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Regulation applying to welding of pressure equipment – a comparative study

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Background

Small and medium size stocked components intended for nuclear applications are often manufactured and welded in accordance with the rules stated in ASME Boiler and Pressure Vessel Code Section III and IX. However, the Swedish regulation SSMFS 2008:13 specifies that welding of systems and components for nuclear applications as well as welding operations in connection with installations in nuclear facilities must be qualified and controlled in accordance with European and/or ISO standards. Changing the manufacturing process for these components in accordance with the European standards is costly, time consuming and often even undesirable due to the increased risks of making mistakes during manufacturing using new and partly unfamiliar working instructions.

A comparison between European standards and ASME Code Section III and IX regarding rules for manufacturing and welding of pressure equipment is therefore of great interest.

Objectives

The aim of this study is to perform a detailed comparison between the European Pressure Equipment Directive[1] (PED) and ASME Boiler and Pressure Vessel Code Section III and IX. Areas of special interest are (1) rules for welding qualifications, (2) monitoring of welding activities during manufacturing and (3) the extent of supervision by independent inspection bodies required by the two quality systems.

Results

The PED was in force in November 1999 and has been mandatory in European Union Member States since May 2002. Most of the standards referred to in the PED are relatively new although some of the standards were adopted in the early 1990s. On the other hand, the ASME B&PV Code has been used for a long time now and is the result of several decades of industrial experiences.

The authors present a comparison of requirements for welding procedure qualification as well as a comparison of welder qualifications. The requirements for welders and welding operators are more similar than in relation to welding procedure qualification. The SS-EN standard often requires more examinations and tests for welding procedure qualifications. However, most of the SS-EN qualifications cover a larger scope of application resulting in a smaller number of procedure qualifications. Although it may be concluded that both ASME Code and SS-EN standards ensure an almost equivalent level of intrinsic quality, there are numerous differences between their requirements for procedure qualifications. These differences are also discussed in the report.

The range of approval for welder qualifications depends on essential variables and is sometimes less restricted in ASME Code (IX) but so-

1. The European Pressure Equipment Directive with the product standards SS-EN 13445/13480 and connecting SS-EN and SS-EN ISO standards for welding.

metimes less restricted in the SS-EN standard (287-1). In practice, it is sometimes admitted that an ASME IX welder qualification is replaced by a SS-EN 287-1 qualification and vice versa.

The different approaches taken by the PED and ASME B&PV Code for quality assurance are also illustrated by their rules for the quality system of welding companies. In this respect, the requirements are fundamentally different. The PED specifies that a Notified Body must carry out the assessment of the quality system, and under the ASME Code an Authorized Inspection Agency must carry out the assessment of the quality system. The requirements imposed by the PED imply that surveys of welding activities by the Notified Body are only possible when the manufacturer selects this kind of approach. On the other hand, ASME Code Section III specifies that surveys of welding activities performed by an Authorized Inspector are mandatory. The report discusses the details and consequences of the different approaches.

It is pointed out in the report that the two regulatory frameworks must be understood as indivisible. The design and manufacture of pressure vessels requires the application of all relevant parts of the standard in order to fulfill the requirements of the standard. It is only permitted to use other standards in exceptional cases when a standard gives no information on specific parts of pressure vessels. In such a case, special attention should be given to ensure that application of the other standard(s) is made consistent with the safety philosophy and general safety requirements. From this perspective, it is not a valid option to only apply the technical requirements of ASME Code Section III, without the formal and administrative requirements (such as appropriate stamping, survey by an Authorized Inspections Agency, certification by a Registered Professional Engineer (RPE), etc.).

Project information

Contact person at SSM: Peter Ekström
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Contents

Summary

Since no fewer than ten years, the European Pressure Equipment Directive together with the related SS-EN[1] standards provides the regulatory framework in the European Union for the construction of pressure components. As such, the Pressure Equipment Directive is not applicable to the construction of nuclear pressure equipment, i.e., to pressure equipment whose failure may cause release of radioactivity. However the following question may be raised especially when new projects of nuclear installations are contemplated in the European Union: under which conditions the Pressure Equipment Directive and the related SS-EN standards might be used for constructing nuclear pressure equipment? A special case related to this issue is the potential use of the SS-EN standards for qualification of welding procedure specifications and welders for the manufacturing of nuclear pressure equipment. With regard to this, the present report provides a comparison between the requirements of Section IX of the ASME Boiler and Pressure Vessel Code when used for the construction of nuclear pressure components in conformity to Section III, Division 1 and the requirements of the SS-EN Standards for welding and welding qualification when used for the construction of pressure components in conformity to the Pressure Equipment Directive. More specifically, the report provides a detailed comparison between the European Pressure Equipment Directive and ASME Boiler and Pressure Vessel Code Section III and Section IX regarding welding, rules for welding qualifications, monitoring of welding activities during fabrication. It also compares the extent of supervision by independent inspection bodies required by the two quality systems.

While Section III of the ASME Code is a construction code that provides rules governing the construction of nuclear pressure equipment, the Pressure Equipment Directive provides rather qualitative technical requirements formulated as “essential safety requirements”. In the same way, Section IX of the ASME Code provides the technical requirements applicable to the welding qualifications. For their part, the standards provide technical solutions for meeting the requirements of the Directive. In particular, numerous SS-EN Standards related to the welding qualification have been issued. The main differences between the ASME Boiler and Pressure Vessel Code and the Pressure Equipment Directive are detailed in Chapter 2 of the report.

When compared to the approach taken by the Pressure Equipment Directive, the approach taken by Section III of the ASME Code is characterized by the key role of the quality assurance program of the manufacturer and the survey thereof by the Authorized Inspection Agency. Under the requirements of the Pressure Equipment Directive and the related SS-EN Standards, the survey is governed indirectly by the Directive and directly by the conformity assessment procedure selected by the manufacturer. These typical characteristics of Section III of the ASME Code and the Pressure Equipment Directive with regard to quality assurance are developed in Chapter 3.

The differences in quality assurance requirements between Section III of the ASME Code and the Pressure Equipment Directive are exemplified in the rules and requirements for surveillance and inspection of activities related to welding, as described in Chapter 4.

Welding procedure qualifications and welder applications in conformity to Section IX of the ASME Code or to the series of the SS-EN Standards related to welding share common features, as shown in Chapter 5. The use of essential and non-essential variables per welding process, the grouping of the base metals in order to

[1] SS-EN standards are EN standards adopted as Swedish standards. SS-EN will be used in this report as designation for EN-standards which are also adopted as Swedish standards.

reduce the number of qualifications and the definition of welding positions are examples thereof. The practical implementation of these common features leads however to differences.

As far as the qualification of the welding procedures is concerned, it should be emphasized that the SS-EN approach uses numerous standards depending on the specific objective, the welding process or the base material. For its part, Section IX of the ASME Code provides in one volume the complete set of requirements but these are to be completed by the additional requirements provided in Section III depending on the ASME Code Class of the concerned pressure component. Although it may be concluded that both Section III and the SS-EN Standards ensure an almost equivalent level of intrinsic quality of the procedure qualifications, there are numerous differences between their respective requirements, which are detailed in Chapter 6.

For the qualification of the welders, the requirements of Section IX of the ASME Code and these of the SS-EN Standards are more similar than for the qualification of the welding procedures. A more detailed comparison is provided in Chapter 7.

