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COMPARISON OF EN & ASME WELDING AND ITS ALLIED PROCESSES STANDARDS

EN & ASME STANDARDIEN VERTAILU HITSAUKSESSA JA SIIHEN LIITTYVISSÄ PROSESSEISSA

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ABSTRACT

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This thesis is made in cooperation with Wärtsilä and Sandvik. The main purpose of the thesis is to clarify the best suitable American standards for European standards used in Wärtsilä's investigation checklist and to make wide and easily readable tables for Wärtsilä and their subcontractors. One of the most important issues is to make clear if the compared American standards are demanding enough for Wärtsilä's needs. The research is done by comparing EN standards mentioned in Wärtsilä's investigation checklist to corresponding ASME, AWS, ASNT and ASTM standards.

The research shows that there is visible lack of requirements in American standards compared to European ones. Some areas of American standards are more demanding than European standards but in larger scale EN standards are much wider and more demanding than American standards. Because of these reasons, usage of European standards should be recommended for Wärtsilä's subcontractors to ensure the quality and reliability of production.

TIIVISTELMÄ

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EN & ASME standardien vertailu hitsauksessa ja siihen liittyvissä prosesseissa

Kandidaatintyö

2016

35 sivua, 2 kuvaa ja 18 taulukkoa ja 10 liitettä

Tarkastajat: Professori Jukka Martikainen
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Hakusanat: standardi, ASME, AWS, ASNT, ASTM, EN, ISO, hitsaus

Tämä työ on tehty yhteistyössä Wärtsilän ja Sandvikin kanssa. Tutkimuksen tavoitteena on selvittää eurooppalaisia standardeja parhaiten vastaavat amerikkalaiset standardit, sekä tehdä standardien vertailusta kattavat ja helposti luettavat taulukot Wärtsilän ja heidän alihankkijoidensa käyttöön. Yhtenä tärkeimmistä tavoitteista on selvittää, ovatko amerikkalaiset standardit tarpeeksi vaativia Wärtsilän käytettäviksi. Tutkimus on tehty vertailemalla Wärtsilän tarkastusvierailuilla käyttämän tarkastuslistan sisältämiä EN-standardeja vastaaviin ASME-, AWS-, ASNT- ja ASTM-standardeihin.

Tutkimuksesta selviää, että amerikkalaisissa standardeissa on selviä puutteita verrattuna eurooppalaisten standardien vaatimuksiin. Joissain amerikkalaisten standardien osissa on korkeampia vaatimuksia kuin EN-standardeissa, mutta pääsääntöisesti eurooppalaiset standardit ovat huomattavasti kattavampia kuin amerikkalaiset standardit. Näistä syistä eurooppalaisten standardien käyttäminen olisi Wärtsilän alihankkijoille suositeltavaa, jotta tuotannon laatu ja luotettavuus pystytään varmistamaan.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASME	American Society of Mechanical Engineering
ASNT	American Society of Nondestructive Testing
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CJP	Complete joint penetration
IIW	International Institute of Welding
NDT	Nondestructive testing
PJP	Partial joint penetration
WPQR	Welding Procedure Qualification Report
WPS	Welding Procedure Specification

a	Cut thickness
Rz5	Mean height
t	Nominal thickness of a plate or wall
u	Angularity

1 INTRODUCTION

This thesis is made in cooperation with Wärstilä and Sandvik. Some comparison of specific European and American standards have been done before this thesis, but Wärtsilä has no wider comparison lists containing multiple standards used in manufacturing.

1.1 Background

Wärtsilä Oy has a lot of subcontractors all over the world. EN ISO standards are usually used in Europe and they are meant to be international standards, but for instance, the United States have their own standards for many applications. ASME (American Society of Mechanical Engineering) standards are one of the most used standards in the United States. There are multiple other standards used in America and other continents. ASTM (American Society for Testing and Materials), ASNT (American Society of Nondestructive testing) and AWS (American Welding Society) have more specific standards for various construction phases.

1.2 Goals and definitions

The main goal of the thesis is to make easily readable lists of standard comparison for Wärtsilä's subcontractors. Comparison enables easier inspection visits to subcontractors using other than EN ISO standards in their processes of manufacturing. Also, if a customer demands using ASME standards, it is much faster to prove that the used EN ISO standard is at least as demanding as the corresponding ASME standard. Different American standards have various demands for the same purposes, which is why it is important to find the most arduous American standard to ensure the quality of the research.

1.3 Research methods

This thesis is made by examining European and American standards. Standard comparison is done by using Excel tables and hyperlinks are used to clarify the comparison. Compared standards are the most essential standards used in Wärtsilä's investigation visits. All the investigated processes and standards can be seen from table 1 presenting the checklist used in investigation visits. The requirement levels such as 442 of flame cutting and grade C of weld quality are also marked into the table.

Table 1. Wärtsilä's checklist for investigation visits.

The auditee	Requirements	OK	Not OK	Note:
Flame cutting process	EN 9013 442			
Flame cutting process	Document			
Material	EN 10025-2			
Shaping process	Document			
The connection of weld	EN 5817 C			
Welding quality straight weld	EN 5817 C			
Welding quality corners	EN 5817 C			
Welding, WPS, Qualification	Document			
Pre-treatment	EN 8501-3			
NDT-inspection	Document, ITP			
Welding test	Root			
Shot blasting	FeSa 2.5			
Painting	Film thickness			
Painting	Surface quality			
Package	Rigid			

2 THERMAL CUTTING STANDARDS AND TOLERANCES

The same thermal cutting standard is used in Europe and America but there are two different names for the standards. ASME has no thermal cutting standard, but AWS C4.6M (2012) and EN ISO 9013 (2002) contain totally same information. AWS's first adoption of the EN ISO standard was made 10.7.2006 and it was reapproved 30.10.2012. (AWS C4.6M, 2012, p. 1.)

EN ISO 9013 (2002) is applicable while using plasma, laser or oxyfuel flame cutting. The standard applies when cutting thicknesses for the three cutting methods are within the following range (EN ISO 9013, 2002, p. 6):

- Oxyfuel flame cutting: from 3 mm to 300 mm
- Plasma cutting: from 1 mm to 50 mm
- Laser cutting: from 0.5 mm to 40mm.

According to EN ISO 9013 (2002), every flange of a cut surface should be assessed separately. For example, V-, X- and K-seams are multi-flank cuts and every cut surface of the seams need their own evaluation. Gouges, oxide remaining and melting beds at the start of a cut are not taken into account while defining the quality levels in this standard. (EN ISO 9013, 2002, p. 26.) Tables of angularity, mean height and deviation limits follow a color code clarifying the usage of the tables on technical drawings.

2.1 Angularity (u)

The angularity of cut surfaces are divided into 5 different sections and number 1 is the most demanding tolerance class. Angularity shall be measured three times in 20 mm and these measurement sets should be done two times on each meter of the cut. Lowercase "a" indicates the cut thickness and it is also a millimeter value. (EN ISO 9013, 2002, p. 24.) Numerical values and the corresponding tolerance marking can be seen from table 2.

Table 2. Angularity tolerance (mod. EN ISO 9013, 2002, p. 29).

Range	u (mm)
1	0.05 + 0.003a
2	0.15 + 0.007a
3	0.4 + 0.01a
4	0.8 + 0.02a
5	1.2 + 0.035a

2.2 Mean height of the profile (Rz5)

Mean height of the profile is divided into 4 tolerance sections. Just like in angularity tolerances, the most demanding tolerance class is 1. If there are no specific demands, the mean height shall be measured once on each meter of the cut. (EN ISO 9013, 2002, p. 24.) Accurate values for Rz5 and the tolerance classes of the values are listed in table 3.

Table 3. Mean height of the profile (mod. EN ISO 9013, 2002, p. 29).

Range	Rz5 (mm)
1	10 + 0.6a
2	40 + 0.8a
3	70 + 1.2a
4	110 + 1.8a

2.3 Dimensional tolerances

Dimensional tolerances are divided into two different classes. EN ISO 9013 (2002) includes two accurate tables for limit deviations for piece thicknesses from 0 mm to 4000mm. These tables are usable only for pieces with 4:1 length-width -ratio. If the length-width ratio is higher than 4:1, the manufacturer is able to decide the allowable deviation limits. Deviation limits do not include digressions of angularity or perpendicularity. (EN ISO 9013, 2002, p. 34.) Dimensional tolerance class 1 is listed in table 4.

Table 4. Dimensional tolerance class 1 (mod. EN ISO 9013, 2002, p. 35).

Work piece thickeness	Nominal dimensions							
	> 0 < 3	≥ 3 < 10	≥ 10 < 35	≥ 35 < 125	≥ 125 < 315	≥ 315 < 1000	≥ 1000 < 2000	≥ 2000 < 4000
	Limit deviations							
> 0 ≤ 1	± 0.04	± 0.1	± 0.1	± 0.2	± 0.2	± 0.3	± 0.3	± 0.3
> 1 ≤ 3.15	± 0.1	± 0.2	± 0.2	± 0.3	± 0.3	± 0.4	± 0.4	± 0.4
> 3,15 ≤ 6.3	± 0.3	± 0.3	± 0.4	± 0.4	± 0.5	± 0.5	± 0.5	± 0.6
> 6,3 ≤ 10	-	± 0.5	± 0.6	± 0.6	± 0.7	± 0.7	± 0.7	± 0.8
> 10 ≤ 50	-	± 0.6	± 0.7	± 0.7	± 0.8	± 1	± 1.6	± 2.5
> 50 ≤ 100	-	-	± 1.3	± 1.3	± 1.4	± 1.7	± 2.2	± 3.1
> 100 ≤ 150	-	-	± 1.9	± 2	± 2.1	± 2.3	± 2.9	± 3.8
> 150 ≤ 200	-	-	± 2.6	± 2.7	± 2.7	± 3	± 3.6	± 4.5
> 200 ≤ 250	-	-	-	-	-	± 3.7	± 4.2	± 5.2
> 250 ≤ 300	-	-	-	-	-	± 4.4	± 4.9	± 5.9

There are remarkable differences in tolerance classes 1 and 2. The less strict dimensional tolerance class 2 can be seen from the table 5.

Table 5. Dimensional tolerance class 2 (mod. EN ISO 9013, 2002, p. 35).

