (some example in the two last years on the welding process qualified);
- Give references for their laboratory (or Supplier laboratory) for the destructive tests (reference to ISO 17025 or equivalent national standard);
- Witness the qualification with trained inspector (certification and training process of the inspector to be provided);
- Provide the templates of the qualification reports in English version;
- Based on these evidences IO can agree for using a third party which is not in the two above mentioned lists.

#### 7.4.4 Examination and Testing

##### 7.4.4.1 General

**[B1-469-R]** Examination and testing shall be made in accordance with the relevant part EN ISO 15614-1 or EN ISO 15614-11.

**[I]** In addition to the requirements of EN ISO 15614-1 the following tests shall be executed:

- **[B1-471-R]** a micro examination shall be performed in accordance with EN ISO 17639;
- **[B1-472-R]** Determination of the ferrite delta content. Ferrite content allowed in the weld metal of the stainless steel components is 5 - 12 %, preferably less than 10%.

**[I]** In case of autogenous welding (i.e. no use of filler metal), the ferrite content requirement is not applied.

##### 7.4.4.2 Microscopic examination

**[B1-475-R]** The evaluation of the microscopic structure shall be done according to EN ISO 17639:

- No cracks are allowed in the welds detected by microscopic examination (magnitude x200).

##### 7.4.4.3 Ferrite content

**[B1-478-R]** The determination of the ferrite content on weld shall be performed with ferrite scope according to EN ISO 8249. Sampling shall be done according EN ISO 17655.

##### 7.4.4.4 Impact test

**[B1-480-R]** For weld thickness  $\geq 12\text{mm}$ , impact tests are mandatory according to EN 15614-1 [8](#).

**[I]** As stainless steel base material has no specific value the requirement below shall be applied.

**[B1-482-R]** The next requirements of the impact test shall be applied for stainless steels:

- Standard EN 13445 provides the rules for definition of the materials requirements;
- Standard EN 13445-2 Table B.1-1 requires an impact energy  $Q > 40\text{J}$  at  $20^\circ\text{C}$  for the stainless steels belonging to the group 8 (in accordance with [6]).

This value of the impact energy  $Q = 40\text{J}$  will be applied for all the stainless steels as criteria for the impact test to be performed in course of the WPQR activities.

#### 7.4.5 Range of Qualification for vacuum boundaries

**[I]** Relevant part EN ISO 15614 applies with the following additional provisions.

##### 7.4.5.1 Accepted welding processes

**[I]** A qualified joint between two pieces made of a material does not qualify a dissimilar joint (like 316 L(N)-IG and XM-19 as example) and vice versa.



**Table 7.4-1 Common Welding Processes**

<b>Name</b>	<b>N (a)</b>	<b>AWS (b)</b>
Shielded Metal Arc Welding	111	SMAW
Submerged Metal Arc Welding	121	SAW
Gas Metal Arc Welding	131 135	GMAW
Flux Cored Arc Welding	132 136	FCAW
Manual Gas Tungsten Arc Welding	141	GTAW
Automatic, or mechanized Gas Tungsten Arc Welding	142	
Electron Beam Welding	51 511	EBW
Laser Beam Welding	52 521 522 523	LBW
(a) N is the reference number as specified in ISO 4063 (in the European Union published as EN ISO 4063).		
(b) AWS are the reference codes of the American Welding Society, which are commonly used in North America.		

**[B1-489-R]** Implementation of welding processes not listed in Table 7.4-1 shall be subjected to the prior acceptance by IO.

**[B1-797-R]** Autogenous, high-power density joining processes such as electron beam (EB) and laser welding is forbidden for the joining of XM19

#### 7.4.5.2 Range of Approval / Base Materials

**[B1-491-R]** Qualification on production metal type and grade is mandatory. For different grades of stainless steel (304, 304L, 316, 316L and 316LN-IG) cross qualification can be accepted for manual welds when 316L filler is used.

**[B1-492-R]** For *automatic welds*, the IO requires a proof sample to be welded for each material to be cross-qualified.

This proof sample would be produced without witnessing of an Independent Inspection Authority (IIA). All requirements concerning the proof sample shall be the same as those required for the welding qualification sample, except that only radiographic and macrographic examination shall be performed on it.

The acceptance of the proof sample extends the WPS qualification for the given type or grade of materials. The limits given by the standard EN 15614-1 or EN 15614-11 have to be respected.

**[B1-493-R]** Transition welds joining dissimilar materials other than 304, 304L, 316, 316L and 316L(N)-IG must have specific qualification tests performed.

**[I]** Qualifying a joint between different sub-groups (dissimilar weld) doesn't qualify welds between materials of the same subgroup individually, and vice versa (e.g. qualified joint 8.1/8.3 doesn't cover 8.1/8.1).

**[I]** It is recommended to perform trials in case of change of heat number for the automatic autogeneous welding process, particularly for the orbital GTAW welding of thin tube.

#### 7.4.5.3 *Range of Approval / Welding Consumables*

**[I]** Qualification using filler does not qualify autogenous welds (fusion welding without filler material) or vice versa.

#### 7.4.5.4 *Range of Approval / Type of joint*

**[I]** The following requirements, replacing the quoted sections of EN ISO 15614-1, shall be considered for the vacuum boundary welds.

**[I]** The requirements from EN ISO 15614-1 section 8.4.3 lines a), b) and c) are replaced by as follows:

**[B1-501-R]** a) Butt welds don't qualify fillet welds;

**[B1-502-R]** b) "Butt joints in pipe also qualify branch connections with an angle  $\geq 60^\circ$ " - doesn't apply;

**[B1-503-R]** c) T-joints butt welded don't qualify fillet welds.

**[B1-504-R]** The requirements from EN ISO 15614-1 section 8.3.2.3 are changed as follows:

- The weld qualification of the plates does not cover the welding of the pipes.