Two specific parameters affecting the qualification of the welding procedure are the preheat and postweld heat treatment. Those are essential variables as the heat treatment can affect the strength and toughness of the welded joints, and the level of residual stress. As detailed in Chapter 8, most of the requirements of Section IX of the ASME Code and these of the SS-EN Standards are similar.

The different approach taken by the ASME Boiler and Pressure Vessel Code and the Pressure Equipment Directive for quality assurance is also illustrated by their respective rules and requirements for the quality system of the welding companies. When compared to the assessments of the manufacturer’s quality system by the Notified Body as required by the Pressure Equipment Directive, the weight and impact of the assessment of the manufacturer’s quality system by the Authorized Inspection Agency under the requirements of the ASME Code are fundamentally different. An important characteristic of the Pressure Equipment Directive is that the assessment and survey of the manufacturer’s quality system by the Notified Body depends on the risk category of the pressure equipment and the conformity assessment procedure selected by the manufacturer. These differences are developed in Chapter 9.

The applicable requirements of the ASME Boiler and Pressure Vessel Code and Pressure Equipment Directive for the inspection of the welded joints do not differ significantly as shown in Chapter 10. However, it should be emphasized that Section III of the ASME Code considers the safety function of the pressure equipment by specifying different requirements depending on the ASME Code Class.

Some typical issues related to the practical implementation of the monitoring and supervision of the welding processes are shortly described in Chapter 11.

Even if it may happen that certain requirements of the Pressure Equipment Directive or the ASME Code may be found impractical in some specific cases, these both do not include provisions on how relief from their respective requirements might be envisaged. Nevertheless documents issued by the ASME Boiler and Pressure Vessel Committee and the European Commission and referred to in Chapter 12 are sometimes useful when difficulties for meeting the requirements are encountered.

The report is written as a brief factual description of the similarities and differences of the approaches taken respectively by the ASME Boiler and Pressure Vessel Code and the Pressure Equipment Directive for the activities related to the welding of pressure equipment. Some personal recommendations and conclusions of the Authors are nevertheless provided in Chapter 13.

1. Introduction

Under contract 2013-1271 granted by Strålsäkerhetsmyndigheten (SSM) to Vinçotte Nuclear Safety (VNS), the latter shall draw up *a report providing a detailed comparison between the European Pressure Equipment Directive (PED) and ASME Boiler and Pressure Vessel Code Section III and Section IX regarding welding, rules for welding qualifications, monitoring of welding activities during fabrication, etc*. It is also required that *the extent of supervision by independent inspection bodies required by the two quality systems shall be compared and evaluated both from a practical and a regulatory point of view*.

More precisely the SSM technical specifications require the report should include as a minimum the following:

- *Rules and requirements for surveillance and inspection of welding procedure qualifications.*
- *Rules and requirements for surveillance and inspection of qualification of welders and operators.*
- *Rules and requirements for welding procedure qualifications, including a detailed comparison of the applicable standards regarding arc welding of steel.*
- *Rules and requirements for qualification of welders, including a detailed comparison of the applicable standards regarding arc welding of steel.*
- *Rules, requirements and recommendations for preheating and post weld heat treatments.*
- *Rules and requirements concerning the quality system for welding companies.*
- *Rules and requirements for surveillance and inspection of welding processes during fabrication of pressure equipment.*
- *Practical experiences of monitoring and supervision of welding processes during fabrication of pressure equipment.*
- *Interpretations, guidelines, code cases and any relaxations of requirements.*
- *Conclusions and recommendations*.

VNS used this specified minimum content as the backbone of his report. However he also added for purpose of clarity two introductory chapters related to the ASME B&PV Code and PED and their respective requirements for quality assurance. An important feature of Section III of the ASME B&PV Code is that it addresses the construction of nuclear pressure vessels and it also requires the manufacturer to implement a quality assurance program. For its part, the PED is not applicable to items specifically designed for nuclear use and does not require each manufacturer to have a quality system or quality assurance program.

The report was not written to provide an exhaustive comparison between Sections IX and III of the ASME B&PV Code on one side and the PED and EN standards on the other side for the matters related to welding. It has rather been written to allow the reader to get acquainted with their main similarities and differences but also to identify the areas where, despite the apparent similarity, some differences may exist.

It should be highly emphasized that the reading of the report does not replace the careful reading of the analyzed codes and standards. With regard to that, the report should rather be considered as a guide.

The present issue of the report is the final version. It includes the modifications to the draft version as per the comments raised by SSM.

2. Short introduction to the ASME B&PV Code and the PED

2.1. Respective scopes of the ASME B&PV Code and PED

The American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME B&PV Code or ASME Code) provides a set of rules governing the construction of boilers, pressure vessels, transport tanks and nuclear components, and the inservice inspection of nuclear components and transport tanks. The rules are rules of safety related only to pressure integrity and consist in mandatory requirements, specific prohibitions, and nonmandatory guidance. The ASME B&PV Code includes ten Sections. The sections of interest for this report are Section II '*Materials*' [1], Section III, Division 1 '*Rules for Construction of Nuclear Facility Components*' [2], Section V '*Nondestructive Examination*' [3], and Section IX '*Welding and Brazing Qualifications' [4]*.

The European Union Pressure Equipment Directive 97/23/EC [5], referred to as PED, provides for an adequate legislative framework on European level for equipment subject to a pressure hazard. The Pressure Equipment Directive arises from the European Community's Program for the elimination of technical barriers to trade and is formulated under the "*New Approach to Technical Harmonization and Standards*". Its purpose is to harmonize national laws of Member States regarding the design, manufacture, testing and conformity assessment of pressure equipment and assemblies of pressure equipment. It therefore aims to ensure the free placing on the market and putting into service of the equipment within the European Union. Formulated under the New Approach the Directive provides for a flexible regulatory environment that does not impose any detailed technical solution.

The pressure components included in the scope of the ASME B&PV Code are given in the respective Sections of the Code. For instance the power boilers included in the scope of Section I [6] of the ASME B&PV Code are defined in the Preamble to this Section. The scope of Section VIII Division 1 [7] of the ASME B&PV Code for the construction of pressure vessels is given in paragraph U-1 of the Introduction. The scope of Section III is defined in Article NCA-1000 of Subsection NCA of Section III [8]. As stated in Subarticle NCA-1100, *the rules [of Section III] constitute requirements for the design, construction, stamping and overpressure protection of items used in nuclear power plants and other nuclear facilities*.

The PED [5] addresses the pressure equipment presenting a significant hazard due to pressure. Although paragraph 3 in Article 1 of the PED excludes numerous pressure equipment, the scope of application of the Directive is larger than the scope of the ASME B&PV Code. The PED is indeed applicable not only to the heavy equipment manufactured in the traditional sector of the boiler, pressure vessel and piping industries but also to consumer goods.

Nevertheless it is important to mention that, as per point 3.8 in Article 1 of the PED, the Directive is not applicable to "*items specifically designed for nuclear use, failure of which may cause an emission of radioactivity*". For this pressure equipment, the national laws of the Member States of the EU are applicable (see paragraph 2.3 below).