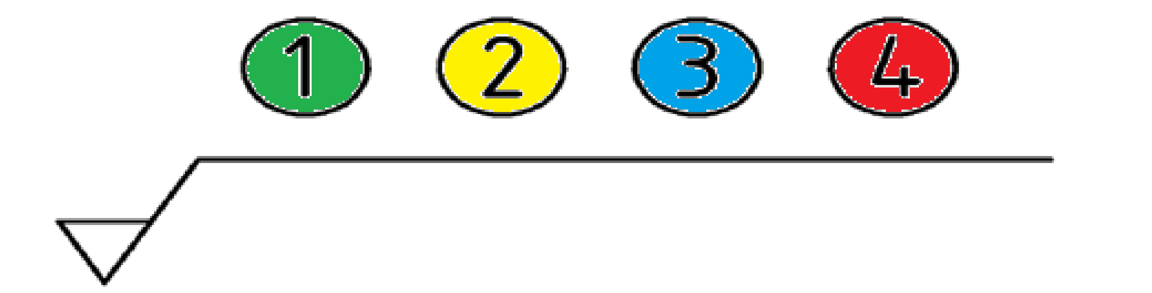
Work piece thickness	Nominal dimensions							
	> 0 < 3	≥ 3 < 10	≥ 10 < 35	≥ 35 < 125	≥ 125 < 315	≥ 315 < 1000	≥ 1000 < 2000	≥ 2000 < 4000
	Limit deviations							
> 0 ≤ 1	± 0.1	± 0.3	± 0.4	± 0.5	± 0.7	± 0.8	± 0.9	± 0,9
> 1 ≤ 3.15	± 0.2	± 0.4	± 0.5	± 0.7	± 0.8	± 0.9	± 1	± 1.1
> 3,15 ≤ 6.3	± 0.5	± 0.7	± 0.8	± 0.9	± 1.1	± 1.2	± 1.3	± 1.3
> 6,3 ≤ 10	-	± 1	± 1.1	± 1.3	± 1.4	± 1.5	± 1.6	± 1.7
> 10 ≤ 50	-	± 1.8	± 1.8	± 1.8	± 1.9	± 2.3	± 3	± 4.2
> 50 ≤ 100	-	-	± 2.5	± 2.5	± 2.6	± 3	± 3.7	± 4.9
> 100 ≤ 150	-	-	± 3.2	± 3.3	± 3.4	± 3.7	± 4.4	± 5.7
> 150 ≤ 200	-	-	± 4	± 4	± 4.1	± 4.5	± 5.2	± 6.4
> 200 ≤ 250	-	-	-	-	-	±5.2	± 5.9	± 7.2
> 250 ≤ 300	-	-	-	-	-	±6	± 6.7	± 7.9

2.4 Tolerance markings on technical drawings

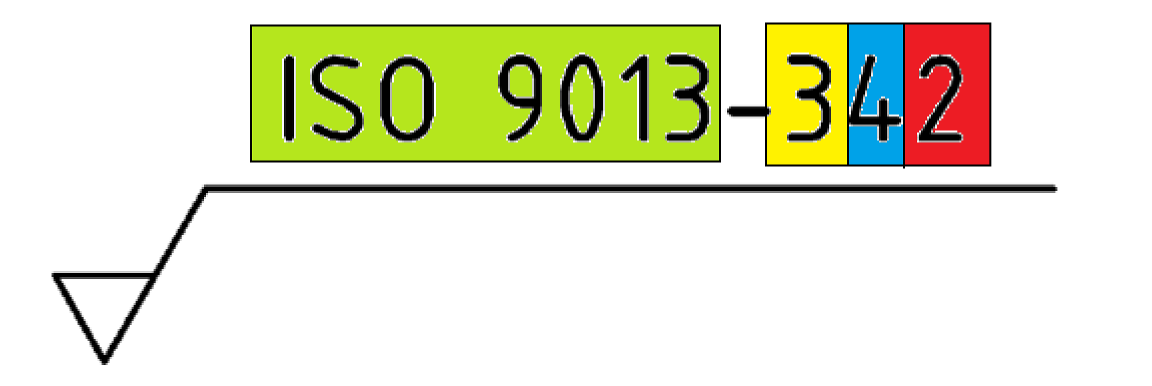
Markings of the required qualification classes on technical drawings have to be done in accordance with ISO 1302 (2002). There are 4 required indications given in EN ISO 9013 (2002). Precise tolerance classes are given in previous chapters. Mandatory indications are angularity, mean height of the profile, deviations limits of the profile and indication of the standard. Same indication methods shall be used while using AWS C4.6M (2012) standard. (EN ISO 9013, 2002, p. 40.)

The right way to mark the tolerance classes to technical drawings can be seen from table 6. Different indications are marked in colors to clarify the idea. The same color code has been used in previously expressed standard tables.

Table 6, Marking tolerances on technical drawings (mod. EN ISO 9013, 2002, p. 40).



Number	Indication
1	Indication of the standard
2	Angularity tolerance, u (1–5)
3	The range for the mean height of the profile, Rz5 (1–4)
4	Dimensional tolerance class (1–2)
Example	



3 MATERIAL STANDARDS

Used production materials vary in different countries and standards. Identical materials are hard to find, but materials with similar mechanical attributes can be found.

3.1 Material codes

As known, EN ISO standard’s codes for steels are very informative. The first letter tells if the material is a structural steel or cast, numbers tell the minimum yield strength requirement and the last marking indicates impact properties of the material and the temperature where the impact tests are done. (EN 10027-1, 2005, p. 8.)

ASME and ASTM have their own tables of materials containing some materials with the same requirements compared to each other, but there are also notable alloying and strength differences between “same” materials. First letters of the material code tell the standard where the material is from. SA-letters are the mark of ASME material and letter A is ASTM’s marking of its materials. Material names of American standards are basically only standard numbers and they are not telling anything about material properties.

Compared to each other, EN ISO standards’ material codes are far more useful than ASME’s or ASTM’s material names. Finding exactly right material for structural or engineering purposes can take a lot of time if searching from ASME or ASTM standards. EN ISO standards offer easier and more informative naming system, which simplifies the material selection procedure.

Examples of EN and ASTM materials are given underneath this chapter. The main differences and the weakness of ASME’s and ASTM’s marking system can easily be seen from these two examples of structural steel markings.

- S235JR
- A36

ASTM’s A36 is commonly used structural steel in the United States. This material, just like most of the other ASTM materials, has no requirements on impact strength. Its minimum yield strength is 250 MPa and tensile strength should be from 400 to 550 MPa. These facts cannot be seen from the material code contrary to EN's material name S235JR which only lacks the tensile strength requirement. (ASTM A36 / A36M, 2004, p. 1–4; EN 10025-2, 2004, p. 43.)

3.2 Testing of structural steels

There are three required tests to be carried out for structural steels according to EN ISO 10025-1 (2004). Required tests are tensile and impact tests and chemical analysis. The most essential characteristics for customers are elongation, weldability, durability, tensile, yield and impact strength. Those attributes are seen from the three tests. If the customer demands, the manufacturer shall do impact tests at another temperature and give product analysis. (EN ISO 10025-1, 2004, p. 24–27.)

ASTM has less strict standard for testing of structural steels. Chemical analysis and tensile tests are required as in corresponding EN standards. Impact tests, additional impact tests with different temperatures and product analysis shall be done according to customer's demands. (ASTM A6 / A6M, 2014, p. 5–27.) Table 7 shows the comparison between European and American standards.

Table 7. Required tests for hot rolled products of structural steels. (EN ISO 10025-1, 2004, p. 24–27; ASTM A6 / A6M, 2014, p. 5–27).

Test	EN ISO	ASTM
Chemical analysis	Required	Required (ASTM A6 / A6M, 2014, p. 5)
Tensile test	Required	2 results required (ASTM A6 / A6M, 2014, p. 10)
Impact test	Required	Recommended (ASTM A6 / A6M, 2014, p. 26–27)
Impact test at another temperature or on transverse test pieces	Additional	Additional (ASTM A6 / A6M, 2014, p. 26–27)
Product analysis	Additional	Recommended (ASTM A6 / A6M, 2014, p. 26)

3.3 Finding similar materials

Impact strength is one of the key values while choosing the best suitable material for production. As seen from the table 7, ASME and ASTM have no requirements for materials' impact testing. Impact tests and product analysis have to be demanded by the customer to ensure material's validity for specific use.

ASME, ASTM, and EN standards have their own ways to define material properties. ASME and ASTM give tensile and yield strength requirements for only one material thickness in contrast to EN’s four thickness levels for tensile strength and two thickness levels for yield strength. Elongation percent of test pieces are also defined differently in ASTM and EN standards. ASTM standards offer elongation percent for two shape categories: “plates and bars” and shapes. Elongation percent is given for 50 mm and 200 mm long test pieces, but the values are given for only one thickness level. EN standards present elongation values for test piece thicknesses from under 1mm up to 250 mm. The lengths of EN standard’s test pieces are 80 mm or over, so comparison of elongation between EN and ASTM standards is difficult. (ASTM A36 / A36M, 2004, p. 3; EN 10025-2, 2004, p. 43.)

Example tables of material alloying requirements and ASME’s most commonly seen basic material’s alloying and strength requirement tables can be found from annex I. Every material has its own requirement table, but ASTM A36 was chosen to be the example material that gives the basic idea of ASTM’s way to report the material requirements. Entire chemical requirement table of EN standard’s materials is listed in annex II and lightened version of strength requirement table can be seen in table 8.

Table 8. Material comparison (mod. EN 10025-2, 2004, p. 43; ASTM 01.04, 2016; ASTM A36 / A36M, 2004, p. 1–4; ASTM A562 / A562M, 2001, p. 1–2; ASTM A633 / A633M, 2001, p. 1–5; ASTM A225 / A225M, 2003, p. 1–3).

EN						ASTM			
Designation		Tensile strength R_m (MPa)	Minimum yield strength R_{eH} (MPa)	Minimum % elongation after fracture		Material	Tensile strength (MPa)	Yield point (MPa)	Elongation % in 50 mm
		Nominal thickness (mm)	Nominal thickness (mm)	L_0= 80 mm Nominal thickness (mm)	L_0=5.65* $\sqrt{S_0}$ Nominal thickness (mm)				
		under 3	under 16	1–1.5	3–40				
S235JR	1.0038	360–510	235	18	26	ASTM A562	380–515	205	26
S235J0	1.0114	360–510	235			ASTM A562	380–515	205	26
S235J2	1.0117	360–510	235	16	24	ASTM A562	380–515	205	26
S275JR	1.0044	430–580	275	16	23	ASTM A36	400–550	250	23
S275J0	1.0143	430–580	275			ASTM A36	400–550	250	23
S275J2	1.0145	430–580	275	14	21	ASTM A36	400–550	250	23
S355JR	1.0045	510–680	355	15	22	ASTM A633	485–620	345	23
S355J0	1.0553	510–680	355			ASTM A633	485–620	345	23
S355J2	1.0577	510–680	355			ASTM A633	485–620	345	23
S355K2	1.0596	510–680	355	13	20	ASTM A633	485–620	345	23
S450J0	1.0590	-	450		17	ASTM A225M Grade D	550–725	415	17

Table 8 shows the requirements of mechanical properties for steels with impact strength requirements. There are listed some comparable materials of ASTM 01.04 (2016) on the right side of the table, but the materials are not totally corresponding as seen from the tensile and yield strength requirements. Most of the ASTM, as well as ASME materials, have no impact strength requirements, so the compared materials are not necessarily the best option and some of the compared materials are not even low-alloy steels. The elongation requirements should also be noticed. ASTM 01.04 (2016) and the standards it is containing determines the elongation percent by 50 mm long test piece as opposed to EN standard’s 80 mm. (EN 10025-2, 2004, p. 43; ASTM 01.04, 2016.)

4 WELDING QUALITY AND QUALITY ASSURANCE

Quality of weld depends on many factors. Existence of proper WPS (Welding Procedure Specification) and WPQR (Welding Procedure Qualification Report), qualified welders and coordinators and quality tests ensure high-class products and welds.

Welding quality is one of the key factors of every welded structure. Therefore, welding quality is strictly defined in both ASME and EN standards. EN ISO 5817 (2014) contains an accurate list of imperfections that are not allowed in welds. The list contains a quality level division which is not used in ASME standards. ASME standards have also fewer imperfection requirements than EN standards. (EN ISO 5817, 2014, p. 18–47; AWS D1.1, 2000, p. 176.)

4.1 Quality management

To ensure the quality of welds, welding coordination's importance is emphasized. The most substantive duties for welding coordinators while using EN standards are making a requirement and technical review, dealing with sub-contractors, ensuring the qualifications of welders and taking care of the welding equipment. (EN ISO 14731, 2006, p. 18.)

ASME and AWS have no demands on welding coordinating. Coordinators are demanded in EN ISO standards, and these standards are used in IIW (International Institute of Welding) member countries including the United States. That is one reason why the usage of ASME or AWS standards may cause weaknesses on weld quality.

EN ISO 3834-1 (2005) standard makes possible to use suitable quality level for manufacturing. The standard is divided into three sections having different requirements for example WPS usage, welding coordination personnel, equipment maintenance and production planning. EN ISO 3834 standard's section are 2, 3 and 4, section 2 is the most demanding one. Section 1 presents the criteria for appropriate quality level selection. (EN ISO 3834-1, 2005, p. 16.)