#### 7.4.6 **Welding Procedure Qualification Record (WPQR)**

**[B1-507-R]** The results of the weld qualification shall be included in a WPQR according to Annex A of EN 15614-1 and EN 15614-11 which shall:

- Describe the essential variables (both specified and actual) governing the execution of weld on the test piece(s);
- All electrical parameters and travel speed shall be provided;
- Describe the non-destructive examinations performed and the results obtained;
- Describe the destructive tests carried out, together with the required values and the results obtained;
- Attach material certificates of the base metal and filler metal.

**[B1-513-R]** The report must contain the decision of the IIA in charge of the qualification.

### 7.5 **Welder and Welding Operator Qualifications**

#### 7.5.1 **General**

**[B1-516-R]** The Manufacturer shall assign skilful and qualified personnel in welding operations. Welders shall be qualified according to EN ISO 9606-1 and Welding operators shall be qualified according to the EN ISO 14732.

**[B1-517-R]** The qualifications must take place prior to any fabrication work of the components in order to verify that the welders and operators have the necessary skill to properly execute welds using qualified welding procedures.

**[B1-518-R]** The Manufacturer shall establish and maintain permanently a list of qualified welders and welding operators.

### **7.5.2 Qualifications**

**[B1-520-R]** The qualifications of the welders and operators shall be certified by an ITER recognised Independent Inspection Authority.

**[B1-521-R]** The certificates shall be available before starting of the corresponding production welds.

### **7.5.3 Training on specific local conditions**

**[B1-523-R]** Welders shall be trained in the same local conditions as the production welds where local access and the orientation of the production piece are particularly difficult. A training program shall be proposed for approval of IO. Materials and welding processes particularly difficult to implement (e.g. welding of XM-19 materials with ER209) shall be considered as well for the training program.

**[B1-524-R]** For this training the same welding process and filler material shall be used as per production welds. NDT inspections (volumetric and surface) shall be performed on the samples produced by the Welders in the frame of this training in order to check the quality level of weld imperfections are within the applicable criteria. In case the NDT results are not fully acceptable, the welder is not allowed to perform the work using the concerned WPS and should repeat the training.

**[I]** IO may request the update of the welding program during the execution of the contract based on the cause analysis of NCR.

## 8 PRODUCTION WELDS

### 8.1 General

**[B1-528-R]** Welding of the components parts shall only be undertaken if the following conditions are satisfied:

- a. base and filler materials certification were reviewed upon receipt;
- b. a Welding Procedure Specification is held by the manufacturer;
- c. Welding Procedure Specifications to be used in production shall be qualified by reference to an appropriate WPQR;
- d. The welders and welding operators are qualified for the work allocated to them and their approval is valid;
- e. Welding equipment is maintained and involved measuring devices are dully calibrated/verified; This requirement shall be inserted in the Manufacturer's QP or in the dedicated protocol.
- f. Demonstration that the proposed weld is inspectable as defined in the Welding Data Package.

**[I]** All documentation listed above shall be approved by IO.

### 8.2 Joints identification and traceability

**[B1-536-R]** All the permanent joints shall be identified with a unique number (consistent with WIP and the welding map) that shall be traceable back to the WPS, welder/operator, base and filler materials, NDT reports and NCRs.

### 8.3 Joint Preparation and Examination

**[B1-538-R]** The surfaces to be welded shall be cleaned to ensure removal of oxide, scale, oil grease or other foreign substance and shall be free of defects such as inclusions, cracks and laminations to avoid any detrimental effect on weld quality. If any indication is visually detected the manufacturer shall perform liquid penetrant test of weld surfaces according to the EN ISO 3452-1.

**[B1-539-R]** During the whole welding operation, the edges to be welded shall be held so that the alignment tolerances are satisfied.

### 8.4 Fused Tack Welding and permanent attachment

**[B1-541-R]** The procedure of welding of tack welds fused in the weld bead implemented on the final surface of the component shall be qualified in accordance with the standard with relevant part of ISO-15614-n and welder of such tack welds shall also be qualified accordingly.

**[B1-542-R]** If any, permanent Attachments shall be welded to the component structure by qualified welders using a qualified procedure.

### 8.5 Temporary Attachments and stiffeners

**[I]** The procedure of welding of temporary attachments and stiffener shall be performed according to the following requirements:

- **[B1-545-R]** Welding shall be performed according to a WPS approved by the Manufacturer (not part of WDP and not submitted to acceptance by an IIA);
- **[B1-546-R]** WPS used for welding temporary attachment shall be provided for information to IO prior to the execution of the weld;

- **[B1-547-R]** Manufacturer shall take all precautions so that the tack welding does not generate metallurgical or homogeneity defects;
- **[B1-548-R]** The welder shall be qualified as per EN ISO 9606-1;
- **[B1-549-R]** The material and consumables shall be so that they do not affect the properties of the metal of the part to which they are welded;
- **[B1-550-R]** Temporary attachments and stiffener shall be removed using a technique which does not affect the properties of the metal of the component to which they are welded;
- **[B1-551-R]** After removal the corresponding area shall be inspected by VT and PT:
  - The area of the removed tack weld shall be free of surface cracks;
  - No defect other than the ones allowed by the applicable material specification shall be detected.
- **[B1-554-R]** If a defect is found after removal of the tack weld, then repairing shall be carried out in accordance with section 10.8.

## **8.6 Execution of welds**

**[B1-556-R]** The welder or welding operator shall have available applicable WPSs and detailed work instructions based on the approved WPSs and defining all the essential variables under direct control by the welder.

**[B1-557-R]** Arc strikes on parts outside the weld preparation shall be avoided. Where arc strikes occurs accidentally the affected area shall be repaired in accordance of standard 13445-4 point 11.1.

**[B1-558-R]** For this purpose, the equipment (cables, earth clamps, etc.) shall be kept in good condition. The arc welder shall strike the arc in the groove and not on the adjacent surface.

**[B1-559-R]** In TIG welding, it is forbidden to strike the arc on copper plates. TIG welding equipment shall preferably be equipped with remote striking devices (high frequency, etc.).

**[B1-560-R]** If traces of arc strikes are detected, these shall be removed and their location shall be carefully examined by liquid penetrant examination method to ensure that no cracking has occurred.