2.2. Main differences between the ASME B&PV Code and PED

The fundamental difference between the ASME B&PV Code and the PED is that, unlike the ASME &PV Code, the PED is not a construction code. The applicable technical requirements in the PED are given in Annex 1 to the Directive and are formulated as “*essential safety requirements*” that are related to the design, manufacturing and materials. They are expressed mainly in a qualitative way through general objectives. The only numerical values provided in the essential safety requirements are found in point 7 of Annex 1. They concern the safety coefficient to be applied on the tensile properties of the material to define the maximum permissible general membrane stress, the maximum joint coefficient for welded joints, the multiplying coefficient used in the determination of the hydrostatic test pressure and some minimum values to be obtained in material mechanical tests for the characterization of the ductility and impact resistance.

A major difference between the ASME B&PV Code and the PED is related to the Quality Assurance requirements, as discussed in paragraph 3 below. There are other main differences between the ASME B&PV Code and the PED, most of them being due to the differences between the ASME B&PV Code and the essential safety requirements of the PED. Two of those differences are summarized hereafter, i.e., the hazard analysis and the operating procedures. They are related to requirements of the PED that do not have any equivalent in the ASME B&PV Code.

Point 3 in the Preliminary Observations of Annex 1 to the PED requires the manufacturer to produce and document a hazard analysis in order to identify *those [hazards] which apply to the equipment on account for pressure* under all the conditions which are reasonably foreseeable. Practically, for all the foreseeable operating conditions, the potential failure modes of the equipment and their causes are identified. The hazard analysis determines the applicable essential safety requirements and the means for eliminating or preventing the pressure related hazards. Then the manufacturer must *design and construct [the equipment] taking into account of his analysis.*

Clause 3.4 in Annex 1 to the PED requires the manufacturer to provide operating instructions. In particular, the operating instructions provide the prescriptions to be met for coping with the residual hazards from the hazard analysis.

2.3. Legal status of the ASME B&PV Code and PED

In the North-American (U.S. and Canada) context, a Standard can be defined as a set of technical definitions and guidelines that function as instructions for designers, manufacturers, operators, or users of equipment. A Standard becomes a Code when it has been adopted by one or more governmental bodies and is enforceable by law. As such, the ASME B&PV Code is a Standard. However, various Sections of the ASME B&PV Code have been adopted into law, becoming so a Code, by all the 50 States of the U.S. and all the Canadian provinces.

In US, Title 10, Chapter I, of the *Code of Federal Regulations* (CFR) [9] contains the regulations of the US Nuclear Regulatory Commission (NRC). As per § 50.55a, *Codes and standards*, of Title 10 of the U.S. Code of Federal Regulations (10CFR), the ASME Boiler and Pressure Vessel Code, Section III, Division 1 [2] (excluding Nonmandatory Appendices), the ASME Code for the Construction of Nuclear Facility Components, and Section XI [10], the ASME Code for Inservice Inspection Nuclear Power Plant Components are incorporated by reference in the U.S. Code of Federal Regulations. By their *incorporation by reference*, both Sections of the ASME B&PV Code have the same legal status as a regulation.

Outside the US and Canada, many countries have accepted the ASME B&PV Code. In these countries, the ASME Code is applied in many different ways, only seldom to its full extent. For instance, (i) the manufacturer does not have the ASME Certificate of Authorization, (ii) there is no involvement of ASME Authorized Inspection Agency, therefore no ASME stamp, or (iii) only design calculations are made in accordance with the ASME Code.

In the European Union Member States, the PED [5] was in force on November 29, 1999 and is mandatory from May 30, 2002. As for any other new harmonized directive, Member States were required to adopt the PED by incorporating the provisions in the Directive into national law that replaces the national laws, standards, and conformity assessment procedures. Any manufacturer of pressure equipment within the scope of the PED and placed on the EU market is required to affix the CE marking indicating that the equipment is in compliance with the essential safety requirements of the Directive.

2.4. Use of ASME B&PV code and PED for constructing nuclear pressure equipment PED

Referring to para 2.3 above, in U.S., the systems and components of Boiling and Pressurized Water Cooled Nuclear Power Reactors must meet the requirements of the Section III, Division 1 [2] of the ASME B&PV Code (ASME Code, Section III or ASME III) for their construction. This also means that the requirements of the standards referred to in Section III, Division 1 also apply to the construction of nuclear systems and components. In particular, Section II (Materials) [1], Section V (Nondestructive Examination) [3] and Section IX (Welding and Brazing Qualifications) [4] make also part of the regulations. Paragraph 50.55a, *Codes and standards*, of 10CFR [9] also specifies the conditions to which Section III of the ASME B&PV Code is subjected.

It should also be emphasized that the requirements of Section III, Division 1 as well as these referred to in that Section are not the only requirements applicable to the construction of nuclear systems and components in US. Other requirements are specified in 10 CFR: for instance, fracture toughness requirements for ferritic materials of pressure-retaining components of the reactor coolant pressure boundary of light water nuclear power reactors are provided in Appendix G to Part 50 of 10 CFR [11]. Guidance is also provided in other documents issued by the US NRC, such as the Regulatory Guides [12] and the Standard Review Plans (NUREG-800): for instance the acceptable damping values found acceptable by the US NRC for use in the seismic response analysis of Seismic Category I nuclear power plant structures, systems, and components are provided in Regulatory Guide 1.61, *Damping Values for Seismic Design of Nuclear Power Plants* [14].

As mentioned in paragraph 2.1 above, the PED [5] is not applicable to the construction of nuclear pressure equipment, i.e., to pressure equipment whose failure may cause release of radioactivity. The exclusion of the nuclear pressure equipment from the scope of the PED is due to the fact the PED aims at preventing the pressure hazard only. With regard to that it is noteworthy that the French Nuclear Safety Authority has issued a regulation extending to nuclear pressure equipment the approach and essential requirements of the PED while adding specific nuclear and radioactivity safety requirements. This regulation, referred to as the December 12, 2005 Order related to Nuclear Pressure Equipment [15], also introduces three levels (N1 to N3) depending in particular on the magnitude of the potential release of radioactivity when assuming failure of the equipment.

2.5. Hazard Categories (or Risk categories) in PED and Code Classes in ASME Code Section III

The PED [5] provides the classification of pressure equipment within its scope into 4 Hazard Categories (I to IV) depending on the pressure hazard. Category I relates to the lowest and Category IV relates to the highest hazard Category. Equipment below Category I fall under a separate fifth category for which "Sound Engineering Practice" (SEP) is applicable.

In order to determine which Category an equipment falls into, the manufacturer needs to identify: (i) the type of equipment (vessel, steam generators or piping), (ii) the state of the intended fluid contents (gaseous or liquid), and (iii) the fluid group of the intended contents (Group 1 or Group 2). Group 1 comprises those fluids classified according to the Directive on the Classification of Dangerous Substances (67/548/EC [16]). Group 2 comprises all other fluids including water and steam. Annex II in the PED contains nine charts for determining the Category of a pressure equipment. On each of these charts, maximum allowable pressure (PS) (bar) is plotted against, for vessels, the volume in liters, V(L), and for piping and accessories expressed in diameter, the nominal size (DN). These nine charts have up to five bands relating to the different Categories (SEP, I, II, III or IV). Demarcation lines on each chart indicate the upper limit of maximum allowable pressure and volume or nominal size for each Category. The manufacturer has to plot the maximum allowable pressure and volume or nominal size for their piece of equipment on the relevant chart to identify which Category the item of equipment falls into. In general, the lower the pressure and volume, the lower the Category for the equipment.