ASME and AWS standards give no possibility to choose quality levels for manufacturing. Different American standards have variant requirements for welding operations and records. Standards are not distributed into quality rank order and some standards may have more requirements in certain manufacturing processes than others and vice versa. EN ISO 3834-1 (2005) is however used also in the United States because of its IIW membership. The usage of the EN ISO standard should be considered to ensure the quality of welds due to AWS's and ASME's lack of demands.

4.2 Quality levels and weld imperfections

In EN standards, welds are divided into four quality levels. Those levels are B+, B, C, and D. B+ level is the most demanding level, but it has not been taken into account in EN ISO 5817 (2014) and Wärtsilä is not constantly using that quality level, so it has been left out from this research. (EN ISO 5817, 2014, p. 18–47.)

Neither ASME nor AWS standards have quality level division, but there is a moderate similarity. AWS divides weld imperfection requirements into three sections, statically and cyclically loaded non-tubular welds and tubular welds for both loads. Requirements for cyclically loaded structures are the same and statically loaded welds need less attention. (AWS D1.1, 2000, p. 176.)

Most of the demands in ASME and AWS are comparable to EN's levels B and C. There are many requirements in EN standards that are only recommended in ASME or AWS. One of the most crucial things in AWS standard is the lack of root gap tolerance for fillet welds. Excessive root gap might cause too small a-dimension, which is one of the most essential characters for weld's durability. (EN ISO 5817, 2014, p. 18–47; AWS D1.1, 2000, p. 176.)

The most notorious weld imperfections have been taken into account in AWS D1.1 (2000). For example cracks, weld fusion, undercut and overlapping are forbidden in the AWS standard. EN ISO 5817 (2014) contains a lot of demands that are not even mentioned in the AWS standard. List of weld's visual validity requirements of AWS can be found from annex III. (EN ISO 5817, 2014, p. 18–47; AWS D1.1, 2000, p. 176.)

Table 9 expresses a short example list of EN ISO 5817 (2014) requirements of weld imperfections. If correspondence exists in the AWS's requirements, the equivalent imperfection level is painted yellow. The whole table can be found from annex IV. Letter t represents the nominal thickness of the welded plate or wall.

Table 9. Example limits of imperfections (mod. EN ISO 5817, 2014, p. 18–47; AWS D1.1, 2000, p. 176).

Imperfection	Grade D	Grade C	Grade B
Crack	Not permitted	Not permitted	Not permitted
Lack of fusion	Not permitted	Not permitted	Not permitted
Continuous undercut	Short imperfections: $h \leq 0.2$ t, but max. 1 mm	Short imperfections: $h \leq 0.1$ t but max. 0.5 mm	t from 0.5 to 3 mm : Not permitted t over 3 mm : $h \leq 0.05$ t, but max. 0.5 mm
Overlap	$h \leq 0.2$ b	Not permitted	Not permitted
Spatter	Acceptance depends on application	Acceptance depends on application	Acceptance depends on application
Incorrect root gap (fillet welds)	t over 3 mm $h \leq 1$ mm + 0.3 a, but max. 4 mm	t over 3 mm $h \leq 0.5$ mm + 0,2 a, but max. 3 mm	t over 3 mm $h \leq 0.5$ mm + 0.1 a, but max. 2 mm

4.3 Welder qualification

Welder qualification requirements are similar in ASME and EN standards. Testing of the butt welds is completely the same excluding the EN standards option of replacing radiographic testing by macroscopic examinations which is not allowed in ASME. (EN ISO 9606-1, 2013, p. 44; ASME IX, 2010, p. 54–147.)

Fillet weld testing is more demanding in ASME standard. Requirements of visual, and fracture testing are the same, but ASME has the macroscopic examination in addition. Test of job knowledge is not mandatory in the standards but it is recommended in EN ISO 9606-1 (2012) because some of the European countries demand it. (EN ISO 9606-1, 2012, p. 44;

ASME IX, 2010, p. 6–7.) Table 10 shows abbreviated list of required tests for welder qualification.

Table 10. Abbreviated table of welder qualification test requirements (mod. EN ISO 9606-1, 2012, p. 44 & ASME IX, 2010, p. 6–147).

	EN ISO		ASME	
	Butt weld (plate or pipe)	Fillet weld and branch joint	Butt weld (plate or pipe)	Fillet weld and branch joint
Visual testing	Required	Required	Required (ASME IX, 2010, p. 147.)	Required (ASME IX, 2010, p. 6–7.)
Radiographic testing	Required	Not required	Required (ASME IX, 2010, p. 54.)	N/A
Bend test	Required	Not applicable	Required (ASME IX, 2010, p. 147.)	N/A
Fracture test	Required	Required	Required (ASME IX, 2010, p. 145.)	Required (ASME IX, 2010, p. 6–7.)
Macroscopic examination	N/A	N/A	N/A	Required (ASME IX, 2010, p. 6–7.)
The test of job knowledge	Recommended	Recommended	N/A	N/A

Divergences between welder qualification tests are notable. EN ISO standard demands welder to fulfill requirements of quality level B of EN ISO 5817 (2012) standard. However, imperfections such as excess weld metal, excessive convexity, penetration, undercut and throat thickness shall meet the quality level C. (EN ISO 5817, 2012, p. 44.)

ASME has its own demands on every test taken to the weld. Demands given in ASME IX (2010) are mostly following EN ISO 5817's (2012) level C and it is highlighting crack free welds and complete weld fusion. The whole table of qualification test methods with notes and weld requirements can be found from annex V.

Validity requirements of welder qualification certifications are similar in both EN and ASME standards. According to EN ISO 9606-1 (2013), welder's abilities shall be confirmed every six months by welding coordinator or examiner. Examiner can revalidate the welder for two more years. ASME IX (2010) and AWS D1.1 (2000) demands qualification confirmation also every six months. Qualification expires in both European and American standards if the welder is not able to weld qualified welds. Qualification certification layouts can be found from annex VI. (EN ISO 9606-1, 2013, p. 54–56; ASME IX, 2010, p. 56.)

AWS and EN standards have their own ways to qualify a welder to a certain welding position. EN 9606-1 (2013) contains two tables including the testing positions and to which weld position the used position qualifies. The tables do not consider partial joint penetration (PJP) nor complete joint penetration (CJP) that are mentioned numerous times in AWS D1.1 (2000). Tables in AWS D1.1 are more informative than corresponding EN standard's tables. Different kind of grooves like Y- or K-grooves, CJP, PJP and box tube welding are taken into account in the AWS standard. One remarkable thing between EN and AWS standards is that AWS qualifies welder to weld fillet welds even if the welding tests have been done by using CJP groove weld on a plate. (EN ISO 9606-1, 2013, p. 37; AWS D1.1, 2000, p. 138.)

Demands on position qualifications are still quite similar in AWS and EN standards. A notable fact is that EN standard does not qualify welder to use as many weld positions as AWS D1.1 (2000) standard. For example, if welding test is done by using position J-L045, EN 9606-1 (2013) does not qualify welder to vertical up position, unlike the AWS standard. (EN ISO 9606-1, 2013, p. 37; AWS D1.1, 2000, p. 138.)

Table 11 expresses the comparison between EN ISO 9606-1's (2013) and AWS D1.1's (2000) qualification ranges for different welding positions for butt welds. Uppercase letter A presents AWS's qualification range accordingly to EN ISO's letter E.

Table 11. Comparison of qualification ranges of welding positions for butt welds. Letter A presents AWS's qualification range and letter E EN's qualification range. (Mod. EN ISO 9606-1, 2013, p. 37; AWS D1.1, 2000, p. 138.)

Testing position		Range of qualification				
EN	AWS	PA Flat	PC Horizontal	PE Overhead	PF Vertical up	PG Vertical down
PA	1G	E, A				
PC	2G	E, A	E, A			
PE (plate)	4G	E, A	E	E, A		
PF (plate)	3G Uphill	E, A	A		E, A	
PH (pipe)	5G Uphill	E, A		E, A	E, A	
PG (plate)	3G Downhill	A	A			E, A
PJ (pipe)	5G Downhill	E, A		E, A		E, A
H-L045	6G Uphill	E, A	E, A	E, A	E, A	A
J-L045	6G Downhill	E, A	E, A	E, A	A	E, A

Complete tables of qualification to welding positions using another position can be seen from annexes VII and VIII. Annex VII contains tables of EN ISO standards and AWS's qualification ranges can be found from annex VIII.

4.4 Welding positions

EN ISO 6947 (2011) expresses 11 different welding positions. Positions from PA to PE are presented as main welding positions and these are shown in figure 1. Welding positions from PF to PJ are for vertical welding of pipes and plates. (EN ISO 6947, 2011, p. 34–41.)

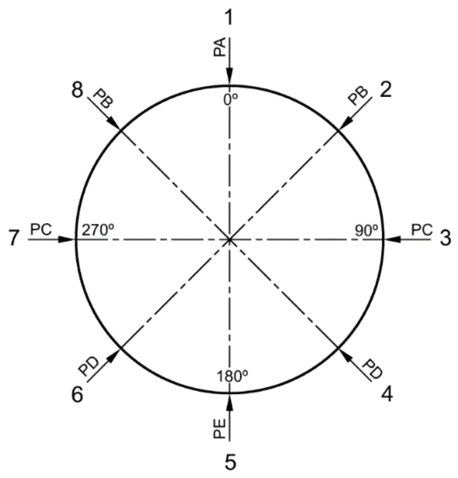


Figure 1. Main welding positions (EN ISO 6947, 2011, p. 12).

AWS A3.0 (2010) and ASME IX (2010) have different coding for welding positions. Fillet welds are marked with upper case letter f, and groove welds with letter g. Vertical welding positions are not divided like in EN standard as the direction of the weld shall be written after the position marking. (AWS A3.0, 2010, p. 2–3.) Comparison of the welding positions can be seen from table 12.

Table 12. Comparison of welding positions (EN ISO 6947, 2011, p. 34–41 & AWS A3.0, 2010, p. 2–3).

EN ISO	AWS, groove welds	AWS, fillet welds
PA	1G	1F/1FR
PB		2F/2FR
PC	2G	
PD		4F
PE	4G	
PF	3G uphill	3F uphill
PH	5G uphill	5F uphill
PG	3G downhill	3F downhill
PJ	5G downhill	5F downhill
H-L045	6G uphill	
J-L045	6G downhill	

4.5 WPS

WPS is required in both ASME and EN standards. According to AWS's standard D1.1 (2000), appropriate WPS should be followed during welding. In EN ISO standards there is a slight difference. According to EN ISO 3834-1 (2005), WPS is only required in standards

3834-2 (2005) and 3834-3 (2005), but there is no specific requirement of the WPS in 3834-4 (2005). (EN ISO 3834-1, 2005, p. 14; AWS D1.1, 2000, p. 158.) Table 13 shows the comparison of WPS usage requirements.

Table 13. WPS usage requirements (EN ISO 3834-1, 2005, p. 14; AWS D1.1, 2000, p. 158.)

EN ISO	AWS
WPS is required in ISO 3834-2 and ISO 3834-3. There is no specific requirement of the WPS in ISO 3834-4.	"All welders, welding operators, and tack welders shall be informed in the proper use of the WPS, and the applicable WPS shall be followed during the performance of welding."

4.6 WPS and WPQR contents

WPS and WPQR contents of American and European standards are almost the same. The compared standards are EN ISO 15614 (2012) and AWS D1.1 (2000). For example, all the welding parameters and joint geometries shall be included in both standards. Examples of EN's and AWS's WPS layouts can be found from annex IX. (EN ISO 15614-1, 2012, p. 50.)

According to AWS D1.1 (2000, p. 137) "The WPS shall include the joint details, filler metal type and diameter, amperage, voltage (type and polarity), speed of vertical travel if not an automatic function of arc length or deposition rate, oscillation (traverse speed, length, and dwell time), type of shielding including flow rate and dew point of gas or type of flux, type of molding shoe, post weld heat treatment if used, and other pertinent information."