**[I]** For the welding, care shall be taken to avoid direct contact between copper and parts to be welded: earth clamps, electric cable lugs, etc.

**[B1-562-R]** During welding operations, the welds shall be subjected to visual in-process inspection for the fit-up and the soundness of the weld passes.

## **8.7 Marking**

### **8.7.1 General requirements**

**[B1-565-R]** A record shall be maintained of which welder or welding operator has carried out each weld. This may be done by marking each weld with a welder identification mark or alternatively by means of records which assure traceability of the welder to his work throughout the construction of the component.

**[B1-566-R]** The methods used for marking shall not result in contamination of the material, significant strain hardening, or sharp discontinuities.

### **8.7.2 Marking Methods**

**[B1-568-R]** The marking procedure shall be submitted to the IO for approval. It shall contain all the used marking techniques and the ways to perform them.

All methods which meet the requirements of section 8.7.1 shall be used, taking into account the following rules:

**[B1-569-R]** 1. The use of electric arc marking pencils is forbidden;

**[B1-570-R]** 2. Stamping is permitted on materials which are more than 6 mm in thickness. Metal stamps shall be round nosed or ball type;

**[B1-571-R]** 3. Electrolytic etching shall be permitted but shall preferably be used for parts of small dimensions and thickness. When this method is used, the concentration of S, Hg, Zn and Pb in the etching solution shall not exceed 250 ppm, and the halogen content shall not exceed 250 ppm. Etching shall immediately be followed by neutralizing, rinsing, and drying;

**[B1-572-R]** 4. The Manufacturer shall draw up an etching procedure prior to any marking operation and submit to IO for approval;

**[B1-573-R]** 5. A vibrating marking tool may be used for thickness less than 6 mm; The tool shall be carbide tipped and the depth of the indentation shall be approximately 0.25 mm or less. However, since this type of marking may be erased on ferritic non-stainless steels, a different method of marking should be used;

**[B1-574-R]** 6. The laser marking is permitted on the tungsten tiles and also on the bronze and steel materials with the final thickness not less of  $t=2.0\text{mm}$ , including the pipes. The depth of laser marking shall not exceeds 0.15mm.

The temporary marking of the pipes with the wall thickness less of  $t=2.0\text{mm}$  during manufacture shall be done by the pen or stickers and shall be specified in the marking procedure.

**[B1-575-R]** 7. A temporary marking code may be painted onto individual components and the code markings tabulated for the finished item of equipment. The use of Ink stamps, indelible ink, paint and adhesive tapes for temporary marking during manufacture are to be tabulated for the finished item of equipment, with the following provisions applying to austenitic stainless steels and nickel base steels.

- a. Component parts shall only be marked in this way provided that the marking may be removed afterwards. The use of these methods shall be as restricted as possible;
- b. The inks, paints, etc., used shall not contain any contaminants and shall be approved by IO when a final surface of the component is marked;
- c. These markings shall be eliminated using a method approved in prior to any heat treatment, whenever there is a risk of surface contamination.

## **8.8 Inspection and Testing during production**

### **8.8.1 General**

**[B1-581-R]** The inspection and testing activities during fabrication, described in this section, shall be the responsibility of the DA and shall be fully implemented for all components.

**[B1-582-R]** All parts shall be inspected during and after the manufacturing process to assure the quality of the finished welds. Such inspections include NDT, joint geometry, dimensional checking, alignment, among others.

### **8.8.2 Manufacturing procedures and manufacturing drawings**

**[B1-584-R]** The DA shall ensure that all manufacturing drawings and welding related procedures (WPS, cleaning, NDT...) are available at the appropriate work area and are fully implemented during welding operations.

**[B1-585-R]** Inspection records shall document the use of the correct and appropriate procedures, and/or drawing including revision status at the time the inspection is performed.

## 9 HEAT TREATMENT

### 9.1 *Dimension Stabilization Treatment on Austenitic Stainless Steel Components*

**[B1-587-R]** In order to fulfil the tight tolerance requirements in the final stage of fabrication of the components, the DA shall ensure that the Supplier applies dimensional stabilization treatment before final machining, in the manufacturing procedure.

**[B1-588-R]** Following procedure applies:

- Before heat treatment, the part is degreased and all the products likely to modify the resistance to corrosion (products containing halogen or carbon) shall be removed to best practise;
- The atmosphere of the furnace shall be vacuum or inert gas;
- The temperature at which the part is introduced into the furnace shall in any case not exceed 120°C and, during heating, the temperature difference in the part shall not exceed 55°C;
- The treatment temperature for SS material shall be higher than 400°C and shall not exceed 425°C, with a holding time of two hours;
- The treatment temperature for structural components containing Cu shall be higher than 300°C (operation temperature) and shall not exceed 325°C , with a holding time of two hours;
- Furnace cooling should be carried out after the heat treatment and the temperature difference in the part shall not exceed 55°C;
- The treatment temperature will be performed for the steel support structure.

**[B1-595-R]** The treatment protocol has to be included in the Preliminary Welding Data Package and the treatment record shall be included in the Final Welding Documentation (Section 12 of this Appendix B1).

**[I]** The Dimensional Stabilization treatment is not considered as a heat treatment for the qualification of welds.

### 9.2 *Other types of heat treatment*

**[I]** The Manufacturer could propose other heat treatment (mainly solution annealing).

**[B1-844-R]** The use of the Post Weld Heat Treatment (PWHT) shall be performed in accordance with Section 10 of the standard EN 13445-4.

## 10 NDT

### 10.1 NDT Personnel

**[B1-598-R]** NDT personnel shall be qualified and certified in accordance with the standard EN ISO 9712: 2012 except for direct visual examination (if the inspector has a qualification in another NDT method, IO accept it as qualification for visual testing).