Section III, Division 1, of the ASME B&PV Code [2] contains three Subsections (NB, NC and ND) that provide criteria for the construction of Class 1, Class 2 and Class 3 components respectively. It should be emphasized that the classification of nuclear pressure equipment into Classes according to Section III of the ASME B&PV Code has no connection with the classification into Hazard Categories according to the PED. The Code Classes of Section III are linked to the Quality Group Classification of the components of nuclear power plants. The Quality Group Classification addresses the importance to safety. Generic Design Criterion 1 in Appendix A to Part 50 of 10CFR [17] requires the systems and components important to safety to be constructed to quality standards commensurate with the importance of the safety functions to be performed. Regulatory Guide 1.26, *Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants* [18], describes a quality classification system. Four Quality Groups (A, B, C, and D) are defined, Group Quality A relating to the components that are the most important to safety. Regulatory Guide 1.26 also provides the quality standards found acceptable by the NRC for satisfying General Design Criterion 1: ASME Section III, Subsection NB (Class 1 components) for pressure equipment of Quality Group A, ASME Section III, Subsection NC (Class 2 components) for pressure equipment of Quality Group B, and ASME Section III, Subsection ND (Class 3 components) for pressure equipment of Quality Group C.

2.6. Essential requirements in PED and Harmonized EN Standards

A pressure equipment that is to be put into service within the European Union has to meet the Essential Safety Requirements set forth in Annex I of the PED [5] (see para 2.2 above). However, as for any other Directive issued by the European Commission under the *New Approach*, the PED does not describe the means to meet these requirements.

The European Standards (ENs) that play a role in the translation of the New Approach Directives into technical solutions (or technical interpretations) are referred to as the Harmonized Standards: the Harmonized Standards are European Standards that support the European legislation.

European Standards have been developed to replace the national standards issued in the past by the national standard bodies of each Member State. Not all the European Standards are Harmonized Standards. The Harmonized Standards have been mandated by the European Commission and address the essential requirements of the New Approach Directives. Notification of the development of a Harmonized Standard is published in the *Official Journal of the European Communities*. Not all the European Standards are Harmonized Standards since a European Standard is not necessarily directed toward essential requirements. Harmonized Standards contain an Appendix Z which defines which Directive and Essential Safety Requirements the standard meets.

Presumption of Conformity is a legal concept surrounding the Harmonized Standards: when using a Harmonized Standard for designing and/or manufacturing a product, conformity with the essential requirements of the Directive addressed in the Harmonized Standard is presumed. The use of a Harmonized Standard by a manufacturer is voluntary: a manufacturer can elect to use a Harmonized Standard, or elect to use a non-Harmonized Standard (e.g., a US Standard) to meet essential requirements. When using a Harmonized Standard, the manufacturer is presumed in conformity with the Directive. On the contrary, using a standard that is not a Harmonized Standard imposes additional responsibilities to the manufacturer.

The most important Harmonized Standards related to the object of this report are given below. Other Harmonized Standards are referred to later in the report.

<u>Pressure equipment</u>

SS-EN 13445:2009	Parts 1 to 8, *Unfired pressure vessels* [19]
SS-EN 13480:2012	Parts 1 to 8, *Metallic industrial piping* [20]

<u>Welding procedures</u>

SS-EN ISO 15614-1,	*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 alloy*s [28].

<u>Personnel qualification</u>

SS-EN 287-1:2011,	*Qualification test of welders – Fusion welding – Part 1: Steel* [21]
SS-EN 473:2008,	*Non-destructive testing – Qualification and certification of NDT personnel – General principles* [22]

3. Quality Assurance requirements in ASME B&PV Code Section III and PED

3.1. Quality Assurance requirements in Section III of the ASME B&PV Code

In US, any supplier of equipment under Section III, Division 1 of the ASME B&PV Code [2] for the commercial nuclear market is required to have a Certificate of Authorization issued by the (ASME) *Society.* A supplier having the required Certificate is designated as a *Certificate Holder*. A Certificate Holder is allowed to use the Code Symbol Stamp to be applied on each item it constructs under his Certificate of Authorization. Qualification of a supplier as by the Society as a Certificate Holder requires implementation of a Quality Assurance program that meets the requirements of ASME Code, Section III, Subsection NCA [8], Article NCA-4000 and ASME Standard NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications* [23], which is referred to in Subsection NCA. Additionally, Appendix B to Part 50 of 10 CFR Part 50 [24] provides the regulatory framework for quality assurance program for the design and construction of nuclear power plants (and fuel reprocessing plants). The NRC endorses NQA-1 in Regulatory Guide 1.28, *Quality Assurance Program Criteria (Design and Construction* [25]. NQA-1 covers eighteen specific quality assurance requirements including items such as design control, control of purchased items and control of special processes, inspection, quality assurance records and audits. The Quality Assurance Program is a controlled system of planned and systematic actions required to provide adequate confidence that items designed and fabricated are in accordance with the rules of the ASME B&PV Code.

The implementation of a Quality Assurance Program requires the existence within the Certificate Holder organization of a quality assurance organization that is independent from to the design and manufacturing organizations and has equal authority. The Quality Assurance Program of the Certificate Holder is documented in a Quality Assurance Manual. The Quality Assurance Manual is a requirement of Section III of the ASME B&PV Code. It details the way the Code and NQA-1 requirements are converted into the Quality Assurance Program. The Quality Assurance Manual also defines the delineation of roles and responsibilities at the highest levels of the organization. Once the Quality Assurance Manual is in place, the high level roles and responsibilities must be further broken down into policies, procedures, and work instructions that direct and control the day-to-day activities required to design, manufacture and inspect the components.

A Certificate Holder is required to have an agreement with an *Authorized Inspection Agency* to provide inspection and audit services. An Authorized Inspection Agency is accredited by the Society in accordance with the provisions set forth in NQA-1. The Quality Assurance Program has to be evaluated and approved by the Society after review by the Authorized Inspection Agency with the participation of the Society. Once the Quality Assurance Program is approved, the Certificate of Authorization is issued by the Society. The Certificate of Authorization is a document that authorizes the Certificate Holder to perform the Code activities and to use an ASME Code Symbol Stamp for the specified scope of activity for a period of three years. The Authorized Inspection Agency is required to perform survey of the Code activities of the Certificate Holder as required by Article NCA-5000 of Subsection NCA in Section III of the ASME B&PV Code.

Using the terminology of Subsection NCA in Section III of the ASME B&PV Code, welding is a *special process*, i.e., a process, the results of which are highly dependent on the control of the process or skill of the operator, or both. The requirements of Subsection NCA relative to the special processes are provided in subparagraph NCA-4134.9 which states: *The Certificate Holder shall prepare instructions, procedures, drawings, checklists, travelers, or other appropriate documents, including the document numbers and revisions to which the process conforms, with space provided for reporting results of completion of specific operations at checkpoints of fabrication, manufacture, or installation. The documents shall include space for: a signature, initials, or stamp; the date that the activity was performed by the Certificate Holder's representative; the Authorized Nuclear Inspector's signature, initials, or stamp; and the date on which those activities were witnessed.*

Subparagraph NCA-4134.9 also refers to NQA-1 by stating that the provisions of NQA-1, Requirement 9, shall apply (see details in paragraph 9.1 below).