4.7 Welding procedure tests for WPS

Welding tests are required in ASME and EN standards, but there are significant differences. Visual inspection, tensile and bend test are required in both EN and AWS standards. EN standards requires also radiographic or ultrasonic tests, surface crack detection, impact and hardness testing and macroscopic examination. In AWS standards, these four tests are only recommended. Besides, requirements on T-joint and branch connections are not even mentioned in the AWS D1.1 (2000). Comparison of welding procedure testing can be seen from table 14. (EN ISO 15614-1, 2012, p. 20; AWS D1.1, 2000, p. 107–102.)

Table 14. Welding procedure tests of welding test pieces (mod. EN ISO 15614-1, 2012, p. 20; AWS, 2000, p. 107–112).

	Test	EN ISO	AWS
Butt joint with full penetration	Visual	100 %	Required (AWS D1.1, 2000, p. 112)
	Radiographic or ultrasonic	100 %	Required (AWS D1.1, 2000, p. 107)
	Surface crack detection	100 %	Not required (AWS D1.1, 2000, p.112)
	Transverse tensile test	2 specimens	2 specimens (AWS D1.1, 2000, p. 112)
	Transverse bend test	4 specimens	4 specimens (AWS D1.1, 2000, p. 112)
	Impact test	2 sets	Not required (AWS D1.1, 2000, p. 112)
	Hardness test	Required	Not required (AWS D1.1, 2000, p. 112)
	Macroscopic examination	1 specimen	3 specimens required for weld size (AWS D1.1, 2000, p. 112)
T-joint- & branch connection with full penetration	Visual	100 %	N/A
	Surface crack detection	100 %	N/A
	Ultrasonic or radiographic	100 %	N/A
	Hardness test	Required	N/A
	Macroscopic examination	2 specimens	N/A
Fillet welds	Visual	100 %	Required (AWS D1.1, 2000, p. 112)
	Surface crack detection	100 %	Not required (AWS D1.1, 2000, p. 112)
	Hardness test	Required	Not required (AWS D1.1, 2000, p. 112)
	Macroscopic examination	2 specimens	3 faces (AWS D1.1, 2000, p. 112)

4.8 NDT-personnel

NDT (nondestructive testing) has to be made by qualified operators. ASNT and EN standards have some differences in the acceptance criteria of professional NDT-personnel. Qualification levels are same in both standards, and candidates' vision have to be examined and proven good. (EN ISO 9712, 2012, p. 22–36.)

ASNT has less strict demands on examination and experience, but the average of examination grades should be higher than in EN ISO standards. Experience requirements of

ASNT standard are given in hours unlike in EN standard and the amount of demanded experience is remarkable small. The validity of qualification also varies between American and European standards. ASNT's NDT personnel validity expires in three years if the candidate is not qualified as level three NDT inspector. (ISO 9712, 2012, p. 18–60; ANSI/ASNT CP-189, 2001, p. 1–9.) More specific list about NDT-personnel qualification can be seen in table 15.

Table 15. NDT-personnel qualification (EN ISO 9712, 2012, p. 18–60; ANSI/ASNT CP-189, 2001, p. 1–9.)

	EN ISO	ANSI/ASNT
Levels of qualification	Levels 1–3	Levels 1–3
Vision examination	Good vision required	Annualy
Experience	Level 1: 1–3 months Level 2: 3–9 months Level 3: 12–18 months depending on NDT method	Level 1: 7.5–400 hours Level 2: 40–1200 hours depending on NDT method
Practical examination	Required	Required
Basic examination	Required (min 95 questions)(questions about materials and basics)	Required (20–40 questions per method depending on NDT method and qualification level)(basic questions about specific NDT method)
Main method examination	Required (min 50 questions)(questions about the specific NDT method)	Required (15–40 questions per method depending on NDT method and qualification level)(More specific questions about the NDT method)
Minimum grade percent	70 % of every section	70 % of every sections and 80 % average
Minimum number of specimens for the practical examination	1–3 depending on the NDT method and qualification level	Level 1: 1 test sample for each technique to be used, level 2: 1 sample per technique and 2 samples per method
Validity	Validity 10 years Revalidation 5 years	3 years (levels 1–2) recertification by the employer every 5 years (level 3)
Recertification	Practical examination	By the employer

5 TREATMENT BEFORE PAINTING OR COATING

Often after welding, it is necessary to make some kind of surface finishing before painting or coating. Post-treatment may contain for example abrasive blasting, brushing or grinding. EN ISO 8501-3 (2007) is usually used in the United States, but corresponding requirements are given also in ASME and AWS standards.

5.1 Preparation grades

EN ISO 8501-3 (2007) gives a strict list of demands for pre-treatment before painting or coating. The list of different kind of requirements is divided into three sections: p1, p2 and p3. P3 is the most arduous requirement given in the list. Just like in weld requirement lists, ASME has no such thing as preparation grades and weld post treatment is not considered in ASME IX (2010) nor AWS D1.1 (2000) standards. Some demands for weld posttreatment are however given in American standards, these requirements are comparable to p2 preparation grade. (EN ISO 8501-3, 2007, p. 10–13.)

Examples of American preparation demands are given in table 16 that presents a lightened comparison of post-weld treatment and preparation grades. Corresponding preparation levels of EN ISO standard are painted yellow and the whole table of demands can be found from annex X.

Table 16. Lightened comparison table of post-weld treatment requirements and preparation grades (mod. EN ISO 8501-3, 2007, p. 10; AWS D1.1, 2000, p. 172; ASME B31.1, 2007, p. 75).

EN ISO				ASME and AWS
Type of imperfection	Preparation grades			No preparation grades
Description	P1	P2	P3	
1 Welds				
1.1 Welding spatters	Surface shall be free of all loose welding spatter	Surface shall be free of all loose and lightly adhering welding spatter	Surface shall be free of all welding spatter	Spatters shall be removed. Tightly adherent spatter remaining after the cleaning operation is acceptable. (AWS D1.1, 2000, p. 172.)
1.2 Weld ripple/profile	No preparation	Surface shall be dressed (e.g. by grinding) to remove irregular and sharp-edged profiles	Surface shall be fully dressed, i.e. smooth	Welds shall be sufficiently free from coarse ripples. (ASME B31.1, 2007, p. 75.)
1.3 Welding slag	Surface shall be free from welding slag	Surface shall be free from welding slag	Surface shall be free from welding slag	Slag shall be removed from all completed welds. (AWS D1.1, 2000, p. 172.)
1.4 Undercut	No preparation	Surface shall be free from sharp or deep undercuts	Surface shall be free from undercuts	
1.5 Weld porosity	No preparation	Surface pores shall be sufficiently open to allow penetration of paint, or dressed out	Surface shall be free from visible pores	
1.6 End craters	No preparation	End craters shall be free from sharp edges	Surface shall be free from visible end craters	

5.2 Rust grades

Rust grades are divided differently in ASTM and EN ISO standards. EN ISO 8501-1 (2007) gives only 4 rust grade possibilities whereas ASTM D610 (2008) has 10 grades. Percentage of the rusted area is harder to estimate than ISO standard’s verbal rust grades. The percentages of ASTM do not take pitting or flaking into account and the precise comparison is almost impossible to do. A suggestive comparison can be seen from table 17. Standards are applicable to hot rolled steel products before or after welding. (EN ISO 8501-1, 2007, p. 10–11; ASTM D610, 2008, p. 2.)

Table 17. Comparison of the rust grades (mod. EN ISO 8501-1, 2007, p. 11 & ASTM D610, 2008, p. 2).

EN ISO		ASTM	
Rust Grade	Explanation	Rust Grade	Maximum % of rusted area
A	Largely adhering mill scale, but little if any rust	10	0–0.01
		9	0.01–0.03
		8	0.03–0.1
B	Steel has begun to rust and the mill scale has begun to flake	7	0.1–0.3
		6	0.3–1
		5	1–3
C	Mill scale has rusted away or it can be scraped, slight visible pitting	4	3–10
		3	10–16.67
		2	16.67–33.33
D	Mill scale has rusted away and pitting is visible	1	33.33–50
		0	50–100

ASTM divides different kinds of rust formations with different letters. Spot, general, pinpoint and hybrid rusting are presented with a letter after the correct rust grade, indicating the maximum percentage of the rusted area. The first letter of rust formation type is the mark used to describe the rusting more systematically. (ASTM D610, 2008, p. 1–5) Figure 2 shows three different types of rust formations of rust grade 6. Hybrid rusting is not shown in the picture because it is just a mix of the other three rust types.

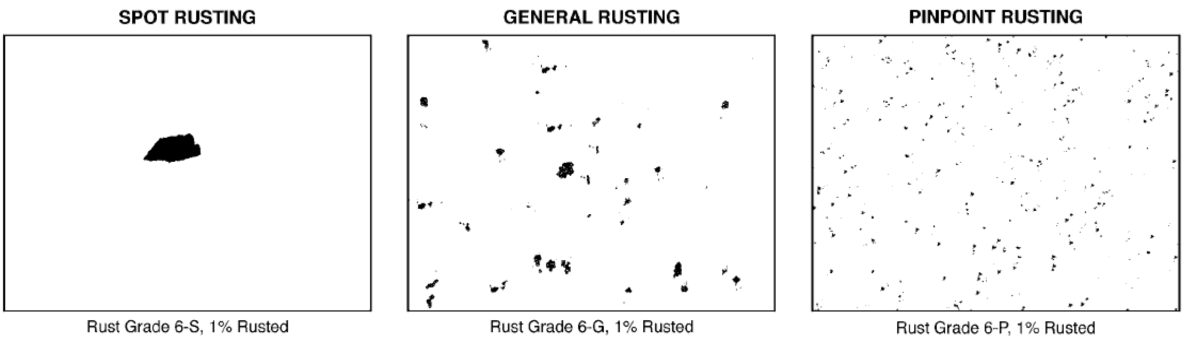


Figure 2. Rust formation types (ASTM D610, 2008, p. 4).

6 CONCLUSIONS

The main objective was to compare EN and ASME standards but ASME has only limited amount of standards for different construction phases. AWS, ASNT and ASTM offer a wider amount of standards with more requirements for investigated sections.

Thermal cutting and weld post treatment standards are the same in Europe and the United States. Neither AWS nor ASME give standard for specifically weld post treatment, but some requirements are mentioned in the standards. Accordingly, thermal cutting standard EN ISO 9013 (2002) is totally same standard as AWS's C4.6M (2012) although the names of the standards are different. (AWS C4.6M, 2012, p. 1.)

Two material standards are commonly used in the United States. ASME and AWS offer codes for numerous different kind of steel alloys used in variable construction methods. Both of the standards have materials with same coding numbers, the only thing that separates these codes are the first letters of the material name. For example, ASME's SA36 and AWS's A36 (2004) are the same materials standardized by different institutes. The materials have same requirements in both standards, but there are multiple steel alloys having same material names but there are notable divergences in requirements. The biggest difference between EN, ASME and AWS standards is that EN gives much more informative material codes for steels. Requirements on hardness and tensile strength are directly seen in EN's material names contrary to American standards. Lack of material's hardness testing in most of the American standards has to be noticed as well. (EN 10025-2, 2004, p. 43; ASTM 01.04, 2016; ASTM A36 / A36M, 2004, p. 1–4.)

AWS gives more specific demands on general weld imperfections than ASME that is naming only basic requirements such as the absence of all kinds of cracks and importance of complete weld fusion. EN ISO 5817 (2014) gives a long list of requirements containing accurate numerical values for three quality levels. AWS has comparable demands on imperfections but lacks the quality level system. Many of the EN requirements are not even mentioned in AWS D1.1 (2000) or ASME IX (2010), but the demanded values are following mainly the EN's quality levels B and C. The absence of demands in American standards should be noticed and highlighted while investigating weld imperfections. (EN ISO 5817, 2014, p. 18–47; AWS D1.1, 2000, p. 176.)