**[B1-845-R]** The inspection shall be performed by the NDT Inspector of a level 1 at minimum.

**[B1-846-R]** The interpretation shall be performed by the NDT Inspector of a level 2 at minimum.

**[B1-847-R]** The procedure shall be validated by the NDT Inspector of a level 3.

### 10.2 Extent

**[B1-885-R]** The minimum required examinations per type of weld, as defined in 5.2.1, shall be performed as in the table given hereinafter.

**Table 10.2-1 Type of welds and NDT extent**

Type of weld	Category	Technic	Extent
All	All	VT <sup>1</sup>	100%
I.1-I.2-I.3- III.1	1-2	RT or UT	100%
		PT after welding (all surfaces)	100%
II.1	1-2	RT or UT	100%
		PT after welding <sup>2</sup>	100%
III.2	2	RT or UT	100%
		PT after welding <sup>2</sup>	100%
I.1-I.2-I.3-II.1-III.1-III.2	3	RT or UT	10%
		PT after welding <sup>2</sup>	100%
I.1-I.2-I.3-II.1-III.1-III.2-III-3-IV-V-VI-VII	4	RT or UT	0%
		PT after welding <sup>2</sup>	100%
IV-V-VI-VII	4	RT or UT	0%
		PT during welding <sup>2</sup> : after first pass	100%
		PT after welding	100%
1- VT shall be done after the completion of manufacturing unless the weld becomes non accessible;			
2- Limited to accessible surfaces.			
<u>Note:</u>			
Types of welds are given in accordance with Section 5.2.1 of this Appendix B1.			

### 10.3 Weld surface finishing

**[B1-603-R]** The surface condition necessary for performing all NDT shall be in accordance with the NDT applicable standards given in EN ISO 17635 Appendix A. This means removing of spatters, slag, scaly oxides, grease etc. liable to interfere with the inspections and NDT.

**[B1-848-R]** The surface roughness Ra shall not exceed 6.3µm in the testing areas.



[I] One particular use of acid pastes is in the removal of weld burn. In general such burns do not affect vacuum performance and are best left alone, provided it complies with requirements defined in section 10.6.

Any scaling (i.e.: loose oxides) should be removed using the techniques described in section 6.4.3.2 (Mechanical Processes on Vacuum Surfaces). If it is desired to remove burns, then slurry blasting with alumina in water or hand burnishing with alumina powder is a satisfactory alternative. Heavy abrading, grinding or wire brushing is prohibited. Hand finishing with suitable pad or a dry stone is also acceptable.

**[B1-605-R]** For liquid penetrant testing, weld surfaces at the final or intermediate stage (root of first passes) shall be left as welded. Cleaning for the liquid penetrant testing should be made in a way that it doesn't mask the discontinuities caused by plastic deformation or clogging from the abrasive materials.

**[B1-606-R]** For radiographic testing of butt welds with penetration > 50 mm, outside and accessible inside shall be made flush with the base material using a suitable mechanical method. Inside weld surfaces are not required to be flush when the first penetration weld run has been made by TIG and when such a run does not contain irregularities liable to hinder radiographic interpretation.

#### **10.4 Applicable NDT techniques**

**[B1-608-R]** NDT methods shall be selected according to Table 3 of EN ISO17635.

The procedure shall be approved by the NDT Inspector of a level 3.

[I] For volumetric inspection, the UT could be used since it is proved that it has the same level of confidence as RT or when the RT inspection is not feasible.

**[B1-611-R]** UT shall be used if technically possible when MIG or MAG (131 or 135 according to the standard ISO 4063) welding processes are used.

**[B1-870-R]** For each requested inspection, a report shall be provided as described in the execution standard provided in table 11.5-1.

##### **10.4.1 Visual Testing**

**[B1-849-R]** The Visual Testing (VT) of the welds shall be made according to the standard: ISO 17637: *Non-destructive testing of welds - Visual testing of fusion-welded joints*.

**[B1-850-R]** The VT shall be made after a possible heat treatment and before any machining or grounding operations of the weld surfaces.

**[B1-613-R]** VT shall cover all welds over their entire length and both weld and root sides when accessible.

The areas from where the temporary attachments have been removed shall also be inspected.

**[B1-614-R]** VT by endoscopic examination shall be established on a dedicated procedure. The acceptance criteria shall be defined, as much as possible, following the EN ISO 5817 level B or the standard EN 13919-1.

**[B1-615-R]** In any case, the detected indications such as lack of fusion or penetration, and cracks shall be considered as rejected, independently of their size.

##### **10.4.2 Liquid Dye-Penetrant Testing**

**[B1-617-R]** PT shall be made after a VT.

**[B1-618-R]** All the welds over their entire length shall be tested. Testing shall also cover adjacent base metal of 15 mm of both sides from the weld. In case of full penetration welds, both weld and root surfaces shall be tested when accessible.

The areas from where the temporary attachments have been removed shall also be inspected.

**[B1-619-R]** For the qualification of new Liquid Dye Penetrant Product(s) the following procedure shall be respected:

1. Confirm that the outgassing rate of representative sample(s) is in compliant with IVH requirements for VQC1. Procedure for outgassing rate measurements as well as resulting test report shall be approved by ITER Vacuum RO;
2. Confirm that there is no risk of leak blockage due to application of Liquid Dye Penetrant. Qualification procedure for the assessment of potential leak blockage as well as resulting test report shall be approved by ITER Vacuum RO.

#### **10.4.3 Radiographic testing**

**[B1-629-R]** For RT performed according to ISO 17636-1, the IQI (Image Quality Indicator) for single wall and single image technique shall be placed on the source side.

**[B1-851-R]** The RT shall be made after the heat treatment and surface finishing.

**[B1-630-R]** All the welds over their entire length shall be tested. Testing shall also cover adjacent base metal over a distance of:

- At least 10 mm in relation to the actual groove when the thickness  $e > 30$  mm;
- At least 5 mm in relation to the actual groove when the thickness  $e \leq 30$  mm.