3.2. Quality Assurance requirements in the PED

The PED does not require each manufacturer to have a quality system or a quality assurance program. Depending on the Hazard Category, a product, production or complete quality assurance is required, whether or not combined with an EC type examination, an EC design-examination or design verification. The various conformance evaluation procedures are described in Annex III to the PED and are summarized in Table 1 below. It is seen that for any pressure component, the conformity assessment may be performed in according with a procedure that does not require Quality Assurance.

Table 1: Conformity assessment procedures permitted by PED

QA system	Without QA		QA according to SS-EN ISO-9000	
Fabrication	**Series**	**Unit**	**Series**	**Unit**
Category I	Module A: Internal production control			
Category II	Module A1: Internal manufacturing check with monitoring of the final assessment		Module D1: Production quality assurance (9002)	Module E1: product quality assurance (final inspection)
Category III	Module B: EC-type examination + module C1: Conformity to type	Module B1: EC-design examination + Module F: Product verification	Module B: EC-type examination + Module E: product quality assurance (final inspection) or: Module B1: EC-design examination + Module D: Production quality assurance (9002)	Module H: Full quality assurance (9001) or: Module B1: EC-design examination + Module D: Production quality assurance (9002)
Category IV	Module B: EC-type examination + Module F: Product verification	Module B: EC-unit verification	Module B: EC-type examination + Module D: Production quality assurance (9002)	Module H: Full quality assurance (9001) with design examination and special surveillance of final assessment

In most cases, quality management systems are certified. The scope of the ISO 9000 series specifies quality system requirements for design, development, production, installation and servicing. All elements, requirements, and provisions adopted by the manufacturer for the quality system must be documented in a systematic and orderly manner. This is done in the form of written measures, procedures and instructions. This documentation must make possible a uniform interpretation of the quality programs, quality plans, quality manuals and quality records.

Depending on the risk category the quality system modules are more or less conservative and strict. For Category II, the PED requirement is limited to the supervision of the quality system. For Categories III and IV the quality system must also guarantee that the pressure equipment conforms to the type or to the design that was separately laid down in an EC type-examination or EC design-examination. The initial quality assurance assessment and periodic supervision are the responsibility of the Notified Body.

If the manufacturer already has an existing quality system in accordance with the ISO 9000 and approved by another accreditation body, this system would form the basis for an assessment in accordance with the PED. The Notified Body will only be required to focus its review on those special elements which are normally not addressed in the ISO quality system, including Technical File, applied standards, and inspection techniques.

Many manufacturers of pressure equipment are certified ISO 9001 [26]. ISO 9001 has found general acceptability as a management and process standard for promoting customer satisfaction through establishing a system of quality assurance requirements that can be used by suppliers, irrespective of size, business type, product or service. Its ability to provide products that meet the technical and regulatory criteria and requirements is questionable. This universality necessitated regulated industries and their regulating bodies to develop supplementary requirements to be applied to the ISO 9001. In a letter sent to the US NRC dated November 4, 2002 (see SECY-03-0117 [27]), ASME cautioned that *although ISO 9001 may be initially appealing, ISO 9001 is a management or process standard and not a safety related standard. Requirements in NQA-1 are more definitive than ISO 9001 in areas such as design controls, independence of design verification, software controls, configuration control, audits and training, qualification and evaluation of personnel.*

4. Rules and requirements for surveillance and inspection of welder, welding operator and welding procedure qualifications

4.1. Introduction: Welding as a special process

Against the background of the quality assurance criteria, welding is listed under the heading of *special processes*. A *special process* is a process the results of which are highly dependent on the control of the process or the skill of the operators, or both, and in which the specified quality cannot be readily determined by inspection or test of the product. Welding is a special process because the quality of the process or product, hence conformity with the standard or construction code, cannot be measured or not completely verified after the welding is done. Non-destructive testing alone does not guarantee the structural integrity of a weld. Destructive testing should also be undertaken as well, but that is obviously impossible. An attempt is made to overcome this obstacle by first qualifying the process and also the operator(s). Consequently, all construction standards and codes provide for a "qualification" of the welding process and the operators. Using parameters similar to those applied during production (also called welding variables) a weld is obtained on a test piece, a simulation. According to the requirements of the applicable standard, the test piece then undergoes a non-destructive examination and/or destructive tests and an examination as part of the formal qualification of the reliability and quality of the process and/or the welder or welding operator.

Qualification requires surveillance and inspection activities. Two types of inspection and surveillance of the qualification activities are considered, from one side the inspection and surveillance by the manufacturer or his representative and on the other side the inspection and surveillance by the Third Party.

4.2. Particular features of ASME Code Section III and PED

Under the rules of Section III of the ASME B&PV Code [2] , and in addition to all inspections and surveillance requirements set forth in its respective Sections and Subsections the welding qualification operations, as all the other construction activities, are subject to a quality assurance program.
As mentioned in paragraph 3.1 above, manufacturers must operate such a system and successfully pass the assessment by the (ASME) *Society* in order to become *Certificate Holder* and *Stamp Holder*.
Welding operations are considered as processes, more in particular as special processes with quality assurance requirements included in Subsection NCA [8], and more specifically, in Subparagraph NCA-4134.9. This Subparagraph introduces also Requirement 9, Control of Special Processes, of the ASME NQA-1 [23]
The manufacturer's quality assurance is subject to periodic assessments (audits) by the (ASME) *Society* as well as by the monitoring by the *Authorized Inspection Agency* involved in the inspection of the equipment (see paragraph 3.1 above).

Under the rules of Section III of the ASME B&PV Code, the inspection and surveillance activities by the Authorized Inspector are governed by Subsubarticle NCA-

5220 in Subsection NCA [8] of Section III: The categories of Inspector's duties, as per NCA-5220 include:

> *"(b)" Monitoring of the Certificate Holder's Quality Assurance Program*
> *"(c)" Reviewing the Certificate Holder's qualification records*
> *"(e)" Witnessing or verifying in-process fabrication, non-destructive examination, and tests*

Subsubparagraph NCA-5270 also requires:

> *The Inspector shall witness in-process fabrication, non-destructive examinations and destructive tests, when feasible; alternatively, he shall check the examination and test records to determine the acceptability of the items involved*.

In the context of PED/EN, the survey of the qualification activities is indirectly governed by the PED and directly by the conformity assessment procedure(s) selected by the manufacturer (sees paragraph 3.2 and Table 1 above). Survey of the welding qualification activities based on the assessment of the quality system is only applicable when the manufacturer selects such an approach. Otherwise the traditional inspection routes apply (procedures A1, C1, F and G).
More specifically, assessment procedure G (EC unit verification for category IV equipment) requires the Notified Body to (see Annex III of the PED):

- approve the procedures for permanent joining of parts or check that they have been previously approved
- verify the qualifications or approvals required for the personnel in charge of the permanent joining.