Both AWS and ASME standards have listed requirements for testing and content of WPS and WPQR. Content requirements of American and European welding procedure certifications are the same. According to EN ISO 3834-1 (2005), WPS is only needed if the manufacturer is using quality level standards EN 3834-2 (2005) or EN 3834-3 (2005). In contrast, AWS nor ASME give no option to ignore the WPS. Welding procedure testing of AWS and EN standards have also some differences. The most noticeable weakness in AWS's testing requirements is the lack of impact and hardness testing and surface crack detection. Besides, AWS has no full penetration T-joint requirements either. (AWS D1.1, 2000, p. 112; EN ISO 3834-1, 2005, p. 16.)

Qualification requirements of welders and welder operators are closely the same in ASME and EN ISO standards. Both of the standards demands revalidation by the examiner in cycle of six months. There are slight divergences in weld testing, fracture tests are mandatory in butt weld test requirements of ASME standard. EN standards offer an option to replace the fracture test with macroscopic examinations. According to EN ISO 9606-1 (2012), demanded quality level of welds is B excluding for example undercuts. ASME IX (2010) names its own requirements for every test taken to the weld. (EN ISO 9606-1, 2012, p. 44; ASME IX, 2010, p. 6–147.)

NDT personnel is divided in both American and European standards to three qualification levels. Requirements in EN ISO 9712 (2012) and ANSI/ASNT CP-189 (2001) are comparable, but the ASNT standard has less strict demands on experience and literal testing. (ISO 9712, 2012, p. 18–60; ANSI/ASNT CP-189, 2001, p. 1–9.)

Requirements on rust grades are not in Wärtsilä's investigation list, but the comparison is done to support EN ISO 8501-3's (2007) post weld treatment standard. Verifying the cleanliness of surfaces before painting or coating is as important factor as weld post treatment to ensure paint adherence. The difference between EN ISO's and ASTM's standards is remarkable. European standard has four literal quality grades for rusted surface in contrast to ASTM's ten rust grades divided by percentage values. The percentage of rusted area is hard to judge even with the help of rusting pictures presented in the standard. (EN ISO 8501-1, 2007, p. 11; ASTM D610, 2008, p. 2.)

Table 18 expresses the summary of comparison of European and American standards. The most suitable and demanding American standards are listed next to the corresponding EN ISO standard. Some other American standards may also have requirements for certain application, but only the compared standards are listed.

Table 18. Comparison of European and American standards.

	European standard	American standard	Correspondance
Thermal cutting	EN ISO 9013	AWS C4.6M	Same standard
Material standards	EN 10025-2	ASTM 01.04	None
Weld imperfections	EN ISO 5817	AWS D1.1	EN ISO standard is more demanding
Rust grades	EN ISO 8501-1	ASTM D610	None
Treatment before painting or coating	EN ISO 8501-3	Some examples	EN ISO standard is used in the United States
Material testing	EN 10025-1	ASTM A6 / A6M	No impact strength requirements in ASTM and ASME standards
WPS content	EN ISO-15614	AWS D1.1	Same
Welding procedure tests	EN ISO 15614-1	AWS D1.1	EN ISO standard is more demanding
Welder qualification	EN ISO 9606-1	ASME IX	Differences in testing and acceptance criteria
Welding positions	EN ISO 6947	AWS A3.0	Different coding for positions
NDT personell	EN ISO 9712	ANSI/ASNT CP-189	EN ISO 9712 has more demanding testing requirements

All in all, it is easy to say that the compared American standards have visible lack of requirements in contrast to EN ISO standards. Some of the American standards may have more strict demands in some specific areas, but in larger scale the usage of European standards should be recommended to ensure the quality and reliability of production.

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Chemical and strength requirements, ASTM A36 (mod. ASTM A36, 2004, p. 2–3).

Product	Thickness (mm)	C, max %	Si, max %	Mn, max %	P, max %	S, max %	Cu, max %
Shapes	All	0.26	0.40 max	-	0.04	0.05	0.2
Plates	≤ 20	0.25	0.40 max	-	0.04	0.05	0.2
	20–40		0.40 max	0.80–1.20	0.04	0.05	0.2
	40–65	0.26	0.15–0.40	0.80–1.20	0.04	0.05	0.2
	65–100	0.27	0.15–0.40	0.85–1.20	0.04	0.05	0.2
	>100	0.29	0.15–0.40	0.85–1.20	0.04	0.05	0.2
Bars	≤ 20	0.26	0.40 max	-	0.04	0.05	0.2
	20–40	0.27	0.40 max	0.60–0.90	0.04	0.05	0.2
	40–100	0.28	0.40 max	0.60–0.90	0.04	0.05	0.2
	>100	0.29	0.40 max	0.60–0.90	0.04	0.05	0.2

Plates, Shapes, and Bars	
Tensile stength	400–550 MPa
Yield point, min	250 MPa
Plates & Bars	
Elongation in 200 mm	20 %
Elongation in 50 mm	23 %
Shapes	
Elongation in 200 mm	20 %
Elongation in 50 mm	21 %

ANNEX II

Chemical requirement table, EN 10025-2 (mod. EN 10025-2, 2004, p. 35–37).

Chemical Requirements with impact stenght requirements (EN 10025-2, 2004, p. 35)													
Designation		Method of deoxidation	C in % max. For nominal product thickness in mm			Si % Max.	Mn % Max.	P % Max.	S % Max.	N % Max.	Cu % Max.	Other % Max.
			≤ 16	> 16 ≤40	> 40							
S235JR	1.0038	FN FN FF	0,17	0,17	0,2	- - -	1,40 1,40 1,40	0,035 0,030 0,025	0,035	0,012 0,012 -	0,55 0,55 0,55	- - -
S235J0	1.0114	FN	0,17	0,17	0,17	-	1,4	0,03	0,03	0,012	0,55	
S235J2	1.0117	FF	0,17	0,17	0,17	-	1,42	0,025	0,025	-	0,55	
S275JR	1.0044	FN	0,21	0,21	0,21	-	1,5	0,035	0,035	0,012	0,55	-
S275J0	1.0143	FN	0,18	0,18	0,18	-	1,5	0,03	0,03	0,012	0,55	-
S275J2	1.0145	FF	0,18	0,18	0,18	-	1,5	0,025	0,025	-	0,55	-
S355JR	1.0045	FN	0,24	0,24	0,24	0,55	1,6	0,035	0,035	0,012	0,55	-
S355J0	1.0553	FN	0,2	0,2	0,22	0,55	1,6	0,03	0,03	0,012	0,55	-
S355J2	1.0577	FF	0,2	0,2	0,22	0,55	1,6	0,025	0,025	-	0,55	-
S355K2	1.0596	FF	0,2	0,2	0,22	0,55	1,6	0,025	0,025	-	0,55	-
S450J0	1.0590	FF	0,2	0,2	0,2	0,55	1,7	0,03	0,03	0,025	0,55	-

Chemical requirements with no impact stenght requirements (EN 10025-2, 2004, p. 37)													
Designation		Method of deoxidation	C % Max.			Si % Max.	Mn % Max.	P % Max.	S % Max.	N % Max.	Cu % Max.	Other % Max.
S 185	1.0035	optional	N/A	N/A	N/A	N/A	N/A	-	-	-	N/A	N/A
E295	1.0050	FN	N/A	N/A	N/A	N/A	N/A	0,045	0,045	0,012	N/A	N/A
E335	1.0060	FN	N/A	N/A	N/A	N/A	N/A	0,045	0,045	0,012	N/A	N/A
E360	1.0070	FN	N/A	N/A	N/A	N/A	N/A	0,045	0,045	0,012	N/A	N/A

Visual inspection acceptance criteria, AWS D1.1 (mod. AWS D1.1, 2000, p. 176).

Discontinuity Category and Inspection Criteria	Statically Loaded Nontubular Connections	Cyclically Loaded Nontubular Connections	Tubular Connections (All Loads)
Cracks; Any crack is unacceptable, regardless of size or location.	X	X	X
Weld/Base-Metal Fusion; Thorough fusion shall exist between adjacent layers of weld metal and between weld metal and base metal.	X	X	X
Crater Cross Section; All craters shall be filled to provide the specified weld size, except for the ends of intermittent fillet welds outside of their effective length.	X	X	X
Unacceptable fillet- and groove weld profiles:			
Excessice undercut	X	X	X
Overlap	X	X	X
Excessive convexity	X	X	X
Insufficient throat	X	X	X
Unacceptable fillet weld profiles are:			
Insufficient leg	X	X	X
Incomplete fusion	X	X	X
Time of Inspection; Visual inspection of welds in all steels may begin immediately after the completed welds have cooled to ambient temperature.	X	X	X
Undersized welds; (L, specified nominal weld size) & (U, allowable decrease from L) $L \leq 5$mm, $U \leq 2$ mm $5\text{mm} \leq L \leq 8$ mm $U \leq 2{,}5$ mm $L \geq 8$mm $U \leq 3$ mm In all cases, the undersize portion shall not exceed 10% of the weld length.	X	-	-
Undercut; If material is less than 25mm thick, undercut shall not exceed 1mm, except that a maximum 2mm is permitted for an accumulated length of 50mm. If material is thicker than 25mm, undercut shall not exceed 2mm for any length of the weld.	X	-	-

Visual inspection acceptance criteria, AWS D1.1 (mod. AWS D1.1, 2000, p. 176).

Discontinuity Category and Inspection Criteria	Statically Loaded Nontubular Connections	Cyclically Loaded Nontubular Connections	Tubular Connections (All Loads)
Undercut; When the weld is transverse to tensile stress, the undercut shall be no more than 0.25mm. In all other cases, undercuts shall be no more than 1mm deep.	-	X	X
Porosity; Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible piping porosity. For all other groove welds and fillet welds, the sum of the visible piping porosity of (1 mm diameter) or greater shall not exceed 10 mm in any linear 25mm of weld and shall not exceed 20 mm in any 300 mm length of weld.	X	-	-
Porosity; The frequency of piping porosity in fillet welds shall not exceed one in each 4 in. (100 mm) of weld length and the maximum diameter shall not exceed 3/32 in. (2.5 mm). Exception: for fillet welds connecting stiffeners to web, the sum of the diameters of piping porosity shall not exceed 3/8 in. (10 mm) in any linear inch of weld and shall not exceed 3/4 in. (20 mm) in any 12 in. (300 mm) length of weld.	-	X	X
Porosity; Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds, the frequency of piping porosity shall not exceed one in 4 in. (100 mm) of length and the maximum diameter shall not exceed 3/32 in. (2.5 mm).	-	X	X
The maximum root surface concavity shall be 1/16 in. (2 mm) (AWS D1.1, 2000, p. 107).	X	X	X
Misalignment; shall not exceed 10 % of the thickness of the thinner part. Max 3 mm (AWS D1.1, 2000, p. 165).	X	X	X

ANNEX IV, 1

Limits for imperfections, EN ISO 5817 (mod. EN ISO 5817, 2014, p. 18–47).

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t (mm)	Limits for imperfections for quality levels		
					D	C	B
1. Surface imperfections							
1.1	100	Crack		≥0,5	Not permitted	Not permitted	Not permitted
1.2	104	Crater crack		≥0,5	Not permitted	Not permitted	Not permitted
1.3	2017	Surface pore	Maximum dimension of a single pore for - butt welds -fillet welds	0.5–3	$d \geq 0.3s$ $d \geq 0.3a$	Not permitted	Not permitted
			Maximum dimension of a single pore for - butt welds -fillet welds	>3	$d \leq 0.3$ s, but max, 3mm $d \leq 0.3$ a, but max, 3mm	$d \leq 0.2$ s, but max,2mm $d \leq 0.2$ a, but max,2mm	Not permitted
1.4	2025	End crater pipe		0.5–3	$h \leq 0.2$ t	Not permitted	Not permitted
				>3	$h \leq 0.2$ t, but max, 2mm	$h \leq 0.1$ t, but max,1mm	Not permitted
1.5	401	Lack of fusion (incomplete fusion)	-	≥0.5	Not permitted	Not permitted	Not permitted
		Micro lack of fusion	Only detectable by micro examination	≥0.5	Permitted	Permitted	Not permitted
1.6	4021	Incomplete root penetration	Only single side butt welds	≥0.5	Short imperfections: $h \leq 0.2$ t but max, 2mm	Not permitted	Not permitted

Limits for imperfections, EN ISO 5817 (mod. EN ISO 5817, 2014, p. 18–47).