#### **10.4.4 Ultrasonic testing**

**[I]** For UT, the standard ISO 22825 is recommended.

**[B1-852-R]** The UT shall be made after the heat treatment and surface finishing.

**[B1-853-R]** All the welds over their entire length shall be tested.

The UT shall also cover an adjacent base metal over the distance of:

- At least 10mm in relation to the actual groove when  $e > 30$ mm;
- At least 5mm in relation to the actual groove when  $e \leq 30$ mm.

**[I]** For nonstandard NDT techniques the qualification will specify the dimensions of the artificial defects to be included in the deformation block. The acceptance criteria shall be approved and accepted by IO and DA.

### **10.5 Quality level and acceptance criteria**

**[B1-637-R]** The criteria used to assess the acceptability of the imperfections shall be as presented in Annex A of EN ISO 17635.

**[B1-639-R]** A procedure which defines the acceptance criteria based on section 10.6 shall be proposed by the Supplier and accepted by IO and DA.

**Table 10.5-1 NDT Summary Table of applicable standards for Quality Levels**

NDT technique	Execution standard	Interpretation standard	Quality Level
VT	EN ISO 17637	EN ISO 5817 / EN 13919-1	B
PT	EN ISO 3452-1	EN ISO 23277	2X
RT	EN ISO 17636-1	EN ISO 10675-1	Level 1
UT	ISO 22825	ISO 11666, if it is demonstrated that it is possible to differentiate the planar and volumetric defects. If not, specific acceptance criteria shall be agreed between DA and IO based on the demonstration block.	

**10.5.1 For Arc fusion welding process**

**[B1-643-R]** The quality level shall be level B in accordance with EN ISO 5817, with the following additional requirements:

- Spatter (602):  
Shall be removed from all pressure part, loaded attachments and cooling channels as best as possible;
- Torn surface (603), grinding mark (604) & chipping mark (605):  
Shall be ground to provide a smooth transition;
- Under flushing (606):  
Not allowed unless justification by calculation.

**10.5.2 For Electron Beam or Laser welding process**

**[B1-651-R]** The quality level shall be level B in accordance with EN ISO 13919-1, with the following additional requirements:

- **[I]** Spatter (602):  
Should be removed from all cooling channels as best as possible;

**[B1-862-R]** There are no quantitative criteria in the standard. However, the DA shall implement all reasonable measures to prevent and remove the spatters from welding during the manufacturing. In addition to a proper welding procedure, which shall minimize the production of the spatters, if not accessible for manual cleaning, an ultrasonic bath followed by a nominal water flow rate shall be applied to remove loosely bonded spatters.

During welding qualification, the maximum number of the spatters in a given area shall be reported in the welding qualification record and set up as acceptance criteria for the production welds.

- **[B1-654-R]** Torn surface (603), grinding mark (604) and chipping mark (605):  
Shall be ground to provide a smooth transition;
- **[B1-656-R]** Under flushing (606):  
Not allowed unless justification by calculation.

### 10.5.3 Vacuum boundary welds

**[B1-659-R]** For the particular situation of the vacuum boundary welds, level B EN ISO 5817 or EN 13919-1 is applicable and more stringent acceptance criteria than those defined in level B EN ISO 5817 or EN 13919-1 shall be applied as shown in the Table 10.5-2.

If achievement of acceptance criteria additional to Level B of EN 5817 specified for defects 504, 507 and 509 are not feasible, the criteria defined in Table 10.5-3 shall be applied.

**Table 10.5-2 Specific acceptance criteria for vacuum boundary welds**

Defect Type in reference to ISO 6520-1:1998		Acceptance criteria additional to EN 5817 level B	Acceptance criteria additional to EN 13919-1 level B
Solid inclusions	Slag inclusions – individual (301)	20% of t or 2 mm, whichever is smaller.	NA
	Slag inclusions – Group (3013)	Aggregate length shall not exceed t in a length of 12t, except when the distance between the successive indications exceeds 6L, where L is the longest indication in the group.	NA
	Inclusions – Tungsten or Copper (304)	Not permitted for t<5mm.	NA
Cavities	Isolated pores – round (2011, 2012)	Diameter <20%t or 2mm, whichever is smaller.	l or h ≤ 0,3t or 2mm whichever is the smaller
	Elongated pores – wormholes (2015 and 2016)	Not permitted.	Not permitted
Profile defects	Linear Porosity (2014)	Not permitted.	Not permitted
	Excess penetration – pipe (504)	Not greater than 5% of the pipe internal diameter up to 2mm max.	h≤0.2mm+0.15t or 5mm, whichever is smaller
	Excess of penetration in the corner of the finger box (504)	NA	h<0.2mm+0.3t or 5mm whichever is smaller
	Excess weld material (502)	Not greater than 10% weld width.	Not greater than 10% weld width
	Fillet leg length (asymmetry)(512)	Unequal leg length should not exceed 20% of the fillet throat thickness.	Unequal leg length should not exceed 20% of the fillet throat thickness.
	Shrinkage groove (root undercut) (5013); Incomplete filled groove(511); Root concavity (515) Sagging (509)	For t<3mm not permitted. For t>3 mm, 0.05t or 0.5mm whichever is smaller. Weld thickness shall not be less than the parent plate thickness	h≤0.05t or 0.5mm whichever is the smaller. Weld thickness shall not be less than the parent plate thickness
	Linear misalignment (507) for circumferential welds	h≤0.1t or 2 mm, whichever is smaller	h≤0.1t or 2 mm, whichever is smaller
Other	Root oxidation	Not permitted where a backing purge gas is specified in the WPS.	Not permitted where a backing purge gas is specified in the WPS.

**[I]** In cases where achievement of acceptance criteria additional to Level B of EN 5817 specified for defects 504, 507 and 509 is proven to be technically non-feasible, the Manufacturer may request a derogation provided that listed below conditions are met. Derogation can be requested only for circular welds on cooling pipes performed by manual or orbital TIG welding. Similar additional acceptance criteria specified for the Level B of EN 13919-1, are not subject to derogation.