4.3. Qualification in the context of Section III of the ASME B&PV Code

The basis for welding qualifications in the context of Section III of the ASME B&PV Code is Section IX, *Qualification standard for welding and brazing procedures, welders, brazers and welding and brazing operators* [4].
So for example, Paragraphs NB/NC/ND 4311 in respectively Subsections NB, NC and ND of Section III refer to Section IX: *Only those welding processes which are capable of producing welds in accordance with the welding procedure qualification requirements of section IX and this subsection may be used for pressure-retaining material or attachments thereto*.
Paragraphs NB/NC/ND -4321 also state: "*Each certificate holder is responsible for the welding done by his organization, and each Certificate Holder shall establish the procedure and conduct the tests required by this Article*[2] *and by section IX in order to qualify both, the welding procedures and the performance of welders and welding operators who apply these procedures*"

Surveillance under Section IX of the ASME B&PV Code (ASME Code Section IX or ASME IX) is governed by the following paragraphs:

- QW-300.2: *The basic premises of responsibility in regard to welding are contained within QW-103 and QW-301.2.*
  These paragraphs require that each manufacturer shall be responsible for con-

[2] Depending of the Section (I, III, VIII…), additional requirements above those of section IX may apply. E.g. ASME III-NB-4335.2 is requiring impact tests of the heat affected zone.

ducting tests to qualify the welding procedures and the performance of welders […].

- QW-301.2: *Each manufacturer shall qualify each welder for each welding process to be used in production welding. […]*
- QW-103.1: *Each manufacturer […] is responsible for the welding done by his organization and shall conduct the tests required to qualify*[3] *the welding procedures he uses and the performance of welders who apply these procedures […].*
- QW-300.2.b: *[...] It is not permissible for the manufacturer, contractor, assembler or installer to have the welding performed by another organization. […]*
- QW-200.2 b: […] *The PQR* [Procedure Qualification Record] *shall be certified*[4] *accurate by the manufacturer or contractor. The manufacturer or contractor may not subcontract the certification function […]*

The appropriate Authorized Inspector will survey and witness these activities at his discretion and depending of the design and construction Code-Section (I, III, VIII…) applicable to the equipment.

4.4. Qualification in the PED/EN context

Qualification of welders

The requirements for qualification of welders in the PED/EN context are provided in SS-EN 287-1:2011, *Qualification tests of welders – Fusion welding – Part 1: Steels* [21].
In particular, Clause 6 in SS-EN 287-1:2011 states: *the welding of the test pieces shall be witnessed by the examiner or examining body* and Clause 10 states: *the certificate*[5] *of qualification test shall be issued under the sole responsibility of the examiner or examining body […]*.It should be pointed that examiner or examining body are not necessarily an external examiner or an external body. However, according to the notes in Clauses 3.3 and 3.4 of SS-EN 287-1:2011 (see definitions below), *in certain cases an external independent examiner [or examining body] can be required.*

For clarity, the terms and definitions used in SS-EN 287-1:2011 are reminded:

- Clause 3.2: *Examiner: person who has been appointed to verify compliance with the applicable standard. Note: In certain cases an external independent examiner can be required*.
- Clause 3.3: *Examining body: organization that has been appointed to verify compliance with the applicable standard. Note: In certain cases (see footnote 9) an external independent examiner can be required*.

Qualification of welding procedures.

The requirements for qualification of welding procedures are provided in SS-EN ISO 15614-1:2004 Standard, *Specification and qualification of welding procedures*

[3] The term “qualification” means that a welder or welding operator has met the requirements of a given standard and is qualified to perform welds to within the scope of the standard.
[4] The term “Certification” as it applies to welders, refers to a document that states: “I or We certify that” the indicated welder or welding operator has successfully completed a practical test of their abilities to perform a sound weld in accordance with some predetermined standard.
[5] The use of the term “certificate” may result in further requirements for the notification and accreditation authorities as this essentially involves the certification of people. Certification could mean that the final award of the certification is undertaken under strict conditions by people not involved in holding and assessing the inspections and tests.

for metallic materials. Welding procedure test [28].
In particular, Clause 6.3 in SS-EN ISO 15614-1 requires that the welding, the inspections, examinations and tests of the welding test pieces have to be carried out in the presence of the examiner or the examining body: *welding and testing of the test pieces shall be witnessed by an examiner or an examining body..*

Remarks on the use of a Third Party Organization

1. Nowhere in these standards (nor in other standards) the terms "examiner" and "examining body" are defined. The reason for that is that these standards can be used in any kind of design and construction code and regulation[6].
   However Clause 7.3 in SS-EN 13445-4:2009 [29] applicable to the fabrication of unfired pressure vessels stipulates *If required, the welding procedure approval records shall be approved by a competent third party, who shall perform examination and tests (or have them carried out) as specified in SS-EN ISO 15614-1: 2004 and this clause.* In the frame of the PED this "competent third party" must be either a notified body, or a third party organization recognized by a Member State.

2. The PED makes frequent use of terms such as qualification and approval of welders, welding operators and operating procedures.
   Clause 3.1.2 in Annex I of the PED [5] specifies:
   […] permanent joining of components […] must be carried out by suitable <u>qualified</u> personnel according to suitable operating procedures.
   For pressure equipment in category II, III and IV, the operating procedures and personnel must be approved by a competent third party which, at the manufacturer's discretion, may be: a notified body,[or] a third party organization recognized by a Member State as provided for in Article 13 of the Directive.
   To carry out these approvals, the third party must perform examination and tests as set out in the appropriate harmonized standards or equivalent examinations and tests or must have them performed.

   Note that the use of the terms "*approved*" and "*qualified*" clearly shows what is meant. A welder or a welding procedure may be qualified without being (still) approved or accepted by the RTPO (Recognized Third Party Organization) or a Notified Body, as appropriate.

3. PED Guideline 6/1 [30] (see copy below) nonetheless seeks to clarify the issue to some extent but the answer presented also soon moves away from the carrying out of examinations and tests and before long there is a mention of a witness. However, there is apparently a need for the activities carried out by the manufacturer to be covered by a quality system acceptable by the notified body and by a competent person.

   Guideline 6/1:
   Question: According to point 3.1.2 (permanent joining) of Annex I, the third party must perform examinations and tests in order to carry out the approvals of operating procedures and personnel. Must the representative of the third party witness the whole permanent joining and testing process?
   *Answer***:** *No, in accordance with and under the responsibility of the notified*

[6] The German AD 2000-Merkblatt - HP 3, in § 2.1.1 and 3.3 refers to the "welding supervisor". "The testing of welders may be carried out by a welding supervisor" and "Manufacturers shall employ their own welding supervisors".
The welding supervisor's tasks, responsibilities, grades and training are given in EN ISO 14731.

body or of a third party organization recognized by a Member State, some practical tasks concerning the approval of joining operating procedures and personnel may be accomplished by a competent person of a manufacturer according to a quality system[7].
*Note**:** **1** The Notified Body or Recognized Third Party Organization must attend part of the different steps in the process for each procedure and for each person*[8].

4. Moreover, the text of the PED Directive shows that the term "approved" could also involve the performance of tests, by the third party or by an organisation designated by that party (or possibly by the manufacturer or by a subcontractor designated by the manufacturer?[9]).
   Many Notified Bodies do not have the facilities for carrying out destructive and/or non-destructive tests, or the facilities are established in another entity, department or section that does not necessarily meet the notification criteria or is not covered by an accreditation.

5. Conversely, PED Guideline 6/9 [31] (see copy below) confirms that this is not necessary in any event (which could appear as surprising).