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t (mm)	Limits for imperfections for quality levels		
					D	C	B
1.7	5011 5012	Continuous undercut Intermittent undercut	Smooth transition is required. This is not regarded as a systematic imperfection.	0.5-3 >3	Short imperfections: $h \leq 0.2$ t $h \leq 0.2$ t, but max. 1 mm	Short imperfections: $h \leq 0.1$ t $h \leq 0.1$ t, but max. 5 mm	Not permitted $h \leq 0.05$ t, but max. 0.5 mm
1.8	5013	Shrinkage groove	Smooth transition is required.	0.5-3 >3	Short imperfections: $h \leq 0.2mm+0.1t$ Short imperfections: $h \leq 0.2$ t, but max. 2 mm	Short imperfections: $h \leq 0.1$ mm Short imperfections: $h \leq 0.1$ t, but max. 1 mm	Not permitted Short imperfections: $h \leq 0.05$ t, but max. 0.5 mm
1.9	502	Excess weld metal (butt weld)	Smooth transition is required.	≥ 0.5	$h \leq 1mm+0.25b$, but max. 10mm	$h \leq 1$ mm+0.15b, but max. 7mm	$h \leq 1$ mm + 0.1b, but max. 5mm
1.10	503	Excessive convexity (fillet weld)		≥ 0.5	$h \leq 1mm+0.25b$, but max. 5mm	$h \leq 1$ mm+0.15b, but max. 4mm	$h \leq 1$ mm + 0.1b, but max. 3mm
1.11	504	Excessive penetration		0.5–3 >3	$h \leq 1$ mm+0.6b $h \leq 1$ mm+1.0b but max. 5mm	$h \leq 1$ mm + 0.3 b $h \leq 1$ mm + 0.6b, but max. 4mm	$h \leq 1$ mm + 0.1b $h \leq 1$ mm + 0.2b, but max. 3mm
1.12	505	Incorrect weld toe	- butt welds	≥ 0.5	$\alpha \geq 90°$	$\alpha \geq 110°$	$\alpha \geq 150°$
			- fillet welds	≥ 0.5	$\alpha \geq 90°$	$\alpha \geq 100°$	$\alpha \geq 110°$
1.13	506	Overlap		≥ 0.5	$h \leq 0.2$ b	Not permitted	Not permitted
1.14	509 511	Sagging Incompletely filled groove	Smooth transition is required	0.5-3 >3	Short imperfections: $h \leq 0.25$ t Short imperfections: $h \leq 0.25$ t, but max. 2 mm	Short imperfections: $h \leq 0.1$ t Short imperfections: $h \leq 0.1$ t, but max. 1 mm	Not permitted Short imperfections: $h \leq 0.05$ t, but max. 0.5 mm

Limits for imperfections, EN ISO 5817 (mod. EN ISO 5817, 2014, p. 18–47).

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t (mm)	Limits for imperfections for quality levels		
					D	C	B
1.15	510	Burn through	-	≥0,5	Not permitted	Not permitted	Not permitted
1.16	512	Excessive asymmetry of fillet weld (excessive unequal leg length)	In cases where an asymmetric fillet weld has not been prescribed	≥0.5	h ≤ 2 mm+0.2a	h ≤ 2 mm+0.15 a	h ≤1.5mm+0.15a
1.17	515	Root concavity	Smooth transition is required.	0.5-3 >3	h≤ 0.2mm+0.1t Short imperfections: h ≤ 0.2 t, but max. 2 mm	Short imperfections: h ≤ 0.1 t Short imperfections: h ≤ 0.1 t, but max. 1 mm	Not permitted Short imperfections: h ≤ 0.05t, but max. 0.5 mm
1.18	516	Root porosity	Spongy formation at the root of a weld due to bubbling of the weld metal at the moment of solidification (e.g. lack of gas backing)	≥0.5	Locally permitted	Not permitted	Not permitted
1.19	517	Poor restart	-	≥0.5	Permitted The limit depends on the type of imperfection occurred due to restart	Not permitted	Not permitted
1.20	5213	Insufficient throat thickness	Not applicable to processes with proof of greater depth of penetration	0.5-3 >3	Short imperfections: h≤0.2mm+0.1a Short imperfections: h≤0.3mm+0,1a but max. 2 mm	Short imperfections: h ≤ 0.2 mm Short imperfections: h ≤ 0.3mm+0,1a but max. 1 mm	Not permitted Not permitted

Limits for imperfections, EN ISO 5817 (mod. EN ISO 5817, 2014, p. 18–47).

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t (mm)	Limits for imperfections for quality levels		
					D	C	B
1.21	5214	Excessive throat thickness	The actual throat thickness of the fillet weld is too large.	≥0.5	Permitted	$h \leq 1$ mm + 0.2a, but max. 4 mm	h≤1mm+0.15a, but max. 3 mm
1.22	601	Stray arc	-	≥0.5	Permitted, if the properties of the parent metal are not affected.	Not permitted	Not permitted
1.23	602	Spatter	-	≥0.5	Acceptance depends on application, e.g. material, corrosion protection	Acceptance depends on application, e.g. material, corrosion protection	Acceptance depends on application, e.g. material, corrosion protection
1.24	610	Temper colour (Discolouration)	-	≥0.5	Acceptance depends on application, e.g. material, corrosion protection	Acceptance depends on application, e.g. material, corrosion protection	Acceptance depends on application, e.g. material, corrosion protection
2 Internal imperfections							
2.1	100	Cracks	All types of crack except micro cracks and crater cracks	≥0.5	Not permitted	Not permitted	Not permitted

Limits for imperfections, EN ISO 5817 (mod. EN ISO 5817, 2014, p. 18–47).

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t (mm)	Limits for imperfections for quality levels		
					D	C	B
2.2	1001	Micro cracks	A crack usually only visible under the microscope (50 x)	≥0.5	Permitted	Acceptance depends on type of parent metal with particular reference to crack sensitivity	Acceptance depends on type of parent metal with particular reference to crack sensitivity
2.3	2011 2012	Gas pore Uniformly distributed porosity	The following conditions and limits for imperfections shall be fulfilled A1) Maximum dimension of the area of the imperfections (inclusive of systematic imperfection) related to the projected area NOTE: The porosity in the project area depends on the numbers of layers (volume of the weld).	≥0.5	For single layer: ≤ 2.5 % For multilayer: ≤ 5 %	For single layer: ≤ 1.5 % For multilayer: ≤ 3 %	For single layer: ≤ 1 % For multilayer: ≤ 2 %
			A2) Maximum dimension of the cross sectional area of the imperfections (inclusive of systematic imperfection) related to the fractured to the fracture area (only applicable to test pieces: production tests)	≥0.5	≤ 2.5 %	≤ 1.5 %	≤ 1 %
			B) Maximum dimension for a single pore for - butt welds - fillet welds	≥0.5	d ≤ 0.4 s, butmax.5mm d ≤ 0.4 a, butmax.5mm	d ≤ 0.3 s, but max.4mm d ≤ 0.3 a, but max.4mm	d ≤ 0.2 s, but max.3 mm d ≤ 0.2 a, but max.3 mm

Limits for imperfections, EN ISO 5817 (mod. EN ISO 5817, 2014, p. 18–47).

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t (mm)	Limits for imperfections for quality levels		
					D	C	B
2.4	2013	Clustered (localized) porosity	Reference length for lp is 100 mm. The total gas pore area within the cluster is represented by a circle of diameter da surrounding all the gas pores. The requirement for a single gas pore shall be met by all the gas pores within this circle. Permitted porous area shall be local. The possibility of the pore cluster masking other imperfections shall be taken into consideration. If D is less than da1 or da2, whichever is smaller, then the total gas pore area is represented by a circle of diameter dAC, where dAC = dA1 + dA2 + D. Systematic cluster porosity is not permitted. dA corresponds to dA1, dA2 or dAC, whichever is applicable.	≥0.5	dA≤25mm or dA, max ≤ wp	dA ≤ 20mm or dA, max ≤ wp	dA ≤15mm or dA, max ≤ wp/2
2.5	2014	Linear porosity	- butt welds	≥0.5	h ≤ 0.4 s, but max.4 mm l ≤ s, but max.75mm	h ≤ 0.3 s, but max.3mm l ≤ s, but max.50mm	h ≤ 0.2 s, but max.2 mm l ≤ s, but max.25mm
			- fillet welds	≥0.5	h ≤ 0.4 a, but max.4 mm l ≤ a, but max.75mm	h ≤ 0,3 a, but max.3 mm l ≤ a, but max.50 mm	h ≤ 0.2 a, but max.2 mm l ≤ a, but max.25mm

Limits for imperfections, EN ISO 5817 (mod. EN ISO 5817, 2014, p. 18–47).

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t (mm)	Limits for imperfections for quality levels		
					D	C	B
2.6	2015 2016	Elongated cavity Wormholes	- butt welds	≥0.5	$h \leq 0.4$ s, but max.4 mm $l \leq$ s, but max. 75 mm	$h \leq 0.3$ s, but max. 3 mm $l \leq$ s, but max. 50 mm	$h \leq 0.2$ s, but max. 2 mm $l \leq$ s, but max. 25 mm
			- fillet welds	≥0.5	$h \leq 0.4$ a, but max. 4 mm $l \leq$ a but max. 75 mm	$h \leq 0.3$ a, but max. 3 mm $l \leq$ a, but max. 50 mm	$h \leq 0.2$ a, but max. 2 mm $l \leq$ a, but max. 25 mm
2.7	202	Shrinkage cavity		≥0.5	Short imperfections permitted, but not breaking of the surfaces: butt welds: $h \leq 0.4$ s, but max. 4 mm fillet welds: $h \leq 0.4$ a, but max. 4 mm	Not permitted	Not permitted
2.8	2024	Crater pipe	The larger value of h or l will be measured	0.5-3 > 3	h or $l \leq 0,2$ t h or $l \leq 0.2$ t, but max. 2 mm	Not permitted	Not permitted

Limits for imperfections, EN ISO 5817 (mod. EN ISO 5817, 2014, p. 18–47).

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t (mm)	Limits for imperfections for quality levels		
					D	C	B
2.9	300 301 302 303	Solid inclusions Slag inclusions Flux inclusions Oxide inclusions	- butt welds	≥0.5	$h \leq 0.4$ s, but max. 4 mm $l \leq$ s, but max. 75mm	$h \leq 0.3$ s, but max. 3 mm $l \leq$ s, but max.50 mm	$h \leq 0.2$ s, but max. 2 mm $l \leq$ s, but max. 25 mm
			- fillet welds	≥0.5	$h \leq 0.4$ a, but max. 4mm $l \leq$ a, but max. 75mm	$h \leq 0.3$ a, but max. 3 mm $l \leq$ a, but max.50 mm	$h \leq 0.2$ a, but max. 2 mm $l \leq$ a, but max. 25 mm
2.10	304	Metallic inclusions other than copper	- butt welds	≥0.5	$h \leq 0.4$ s, but max. 4 mm	$h \leq 0.3$ s, but max. 3 mm	$h \leq 0.2$ s, but max. 2 mm
			- fillet welds	≥0.5	$h \leq 0.4$ a, but max. 4 mm	$h \leq 0.3$ a, but max. 3 mm	$h \leq 0.2$ a, but max. 2 mm
2.11	3042	Copper inclusion		≥0.5	Not permitted	Not permitted	Not permitted
2.12	401	Lack of fusion (incomplete fusion)		≥0.5	Short imperfections permitted: butt welds: $h \leq 0.4$ s, but max. 4 mm fillet welds: $h \leq 0.4$ a but max. 4 mm	Not permitted	Not permitted
	4011	Lack of side wall fusion					
	4012	Lack of inter-run fusion					
	4013	Lack of root fusion					
2.13	402	Lack of penetration	T-joint (fillet weld)	≥0.5	Short imperfection: $h \leq 0.2$ a, but max. 2 mm	Not permitted	Not permitted

Limits for imperfections, EN ISO 5817 (mod. EN ISO 5817, 2014, p. 18–47).