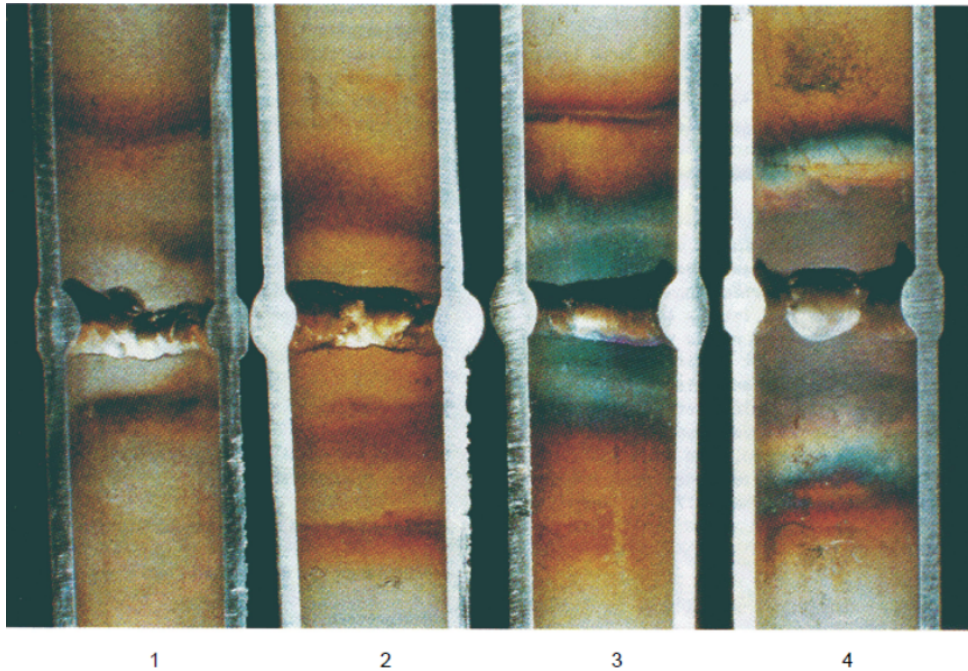
**Table 10.5-3: Conditions for derogation of acceptance criteria additional to Level B of EN 5817**

Defect Type	Conditions for derogation of acceptance criteria additional to Level B of EN 5817
<i>Excess of penetration (504):</i>	<p>Possibility of relaxation is limited to TIG manual welding.</p> <p>Such requirement specified in EN 5817 for the level B is applicable.</p> <p>The measurement of such imperfection must be duly qualified to prove their accuracy and ensure a clear applicability of the acceptance criteria ahead of request for derogation. Qualification procedure shall be accepted by IO.</p> <p>For automatic orbital welding criteria shall be as specified in the Table 10.5-2</p>
<i>Sagging ( 509):</i>	<p>Possibility of relaxation is limited to autogenous TIG welds.</p> <ul style="list-style-type: none"> <li>- For <math>t \leq 2\text{mm}</math> permitted sagging is 0.2 mm</li> <li>- For <math>t &gt; 2\text{ mm}</math> level C of EN 5817 which means 0.1t applies.</li> </ul> <p>Application of relaxed requirement is limited to maximum of 20% of the total weld length per weld.</p> <p>A structural analyses shall prove that this defect is not detrimental for the structural integrity.</p> <p>The measurement of such imperfection shall be duly qualified to prove their accuracy and ensure a clear applicability of the acceptance criteria ahead of request for derogation. Qualification procedure shall be accepted by IO.</p> <p>For TIG welding with filler, criteria shall be as specified in the Table 10.5-2</p>
<i>Misalignment (507):</i>	<p>Possibility of relaxation is limited to the automatic orbital welding.</p> <p>The Manufacturer shall prove the limits of gap and misalignment before welding by a demonstration.</p> <p>Upon successful validation based on a program to be accepted by IO, the proposed tolerance values of the gap and misalignments :</p> <ul style="list-style-type: none"> <li>- become the acceptance criteria of visual inspection before welding;</li> <li>- shall be indicated in the WPS for production joints.</li> </ul> <p>For visual inspection after welding and for manual welding, keep the limit of EN 5817 level B (0.5t).</p>

## 10.6 Oxidation on welds

**[B1-665-R]** Oxidation of welds should be minimized and shall comply with the criteria described here: to evaluate oxidation of welds and adjacent areas on austenitic Cr-Ni steels, the following acceptance criteria based on DIN 25410:2012 is recommended to be proposed in VT and endoscopic examination procedure issued by the Manufacturer and accepted by the DA and IO.

**[I]** The temper colours and shades range as follows: yellow, brown, violet, dark blue, medium blue, light blue, light gray, and gray. In general, test colours from classes 1 to 3 of the standard DIN 25410:2012 (shown below) are permitted. The following criterion is recommended to be considered when accepting and rejecting oxidized welds and adjacent areas on austenitic Cr-Ni stainless steels.



<b>[B1-668-R]</b>	Class 1 = acceptable	(yellow)
	Class 2 = acceptable	(brown)
	Class 3 = acceptable	(violet, dark blue, medium blue)
	Class 4 = not acceptable	(light blue, light grey, grey)

### 10.6.1 Stage of performance

**[B1-673-R]** The NDT shall be carried out after welding and heat treatments or dimension stabilization treatments but before the pressure test.

**[I]** Where welds become inaccessible during manufacture, final NDT is performed before the closure of the concerned area.

**[B1-675-R]** All parts shall be inspected during and after the manufacturing process to assure the quality of the finished welds. Such inspections include the check of joint geometry, dimensional checking, alignment, etc.

**[B1-676-R]** The PT inspection shall be done at the latest possible stage of manufacture. If a machining of the surface is performed, the control shall be done after the final machining.

Welds that are ground flushed (or if the base material less than 1mm is removed) must be controlled on the as-welded ground flush surface.

If there is a reduction of the base material thickness more than 1mm by machining, the PT is mandatory on the final surface.

### **10.7 Cleaning after NDT**

**[B1-679-R]** After NDT such as PT or UT, cleaning must be performed in accordance with procedures qualified and subsequently accepted by the ITER Vacuum RO.