   Guideline 6/9:
   Question: Does the Pressure Equipment Directive require accreditation for the manufacturer's testing laboratory that carries out non-destructive tests (NDT) or destructive tests (DT) of pressure equipment or of parts intended as pressure bearing parts of pressure equipment?
   *Answer**:** No.*
   According to Annex I section 3.1.3 the PED requires qualification for NDT personnel that carry out NDT of permanent joints. No accreditation is required for the manufacturer's NDT or DT laboratory or for the testing laboratory that the manufacturer may subcontract for NDT or DT.[10].

6. PED Guideline 6/4 [32] (see copy below) specifies how a notified body has to deal with a procedure affirmed by another notified body or a third party designated towards this end.

   Guideline 6/4

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7 Such as ISO EN 3834 or equivalent.
8 Loosely interpreted it may be concluded from this "*attend part of the different steps*" could be confined in extreme cases, for example, to checking all document, records and reports, in short, the evidences of qualification.
Unquestionably when the manufacturer operates a quality system, where appropriate, according to ISO EN 3834, or in accordance with EC 97/23 under the supervision of the Notified Body (for example, in the context of the assessment procedures D, E, H…) and when the manufacturer has a qualified welding supervisor (as in EN 14731) named examiner or examining body in the EN 287-1:2004 but who is not necessarily an external independent examiner. This is required only in "certain cases".
Another interpretation could be that a part is attended for each qualification step.
9 In practice it is generally the case that it is not the third party who decides who will perform the tests and inspections but for economic considerations, in particular, it is the manufacturer and the employer of the welder (s) (see also Guideline 6/9)
10 This is probably due to the fact that the manufacturer is at all time responsible for the activities performed by himself or by his subcontractors and that for equipment that is subject to the Notified Body's assessment there is a third party survey. But this may be inconsistent in the frame of other regulations than the PED.

Question: Must a notified body take into account a procedure of permanent joints qualified by another notified body or a recognized third-party organization?
Answer: Yes, a notified body is not allowed to reject an approval of procedure of permanent joints made on the basis of a precise reference and applying competence in accordance with the PED.
Nevertheless, it is its responsibility to verify, if needed, that the joining process and the reference to the manufactured product are adequate.

5. Shared features of welding and welder qualifications

5.1. Same philosophy with other approach?

Both ASME IX and SS-EN (ISO)[11] welding qualifications standards share the same objective of guaranteeing the quality of the welded joints with the purpose to fabricate a welded construction that will operate safely and reliably.

To reach that objective a welding procedure qualification shall demonstrate that the welded permanent joint has properties that are equivalent, or better, than the properties of the joined materials, so that the joint is not weakening the welded construction. The qualification of the welders is to prove that the person has the ability to perform the welding procedure with the required quality.

To reach these objectives, both welding qualifications standards have the same philosophy which can be summarized in four points.

1. Write how you want to weld.
   Writing the preliminary welding procedure specification (WPS) or the welding instruction for the welder.
2. Weld a test piece.
   Welding in specific circumstances a test block as foreseen in the written specification or instruction. In this stage the activities will be duly reported how the test piece is been welded.
3. Execute the examinations and testing.
   A welding procedure qualification will prescribe the tests and examinations to determine the mechanical properties of the weld and his adjacent zone. The qualification for welder or welding operator will prescribe tests and examinations to establish that the weld has the required quality and without defects.
4. Reporting with determination of the range of approval (validity).
   The procedure qualification report (PQR) will have a scope of validity based on the equality of mechanical properties and the certificate of qualification test for welder will have a range of qualification based on the weldability and the control of the specific weld pool.

As described to this point, the ASME IX [4], SS-EN 287-1 [21] and SS-EN ISO 15614-1 [28] standards are almost similar, but the application is thoroughly different. This shall be explained later in the report.

[11] EN(ISO) here designates EN standards planned to be adopted by ISO, whereas EN ISO designates EN standards adopted by ISO.

5.2. Form and structure

Not only the application but also the form and structure of the standards are not the same.

Section IX of the ASME B&PV Code [4] has already a long history, since appearing in the 1940 addenda to the 1937 edition of the ASME B&PV Code. The structure of Part QW devoted to the welding is a compilation of subarticles, spread over four main articles: Article I related to the welding general requirement, Article II concerning the welding procedure qualifications, Article III concerning the welding performance qualifications and Article IV providing welding data including tables and figures. The same way the ingredients listed in a cookbook are used to make a meal, the requirements of Section IX must be met to perform the qualification. In a modular way, Section IX leads from one article to the next and from one subarticle to the next. This approach makes ASME IX one unique code book that can qualify the full range of welding qualifications (all processes, materials, …). ASME IX is in the English (USA) language.

The SS-EN (ISO) qualification standards are relatively new (since 1992) but have their origin in the former national qualification standards. The structure is a more logical step by step way to achieve the qualification (description of test, welding the test piece, examinations and tests, and report with validity). This approach leads to multiple standards for qualification in function of different welding process (arc welding; beam welding; …) or different base materials (steel; nickel; …) or different forms (tube to tube plate; clad; …) The SS-EN (ISO) standards exists in the English, French and German language.

5.3. Application

Section IX makes part of the ASME Boiler and Pressure Vessel Code so that it is specifically applicable to pressure components. The SS-EN (ISO) standards are also designed for the welding of non-pressure retaining constructions.
This explains a part of the differences in the two standards.

5.4. Updating of the standards

ASME IX Code used to be adjusted annually with Addenda which contain additions, revisions and corrections of the articles. From now on a two annual publication cycle (without addenda) will be available.
By this method, the ASME IX can be very good suited to the continuous technical evolutions.

The SS-EN (ISO) welding qualification standards are sometimes revised (1997, 2004) and some of them are ready to be modified in the near future.
Every new edition of a European standard exhibits improvements and clearer statements, when compared to the earlier ones. Today the new proposals are related to ISO standard for the international recognition. A slightly trend towards some ASME interpretations is also noted (e.g., the importance of consumables versus base materials which will be explained a bit further).

Whatever ASME IX or the SS-EN standards are applied, the latest editions have to be used to perform the new qualifications.

5.5. Approval

Section III of ASME B&PV Code does not require a third party certification. The qualification for welding procedures and welders may be certified by the manufacturer himself as an ASME Stamp Holder. The qualifications are available for reference and review by the Inspector of the Authorized Inspector Agency (AIA), also designated as Authorized Nuclear Inspector.

The European PED requires that, for pressure equipment in categories II, III and IV, operating procedures and personnel must be approved by a competent third party which, at the manufacturer's discretion, may be a Notified Body as per Article 12 of the PED or a third party organization recognized by a member state as per Article 13 of the PED.

5.6. Denominations

The ASME IX approach is well explained in the ASME Code where Subsubarticle QW-490 provides the description and definitions of the more common terms relating to welding qualifications. This is supported by the figures and their texts in the Part 'Welding Data'. Abbreviations are used to refer to certain values. (e.g., SMAW, EBW, …).

The SS-EN (ISO) standards use a lot of more symbols and abbreviations, not only for values but also to determine the designation of qualification. In other paragraphs of this report it will be emphasized that some SS-EN (ISO) abbreviations do not match with the ASME ones. The SS-EN (ISO) qualification standard definitions and abbreviations are always listed in the standard and it is sometimes referred to SS-EN ISO 17659, *Welding, multilingual terms for welded joints with illustrations* [34].