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t (mm)	Limits for imperfections for quality levels		
					D	C	B
			T-joint (partial penetration)	≥0.5	Short imperfections:	Short imperfections:	Not permitted
			Butt joint (partial penetration)		butt joint: $h \leq 0.2$ s or i, but max.2 mm	butt joint: $h \leq 0.1$ s or i, but max. 1.5 mm	
					T-joint: $h \leq 0.2$ a, but max. 2 mm	fillet joint: $h \leq 0.1$ a, but max. 1.5 mm	
			Butt joint (full penetration)	≥0.5	Short imperfection: $h \leq 0.2$ t, but max. 2 mm	Not permitted	Not permitted
3 Imperfections in joint geometry							
3.1	507	Linear misalignment	The limits relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centerlines coincide. t refers to the smaller thickness.				
	5071	Linear misalignment between plates	Plates and longitudinal welds	0.5–3	$h \leq 0.2mm+0.25t$	$h \leq 0.2mm+0.15t$	$h \leq 0.2mm+0.1t$
				> 3	$h \leq 0.25$ t, but max. 5 mm	$h \leq 0.15$ t, but max. 4 mm	$h \leq 0.1$ t, but max. 3 mm
	5072	Transversely circular welds at cylindrical hollow sections	Circumferential welds	≥0.5	$h \leq 0.5$ t, but max. 4 mm	$h \leq 0.5$ t, but max. 3 mm	$h \leq 0.5$ t, but max. 2 mm

Limits for imperfections, EN ISO 5817 (mod. EN ISO 5817, 2014, p. 18–47).

No.	Reference to ISO 6520-1	Imperfection designation	Remarks	t (mm)	Limits for imperfections for quality levels		
					D	C	B
3.2	617	Incorrect root gap for fillet welds	Gap between the parts to be joined. Gaps exceeding the appropriate limit may, in certain cases be compensated by a corresponding increase in the throat thickness.	0,5–3 >3	h≤0.5mm+0.1a h ≤ 1 mm + 0.3a, but max. 4 mm	h ≤ 0.3 mm+0,1a h ≤ 0.5mm+0.2a, but max. 3 mm	h ≤ 0.2 mm + 0.1a h ≤ 0.5mm+0.1a, but max. 2 mm
4 Multiple imperfections							
4.1	None	Multiple imperfections in any cross section	$h1 + h2 + h3 + h4 = \Sigma h$ $h1 + h2 + h3 = \Sigma h$	0.5-3 > 3	Not permitted Maximum total height of imperfections: $\Sigma h \leq 0.4t$ or $\leq 0.25a$	Not permitted Maximum total height of imperfections: $\Sigma h \leq 0.3t$ or $\leq 0.2a$	Not permitted Maximum total height of imperfections: $\Sigma h \leq 0.2t$ or $\leq 0.15a$
4.2	None	Projected or cross-sectional area in longitudinal direction	Case 1 (D > l3) $h1 \times l1 + h2 \times l2 + h3 \times l3 = \Sigma h \times l$ Case 2 (D < l3) The sum of the areas $\Sigma h \times l$ shall be calculated as a percentage to the evaluation area lp × wp (case 1). If D is smaller than the shorter length of one of the neighbouring imperfections, the full connection of the two imperfections shall be applied to the sum of imperfections (case 2).	≥ 0,5	$\Sigma h \times l \leq 16$ %	$\Sigma h \times l \leq 8$ %	$\Sigma h \times l \leq 4$ %

Comparison of qualification test methods (mod. EN ISO 9606-1, 2013, p. 44; ASME IX, 2010, p. 6–206).

	EN ISO		ASME	
	Butt weld (plate or pipe)	Fillet weld and branch joint	Butt weld (plate or pipe)	Fillet weld and branch joint
Visual testing	required	required	required e) (ASME IX, 2010, p. 147)	required i) (ASME IX, 2010, p. 6-7)
Radiographic testing	required a)b)	not required	required f) (ASME IX, 2010, p. 54)	N/A
Bend test	required a)c)	not applicable	required g) (ASME IX, 2010, p. 147)	N/A
Fracture test	required a)c)	required d)	required h) (ASME IX, 2010, p. 145)	required j) (ASME IX, 2010, p. 6-7)
Macroscopic examination	d)	d)	N/A	required k) (ASME IX, 2010, p. 6-7)
The test of job knowledge	recommended	recommended	N/A	N/A
Welder qualification	A welder is qualified if the weld imperfections are within ISO 5817, quality levele B. Excess weld metal, excessive convexity, excessive throat thikness, excessive penetration and undercut shall be within ISO 5817, quality level C.		If the test method is required, welder is qualified if the weld imperfections are within notes marked below.	

Comparison of qualification test methods (mod. EN ISO 9606-1, 2013, p. 44; ASME IX, 2010, p. 6–206).

	EN ISO	ASME	
Notes	a) Radiographic testing or bend or fracture tests shall be used. When radiographic testing is used, the additional bend or fracture test are required for welding processes 131, 135, 138 and 311. b) The radiographic testing may be replaced by ultrasonic testing for thicknesses 8mm on ferritic steels only. In this case, the additional tests mentioned in note “a” are not required. c)For outside pipe diameters D ≤ 25 mm, the bend or fracture tests may be replaced by a notched tensile test of the complete test piece. d) The fracture tests may be replaced by a macroscopic examination, of at least two sections, at least one of which shall be taken from the stop/start location. The fracture tests on pipes may be replaced by radiographic testing.	e) “Performance test coupons shall show complete joint penetration with complete fusion of weld metal and base metal.” (ASME IX, 2010, p. 10) f) “Welds made in test coupons for performance qualification may be examined by visual and mechanical examinations (QW-302.1, QW-302.4) or by volumetric NDE.” (ASME IX, 2010, p. 54) g) “The weld and heat-affected zone of a transverse weldbend specimen shall be completely within the bent portion of the specimen after testing. The guided-bend specimens shall have no open discontinuity in the weld or heat-affected zone exceeding 1/8in. (3 mm), measured in any direction on the convex surface of the specimen after bending. Open discontinuities occurring on the corners of the specimen during testing shall not be considered unless there is definite evidence that they result from lack of fusion, slag inclusions, or other internal discontinuities.” (ASME IX, 2010, p. 6) h) “The specimen shall have a tensile strength that is not less than (a) the specified minimum tensile strength of the base metal” (ASME IX, 2010, p. 206).	i) “(a) Visual examination of the cross sections of the weld metal and heat-affected zone shall show complete fusion and freedom from cracks. (b) There shall be not more than 1/8 in. (3 mm) difference in the length of the legs of the fillet.” (ASME IX, 2010, p. 7.) j) “If the specimen fractures, the fractured surface shall show no evidence of cracks or incomplete root fusion, and the sum of the lengths of inclusions and porosity visible on the fractured surface shall not exceed 3/8 in. (10 mm) in fillet weld or 10% of the quarter section in branch joint.” (ASME IX, 2012, p. 7.) k) “Visual examination of the cross section of the weld metal and heat-affected zone shall show complete fusion and freedom from cracks, except that linear indications at the root not exceeding 1/32 in. (0.8 mm) shall be acceptable. The weld shall not have a concavity or convexity greater than 1.5 mm. There shall be not more than 3 mm difference in the lengths of the legs of the fillet.” (ASME IX, 2012, p. 7.)

Welder's qualification test certificates (EN ISO 9606-1, 2012, p. 61).

Welder's qualification test certificate

Designation(s):. . . . .
. . . .

WPS – Reference: Examiner or examining body– Reference No.:

Welder's name:

Identification:

Method of identification:

Date and place of birth:

Employer:

Code/testing standard:

Photograph
(if required)

Job knowledge: Acceptable/Not tested (delete as necessary)

	Test piece	Range of qualification
Welding process(es);		
Transfer mode		
Product type (plate or pipe)		
Type of weld		
Parent material group(s)/subgroups		
Filler material group(s)		
Filler material (Designation)		
Shielding gas		------------------------
Auxiliaries		
Type of current and polarity		------------------------
Material thickness (mm)		
Deposited thickness (mm)		
Outside pipe diameter (mm)		
Welding position		
Weld details		
Multi-layer/single layer		

Supplementary fillet weld test (completed in conjunction with a butt weld qualification): acceptable/not acceptable

Type of test	Performed and accepted	Not tested
Visual testing		
Radiographic testing		
Fracture test		
Bend test		
Notch tensile test		
Macroscopic examination		

Name of examiner or examining body:

Place, date and signature of examiner or examining body:

Date of issue: 2007-01-20

Revalidation 9.3 a)	Valid until 2010-01-20	Revalidation 9.3 b)	Valid until 2009-01-20	Revalidation 9.3 b)	Valid until 2007-07-20

Revalidation for qualification by examiner or examining body for the following 2 years [refer to 9.3 b)]

Date	Signature	Position or title

Confirmation of the validity by employer/welding coordinator/examiner or examining body for the following 6 months [refer to 9.2)]

Date	Signature	Position or title

Welder's qualification test certificates (AWS D1.1, 2000, p. 307).

WELDER, WELDING OPERATOR, OR TACK WELDER QUALIFICATION TEST RECORD

Type of Welder ____________________

Name ____________________ Identification No. ____________________

Welding Procedure Specification No. __________ Rev __________ Date __________

Variables	Record Actual Values Used in Qualification	Qualification Range
Process/Type [Table 4.10, Item (1)]		
Electrode (single or multiple) [Table 4.10, Item (8)]		
Current/Polarity		
Position [Table 4.10, Item (4)]		
Weld Progression [Table 4.10, Item (6)]		
Backing (YES or NO) [Table 4.10, Item (7)]		
Material/Spec.	to	
Base Metal		
Thickness: (Plate)		
Groove		
Fillet		
Thickness: (Pipe/tube)		
Groove		
Fillet		
Diameter: (Pipe)		
Groove		
Fillet		
Filler Metal [Table 4.10, Item (3)]		
Spec. No.		
Class		
F-No. [Table 4.10, Item (2)]		
Gas/Flux Type [Table 4.10, Item (3)]		
Other		

VISUAL INSPECTION (4.8.1)

Acceptable YES or NO _____

Guided Bend Test Results (4.30.5)

Type	Result	Type	Result

Fillet Test Results (4.30.2.3 and 4.30.4.1)

Appearance ____________________ Fillet Size ____________________

Fracture Test Root Penetration ____________________ Macroetch ____________________

(Describe the location, nature, and size of any crack or tearing of the specimen.)

Inspected by ____________________ Test Number ____________________

Organization ____________________ Date ____________________

RADIOGRAPHIC TEST RESULTS (4.30.3.1)

Film Identification Number	Results	Remarks	Film Identification Number	Results	Remarks

Interpreted by ____________________ Test Number ____________________

Organization ____________________ Date ____________________

We, the undersigned, certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of section 4 of AWS D1.1, (__________) Structural Welding Code—Steel.
(year)

Manufacturer or Contractor ____________________ Authorized By ____________________

Form E-4 Date ____________________

Range of qualification for welding positions, EN ISO 9606-1 (mod. EN ISO 9606-1, p. 37).