### **10.8 Repair**

**[B1-681-R]** In the case of need of repair for surface defects of parent material or weld defects, repairing procedure shall follow the following provisions established in 10.8.1, 10.8.2 and 10.8.3.

#### **10.8.1 Repairs on Base material**

**[B1-683-R]** The surface defects, such as accidental arc strikes, tool marks, cutting marks, may be removed by grinding, and the ground area shall have a smooth transition with the adjoining surfaces.

The grinding shall be followed by visual inspection of the surface defects, also assessed according with section 6.3.3.

Ground accidental arc strikes on parental materials shall be tested by PT as per IO's accepted procedure.

#### **10.8.2 Repairs on welds**

**[B1-685-R]** All welded repairs shall be subject to the same NDT requirements as original welded joints. This includes the same acceptance criteria. Such repairs shall be carried out using approved weld procedures and qualified welders and welding operators.

**[B1-686-R]** In case a defect is found, the extension of testing on similar weld type shall be doubled with respect to the percentage lower than 100% defined in Table 10.2-1. In case a defect is found in the additional extension of inspection, all welds of the same type shall be inspected at 100% in the same component.

**[I]** Repairs on weld caps, removing a superficial indication, by surface dressing are permissible provided that the area of repair is subject to NDT and free from unacceptable imperfections, considering the section 6.3.3.

**[B1-688-R]** The extent of testing of repairs shall cover 100 % of the area repaired plus 10mm of the adjacent parent material.

### 10.8.3 Repair procedure

**[B1-690-R]** If an unacceptable defect is detected in the course of non-destructive examination of a welded joint, a repair shall be carried according the present clause:

- Excavation by grinding or process accepted by IO;
- Examination after excavation:
  - *Method*: PT examination.
  - *Extent of examination*: The entire surface of the cavity.
  - *Acceptance criteria*: indication completely removed.

**[B1-696-R]** After repair, the used NDT method and the applicable criteria are the same as those required for the original joint concerned.

**[B1-697-R]** WPS(s) of the repair shall be qualified in accordance with EN ISO 15614-1 and accepted by IO. The WPS shall be based on a WPQR implemented for the component.

**[B1-698-R]** The DA shall notify the repair activity to the IO. Maximum of two (2) repair welding operations shall be performed at the same location. If more than two (2) repair welding operations need to perform, then a NCR shall be issued.

### 10.9 Non conformity process

**[B1-700-R]** The treatment of non conformity shall be described in a dedicated procedure. The judgement of the need of the issue of NCR shall be based on the statement below about the different type of defect and their impact on manufacturing.

**[I]** Definition of Major / Minor defect:

- Major welding defect:
  - Cracks (excluding craters cracks)
  - Defects located on inaccessible part of root pass
  - Repair longer (size) than one fifth of the length
  - Repair deeper than half of thickness
  - Defects found after the Dimension Stabilization *Heat Treatment Procedure*
  - Repair of welds in the same location more than twice
  - Repair welding process different from the one used for the initial weld (laser welding repaired by TIG)
  - Same defects apply too regularly on the same WPS
- Minor welding defect
  - Defects not listed in list of major welding defects

**[B1-713-R]** The procedure shall be accepted by IO.



## 11 PRODUCTION TEST COUPONS

### 11.1.1 General

**[B1-716-R]** To monitor the consistency of weld mechanical properties during the series production, Production Test coupon(s) shall be welded and tested.

### 11.1.2 Reference criteria

**[B1-718-R]** A maximum of two WPS shall be selected by IO for Production Test Coupon.

**[I]** The selection criteria can be as follow:

- criticality of the weld for the design,
- elevated heat input,
- special welding process,
- membrane stress assessment.

**[B1-720-R]** The selection shall be based on the supplier's Manufacturing Design and qualified WPSs. The selection shall be performed as soon as these inputs are available with the relevant level of approval.

**[B1-799-R]** The selected WPSs shall be officially notified to the DA by communication of a document reviewed by IO.

**[I]** The selection will be re-assessed in case of change of supplier's Manufacturing Design and/or if new/updated WPSs are qualified after approval of the WDP.

### 11.1.3 Numbers of Production Test Coupon

**[B1-723-R]** One Production Test Coupon per component and per supplier and per selected WPS shall be welded.

**[B1-724-R]** The Production Test Coupon (s) shall be produced as per the selected WPS, using the same equipment and the same welder. The coupons' dimensions shall be sufficient to cut all required test specimens with provision for re-tests.

**[B1-725-R]** The welding operations shall be notified 30 working days in advance so that an ITER representative can witness Production Test Coupon welding.

### 11.1.4 Manufacturing of Production Test Coupon

**[B1-727-R]** Production test coupon(s) shall, wherever practicable, be attached to the component test plate on one end of the weld so that the edges to be welded in the test plate are a continuation and duplication of the corresponding edges of the welds.

When the Production Test Coupon cannot be attached to the component, then the welding of the Production Test Coupon could be done separately

The weld metal should be deposited in the test plates continuously with the welding of the corresponding weld so that the welding process, procedure and technique are the same.

**[B1-728-R]** Test specimens shall be cut from the Production Test Coupon and tested in accordance with section 11.5 of appendix B1. Production test coupon shall have the necessary dimensions that allows the cutting of the defined test specimens. Testing should be performed by an accredited laboratory. Otherwise an alternative laboratory shall be proposed for acceptance of IO.

**[B1-729-R]** It is required to test the Production Test Coupons systematically. Retesting is allowed as per section 11.6.1.7. The welds on the concerned component performed under a failing WPS shall be considered as non-compliant.

### 11.1.5 Extent of testing

**[B1-731-R]** The type and number of Production Test Coupon(s) after the final heat treatment or dimension stabilization treatment shall be in accordance with Table 11.5-1 for the particular material and thickness applicable. For other group of material, the same destructive tests as for the WPQ should be performed.

**[B1-732-R]** The Production Test Coupon shall be of sufficient size to allow the preparation of the required specimens, including the test specimens for retests.