Testing position	Range of qualification						
	PA Flat	PB Horizontal	OC Horizontal	PD Overhead	PE Overhear	PF Vertical up	PG Vertical down
PA	qualifies	does not qualifie	does not qualifie	does not qualifie	does not qualifie	does not qualifie	does not qualifie
PB	qualifies	qualifies	does not qualifie	does not qualifie	does not qualifie	does not qualifie	does not qualifie
PC	qualifies	qualifies	qualifies	does not qualifie	does not qualifie	does not qualifie	does not qualifie
PD	qualifies	qualifies	qualifies	qualifies	qualifies	does not qualifie	does not qualifie
PE (plate)	qualifies	qualifies	qualifies	qualifies	qualifies	does not qualifie	does not qualifie
PF (plate)	qualifies	qualifies	does not qualifie	does not qualifie	does not qualifie	qualifies	does not qualifie
PH (pipe)	qualifies	qualifies	qualifies	qualifies	qualifies	qualifies	does not qualifie
PG (plate)	does not qualifie	does not qualifie	does not qualifie	does not qualifie	does not qualifie	does not qualifie	qualifies
PJ (pipe)	qualifies	qualifies	does not qualifie	qualifies	qualifies	does not qualifie	qualifies

Range of qualification for welding positions, EN ISO 9606-1 (mod. EN ISO 9606-1, p. 37).

Testing position	Range for qualification				
	PA Flat	PC Horizontal	PE Overhead	PF Vertical up	PG Vertical down
PA	qualifies	does not qualifie	does not qualifie	does not qualifie	does not qualifie
PC	qualifies	qualifies	does not qualifie	does not qualifie	does not qualifie
PE (plate)	qualifies	qualifies	qualifies	does not qualifie	does not qualifie
PF (plate)	qualifies	does not qualifie	does not qualifie	qualifies	does not qualifie
PH (pipe)	qualifies	does not qualifie	qualifies	qualifies	does not qualifie
PG (plate)	does not qualifie	does not qualifie	does not qualifie	does not qualifie	qualifies
PJ (pipe)	qualifies	does not qualifie	qualifies	does not qualifie	qualifies
H-L045	qualifies	qualifies	qualifies	qualifies	does not qualifie
J-L045	qualifies	qualifies	qualifies	does not qualifie	qualifies

ANNEX VIII

Range of qualification for welding positions, AWS D1.1 (Mod. AWS D1.1, 2000, p. 138).

Range of qualification for welding positions for butt and fillet welds (AWS D1.1, 2000, p. 138)															
Qualification test			Production plate welding qualified			Production pipe welding qualified					Production box tube welding qualified				
						Butt Groove		T-, Y-, K-Groove			Butt Groove		T-, Y-, K-Groove		
Profile	Weld type	Position	Groove CJP	Groove PJP (Partial joint penetration)	Fillet	CJP	PJP	CJP	PJP	Fillet	CJP	PJP	CJP	PJP	Fillet
Plate	CJP Groove (Complete joint penetration)	1G	F	F	F, H	F	F		F	F, H	F	F		F	F, H
		2G	F, H	F, H	F, H	F, H	F, H		F, H	F, H	F, H	F, H		F, H	F, H
		3G	F, H, V	F, H, V	F, H, V	F, H, V	F, H, V		F, H, V	F, H, V	F, H, V	F, H, V		F, H, V	F, H, V
		4G	F, OH	F, OH	F, H, OH	F, OH	F, OH		F, OH	F, H, OH	F, OH	F, OH		F, OH	F, H, OH
		3G + 4G	All	All	All	All	All		All	All	All	All		All	All
	Fillet	1F			F					F					F
		2F			F, H					F, H					F, H
		3F			F, H, V					F, H, V					F, H, V
		4F			F, H, OH					F, H, OH					F, H, OH
		3F + 4F			All					All					All
	Plug/Slot		Qualifies welding for only the position tested												
Tubular	CJP Groove	1G rotated	F	F	F, H	F	F		F	F, H	F	F		F	F, H
		2G	F, H	F, H	F, H	F, H	F, H		F, H	F, H	F, H	F, H		F, H	F, H
		5G	F, V, OH	F, V, OH	F, V, OH	F, V, OH	F, V, OH		F, V, OH	F, V, OH	F, V, OH	F, V, OH		F, V, OH	F, V, OH
		2G+5G	All	All	All	All	All		All	All	All	All		All	All
		6G	All	All	All	All	All		All	All	All	All		All	All
		6GR	All	All	All	All	All	All	All	All	All	All	All	All	All
	Fillet	1F rotated			F					F					F
		2F			F, H					F, H					F, H
		2F rotated			F, H					F, H					F, H
		4F			F, H, OH					F, H, OH					F, H, OH
		5F			All					All					All

Example WPS layouts (AWS D1.1, 2000, p. 300).

WELDING PROCEDURE SPECIFICATION (WPS) Yes ☐
PREQUALIFIED ________ QUALIFIED BY TESTING ________
or PROCEDURE QUALIFICATION RECORDS (PQR) Yes ☐

Identification # ________
Revision ______ Date ______ By ______
Authorized by ________ Date ______
Type—Manual ☐ Semi-Automatic ☐
Machine ☐ Automatic ☐

Company Name ________
Welding Process(es) ________
Supporting PQR No.(s) ________

JOINT DESIGN USED
Type:
Single ☐ Double Weld ☐
Backing: Yes ☐ No ☐
Backing Material:
Root Opening ______ Root Face Dimension ______
Groove Angle: ______ Radius (J–U) ______
Back Gouging: Yes ☐ No ☐ Method ______

POSITION
Position of Groove: ______ Fillet: ______
Vertical Progression: Up ☐ Down ☐

ELECTRICAL CHARACTERISTICS

Transfer Mode (GMAW) Short-Circuiting ☐
Globular ☐ Spray ☐
Current: AC ☐ DCEP ☐ DCEN ☐ Pulsed ☐
Other ________
Tungsten Electrode (GTAW)
Size: ______
Type: ______

BASE METALS
Material Spec. ________
Type or Grade ________
Thickness: Groove ______ Fillet ______
Diameter (Pipe) ________

FILLER METALS
AWS Specification ________
AWS Classification ________

TECHNIQUE
Stringer or Weave Bead: ________
Multi-pass or Single Pass (per side) ________
Number of Electrodes ________
Electrode Spacing Longitudinal ______
Lateral ______
Angle ______

SHIELDING
Flux ______ Gas ______
Composition ______
Electrode-Flux (Class) ______ Flow Rate ______
______ Gas Cup Size ______

Contact Tube to Work Distance ________
Peening ________
Interpass Cleaning: ________

PREHEAT
Preheat Temp., Min ________
Interpass Temp., Min ______ Max ______

POSTWELD HEAT TREATMENT
Temp. ________
Time ________

WELDING PROCEDURE

Pass or Weld Layer(s)	Process	Filler Metals		Current		Volts	Travel Speed	Joint Details
		Class	Diam.	Type & Polarity	Amps or Wire Feed Speed			

Example WPS layouts (EN ISO 15614-1, 2012, p. 51).

Record of weld test

Location:

Manufacturer's pWPS No:

Manufacturer's WPQR No:

Manufacturer:

Welder's Name:

Mode of Metal Transfer:

Joint Type and Weld:

Weld Preparation Details (Sketch)*:

Examiner or examining body:

Method of Preparation and Cleaning:

Parent Material Specification:

Material Thickness (mm):

Outside Pipe Diameter (mm):

Welding Position:

Joint Design	Welding Sequences

Welding Details

Run	Welding Process	Size of Filler Material	Current A	Voltage V	Type of current/ Polarity	Wire Feed Speed	Travel Speed*	Heat input*	Metal transfer

Filler Material Designation and Make:

Any Special Baking or Drying:

Gas/Flux: shielding

backing:

Gas Flow Rate – Shielding:

Backing:

Tungsten Electrode Type/Size:

Details of Back Gouging/Backing:

Preheat Temperature:

Interpass Temperature:

Post-Heating:

Post-Weld Heat Treatment:

(Time, Temperature, Method:

Heating and Cooling Rates*):

Other information* e.g.:

Weaving (maximum width of run):

Oscillation: amplitude, frequency, dwell time

Pulse welding details:

Distance contact tube/workpiece:

Plasma welding details:

Torch angle:

. . . .

Manufacturer

Name, date and signature

. . . .

Examiner or examining body

Name, date and signature

* If required.

Comparison of preparation grades (EN ISO 8501-3, 2007, p. 10–13; AWS D1.1, 2000, p. 172; ASME B31.1, 2007, p. 75).

EN ISO				ASME and AWS
Type of imperfection	Preparation grades			No preparation grades
Description	P1	P2	P3	
1 Welds				
1.1 Welding spatters	Surface shall be free of all loose welding spatter	Surface shall be free of all loose and lightly adhering welding spatter	Surface shall be free of all welding spatter	Spatters shall be removed. Tightly adherent spatter remaining after the cleaning operation is acceptable. (AWS D1.1, 2000, p. 172.)
1.2 Weld ripple/profile	No preparation	Surface shall be dressed (e.g. by grinding) to remove irregular and sharp-edged profiles	Surface shall be fully dressed, i.e. smooth	Welds shall be sufficiently free from coarse ripples. (ASME B31.1, 2007, p. 75.)
1.3 Welding slag	Surface shall be free from welding slag	Surface shall be free from welding slag	Surface shall be free from welding slag	Slag shall be removed from all completed welds. (AWS D1.1, 2000, p. 172.)
1.4 Undercut	No preparation	Surface shall be free from sharp or deep undercuts	Surface shall be free from undercuts	
1.5 Weld porosity	No preparation	Surface pores shall be sufficiently open to allow penetration of paint, or dressed out	Surface shall be free from visible pores	
1.6 End craters	No preparation	End craters shall be free from sharp edges	Surface shall be free from visible end craters	

Comparison of preparation grades (EN ISO 8501-3, 2007, p. 10–13; AWS D1.1, 2000, p. 172; ASME B31.1, 2007, p. 75).

EN ISO				ASME and AWS
Type of imperfection	Preparation grades			No preparation grades
Description	P1	P2	P3	
2 Edges				
2.1 Rolled edges	No preparation	No preparation	Edges shall be rounded with a radius of not less than 2mm (see ISO 12944-3)	
2.2 Edges made by punching, shearing, sawing or drilling	No part of the edges shall be sharp; the edge shall be free from fins	No part of the edge shall be sharp; the edge shall be free from fins	Edges shall be rounded with a radius of not less than 2mm (see ISO 12944-3)	
2.3 Thermally cut edges	Surface shall be free of slag and loose scale	No part of the edge shall have an irregular profile	Cut face shall be removed and edges shall be rounded with a radius of not less than 2 mm (see ISO 12944-3)	
3 Surfaces generally				
3.1 Pits and craters	Pits and craters shall be sufficiently open to allow penetration of paint	Pits and craters shall be sufficiently open to allow penetration of paint	Surface shall be free from pits and craters	
3.2 Shelling NOTE: In English terms “slivers” and “hackles” are also used to describe this type of imperfection	Surface shall be free from lifted material	Surface shall be free from visible shelling	Surface shall be free from visible shelling	

Comparison of preparation grades (EN ISO 8501-3, 2007, p. 10–13; AWS D1.1, 2000, p. 172; ASME B31.1, 2007, p. 75).

EN ISO				ASME and AWS
Type of imperfection	Preparation grades			No preparation grades
Description	P1	P2	P3	
3.3 Roll overs/roll laminations/cut laminations	Surface shall be free from lifted material	Surface shall be free from visible roll-overs/laminations	Surface shall be free from visible roll-overs/laminations	
3.4 Rolled-in extraneous matter	Surface shall be free from rolled-in extraneous matter	Surface shall be free from rolled-in extraneous matter	Surface shall be free from rolled-in extraneous matter	
3.5 Grooves and gouges formed by mechanical action	No preparation	The radius of grooves and gouges shall be not less than 2 mm	Surface shall be free from grooves, and the radius of gouges shall be greater than 4 mm	
3.6 Indentations and roll marks	No preparation	Indentations and roll marks shall be smooth	Surface shall be free from indentations and roll marks	