**[B1-733-R]** Prior to cutting the test pieces, the Production Test Coupon shall be submitted to the same NDT as the corresponding production welds in order to ensure that the test specimens are taken from the needed areas.

**Table 11.1-1 Testing of Production Test Coupon**

Material group	Thickness of test plates (t mm)	Test specimens (see Table 11.1-2)
8.1 e.g. 316L and 316L(N)-IG	t ≤ 12 mm	1 FB, 1 RB, 1 TT, 1 Ma
	t > 12 mm	3 IW, 1 TT, 1 Ma
8.2, 8.3 e.g. XM-19	t ≤ 12 mm	1 FB, 1 RB, 1 TT, 1 Mi
	t > 12 mm	3 IW, 1 TT, 1 Mi

**Table 11.1-2 Test specimens & standards**

Designation	Abbreviation
Face bend test to EN ISO 5173:2010+A1:2011	FB
Root bend test to EN ISO 5173:2010+A1:2011	RB
Transverse tensile test to EN ISO 4136:2012	TT
Longitudinal weld tensile test to EN ISO 5178:2011	LT
Impact test; weld deposit to EN ISO 9016:2012	IW
Impact test, HAZ to EN ISO 9016:2012	IH
Macro examination to EN ISO 17639:2013	Ma
Micro examination to EN ISO 17639:2013	Mi
Hardness test to EN ISO 9015-1:2011	HT

### 11.1.6 Performance of tests and acceptance criteria

#### 11.1.6.1 General

**[B1-741-R]** The individual test pieces shall be manufactured, tested and shall meet the acceptance criteria defined.

#### 11.1.6.2 Bend test

**[B1-743-R]** During testing, the test specimens shall not reveal any one single flaw > 3 mm in any direction.

Flaws appearing at the corners of a test specimen during testing shall be ignored in the evaluation.

#### 11.1.6.3 Transverse tensile test

**[B1-745-R]** The tensile strength of the test specimen shall not be less than the corresponding specified minimum value for the parent metal.

**[B1-746-R]** For dissimilar parent metal joints the tensile strength shall not be less than the minimum value specified for the parent metal having the lowest tensile strength.

#### 11.1.6.4 Impact test

**[B1-748-R]** Same requirements as for the WPQ, given in Section 7.4.4.4, have to be followed.

#### 11.1.6.5 Macrography

**[I]** A welding procedure is qualified, if the imperfections in the test piece are within the specified limits of quality level B in EN ISO 5817, except for imperfection types as follows, for which the level C shall be applied:

- excess weld metal,
- excess convexity,
- excess throat thickness and excessive penetration.

**[I]** For the EBW and LBW, the standard EN 13919-1 has to be followed.

**[B1-752-R]** Production Test Coupons should be sectioned and macro examined in four places (including one stop/start area).

**[B1-753-R]** Photographs of the macros giving the date the Production Test Coupon was welded, the welder's identity and identifying the production welds it is covering must be included in the final welding documentation.

#### 11.1.6.6 Micrography

**[B1-755-R]** No crack is allowed, as per criteria applicable in section 7.4.4.2.

#### 11.1.6.7 Retests

**[B1-757-R]** Where individual tests do not conform to the requirements specified in this appendix then the root causes shall be investigated through an NCR. Where the unsatisfactory test result is due to poor testing technique or to a locally limited imperfection the following retests shall be made:

- a. tensile test: the test shall be repeated on two tensile test specimens (with the three (3) test specimens in each set, according to standards defined in Table 11.1-2 Test specimens & standards) taken from the same test plate, all results shall meet the requirements;

- b. bend test: the test shall be repeated on two bend test specimens (according to standards defined in Table 11.1-2 Test specimens & standards) taken from the same test plate; both results shall meet the requirements;
- c. impact test: the test shall be repeated on three Charpy-V-notch specimens (according to standards defined in Table 11.1-2 Test specimens & standards) taken from the same test plate.

Notes for the Impact test:

1. the mean value obtained from all six (6) individual impact test specimens (3 test specimens in the original test and 3 test specimens in the re-test) shall be equal to or greater than the specified minimum value;
2. not more than two (2) of the six (6) individual values of absorbed energy shall be less than the specified minimum value;
3. not more than one (1) of the six (6) individual values of absorbed energy shall be less than 70 % of the specified minimum value.

**[I]** Should any of the retests fail to comply with the requirements, then the welded joints represented by the Production Test Coupon are considered not compliant with this Appendix B1.

*11.1.6.8 Report*

**[B1-766-R]** A test report shall be provided including for each coupon:

- A summary sheet listing all tests, indication of success or failure and comments;
- All reports of tests performed on the coupon.

## 12 FINAL WELDING DOCUMENTATION

**[B1-770-R]** Detailed welding data package, shall include at least following:

- List of applicable documentation (with version) included in Final Welding Documentation (structure to be agreed);
- As-built Welding map;
- Summary welding table (the format is to be proposed by the IO INC Welding Engineer and agreed with the DA, see example below);
- Final Welding and Inspection Plan of all joints;
- NDT and other control reports;
- Actual List of Welders & Operators (version applicable during the manufacture);
- Actual List of inspectors;
- The record of cumulated dimensional heat treatment;
- Reports of Production Test Coupons;
- NCRs related to each component and Deviation Request, if any.

**[I]** Other documentation specifically applicable not included in the WDP

This document will be reviewed by IO before each delivery.

## Example of Summary Welding Table

WELD JOINT #	MATERIAL DESIGNATION	THICKNESS	PARTS #	WELDING PROCESS	WPQR	NDT EXTENSION		WELDING DATE	WELDER STAMP	BASE MATERIAL REFERENCE	FILLER MATERIAL REF.	MIP/PCP #	VT DATE	VT REPORT #	PT DATE	PT REPORT #	UT DATE	UT REPORT #	RT DATE	RT REPORT #	LT DATE	LT REPORT #

**[I]** Any repairs shall be clearly stated and identified as the new weld repairs (e.g. with “R”) in the Summary Welding Table.