5.7. Variables

ASME IX and SS-EN (ISO) standards are working with variables and welding conditions that determine the welding method.
These variables are subdivided into essential variables, nonessential variables and (in ASME IX only) also the supplementary essential variables. Essential variables are those in which a change is considered to affect the mechanical properties of the weldment, and shall require requalification. Nonessential variables are those in which a change may be made without requalification.
ASME IX has grouped all the possible description of variables in Article QW-200. For each qualification process (procedure and performance) a Table is presented with the summation of all applicable variables for that process. There are 14 tables for the welding processes in QW-252 to QW-265. In the columns next to it are crossed the type of the variable: essential, not essential or supplementary essential (supplementary essential variables are only applicable if required by other Sections of the ASME Code, for example when notch toughness test is mandatory). The ASME IX variables could be grouped by welding process in 9 parts: i.e., joints, base

metals, filler metals, positions, preheat, PWHT, gas, electrical characteristics and welding techniques.

Note that when notch toughness requirements are specified e.g., when using PED related materials, the supplementary essential variables is mandatory. The final range of validity for the PQR becomes sometimes very small, so that multiple procedure qualifications are necessary. Depending on the welding process, all variables could be essential, example: the Laser Beam Welding process where every possible variable is essential, except the method of cleaning.

The SS-EN (ISO) works also with essential and nonessential variables. Only the essential variables are mentioned and described in the standards to define the range of approval. Only 8 parts are clearly defined in tables, i.e., welding process, product type (plate and pipe), type of weld (butt and fillet), material group, welding consumables, dimension (material thickness and pipe diameter), welding position and weld detail (backing/single side welding/both side welding/single layer/multi-layer/leftwards welding/rightwards welding). All other essential variables, and also the equivalent of the supplementary essential from ASME, are explained in the text of the standard to determine the full range of validity.

5.8. Base Metal Philosophy

In order to reduce the number of qualifications, the base materials are grouped.
In principle, a qualification with a material from a particular group can be valid for all materials from that group, or for multiple groups. The assignment to a group is based on comparable base metal characteristics, such as chemical composition, weldability and mechanical properties. These assignments do not imply that base metals may be indiscriminately substituted for the base metal used in the qualification test without consideration of compatibility for the standpoint of metallurgical properties, post weld heat treatment, design, mechanical properties at service requirements.

As far as the similarities for the base materials between the standards, there are also a lot of differences.

ASME IX defines the grouping in QW-422, presented in P-numbers and divided into Group-numbers.

EN (ISO) defines the grouping in CEN ISO/TR 15608:2013 [35], presented in Group numbers, divided in sub-group numbers.

The grouping in ASME IX is classified as follows:

- P-No.1 through P-No. 15F for steel and steel alloys (example austenitic stainless steel Type 304 L = P-No.8, group No.1)
- P-No.41 through P-No. 49 for nickel and nickel base alloys (example Inconel alloy 625 = P-No.43)

The grouping in CEN ISO/TR 15608:2013 is classified as follows:

- Group 1 through Group 11: steel (example austenitic stainless steel X2CrNi18 9 = Group 8 subgroup 1)

- Group 41 through Group 48 for nickel and nickel alloys (example NiCr22Mo9Nb = Group 43

American P numbers and European Group numbers look very similar to each other and most numbers are indeed similar, but not all numbers are equivalent. Most equivalent materials have the same numbers as P-No.1, group 1 = Group no.1, subgroup 1. But there are a lot of hidden exceptions, for example:

- SA106GrB is in ASME: P-No.1, group 1
  and in SS-EN (ISO): Group no.11, subgroup 1 (cause: high % C)
- SA355P12 is in ASME: P-No.4, group 1
  and in SS-EN (ISO): Group no.5, subgroup 1
- EN 10216-2/16Mo3 is in ASME: P-No.3, group 1
  and in SS-EN (ISO): Group no.1, subgroup 1

These differences are due to the reasoning related to the base metal philosophy in USA that is different compared to the reasoning in Europe. This is a result of history, the different material codes, and the different requirements of the construction codes. Some of these features are shown as an example in the following non-exhaustive table:

Table 2: Example of base metals in both norms (non-exhaustive)

Comparison RAW		
	SS-EN (ISO)	**ASME**
Base Materials		
Type	Non alloyed, alloyed	Mild, medium alloy, high alloy
Base main value	R_{eh} (MPa)	R_m (Ksi)
Reference Identification	Werkstoffnümmer (example 1.4404)	UNS number (example S31603)
Material standard	EN ….. (example SS-EN 10213-5)	ASTM A or SA … (example SA213)
Nomenclature materiel	EN 10027 (example X2CrNiMo17 12 2)	ASTM (example TP 316 L)
Grouping	CEN ISO/TR 15608 (Group nr. + Subgroup nr.)	ASME IX QW-422 (P-nr + Group nr.)
Properties	%C ↘ and important brittle failure requirements	%C↗ and sometimes KcV
Properties	Higher / Lower allowable stress (f:°T)	Lower / higher allowable stress (f:°T)
Construction standard differences		
Design philosophy	*Fitness for purpose*	*Leak before break*
Design Formulas	*Risk & Hazard analysis (all reasonably foreseeable risks)*	*All loadings*
Testing and NDT	*more*	*less*
Acceptance criteria welds	*imperfections*	*indications*
PWHT based on	*Thickness W*	*Thickness T*
Example with same Temp. X and Pressure Y	*Wall thickness +/- ⇃ (relatively thin)*	*Wall thickness +/- ↾ (relatively thick)*

Note that for a nuclear pressure component constructed in accordance with ASME III the manufacturer should use a SA material (ASTM material incorporated in Section II of the ASME Code, and allowed by Section III). If a European construction

code is used, for equipment subjected to PED, it is desirable to use material conform with a SS-EN standard.
It is the responsibility of the manufacturer (constructor) to prove thoroughly the equivalence (not the similarity) of the materials, if he replaces one material by the other.

It should not be forgotten that many ASME steel specifications (SA Specification) do not specify any notch toughness requirements or minimum requirements less than 27J. This is not in accordance with the essential safety requirement set forth in paragraph 7.5 of Annex I to the PED*: a steel is considered as sufficiently ductile to satisfy 4.1(a) if, in a tensile test carried out by a standard procedure, its elongation after rupture is no less than 14% and its bending rupture energy measured on a ISO-V test-piece is no less than 27Joule, at a temperature not greater than 20°C but not higher than the lowest scheduled operating temperature*.

In fact, an ASME IX welding procedure qualification should be carried out with an ASTM material (or with a European material which received a P-number listed in QW 422). This is less important for the welder performance qualification due to QW-423.2 that allows a European material (not in QW-422) to *have the same P-Number as an assigned metal provided it meets the mechanical and chemical requirements of the assigned* metal. There exists no restriction to use an ASTM material for SS-EN (ISO) qualifications (procedure and welder). The group number may be evaluated from the description of CEN ISO/TR 15608 or the group number may be found in document PD CEN ISO/TR 20173:2009 **[36]**.

5.9. Filler metal philosophy

ASME IX has grouped the electrodes and welding rods into F-numbers. Based essentially on their usability characteristics, which fundamentally determine the ability of welders to make satisfactory welds with a given filler metal. The F-numbers are classified from F-No.1 to F-No.6 for steels and F-No.41 to F-No.46 for Nickel and nickel alloys. These F numbers are in full relation to the AWS-SFA 5.xx numbers which are the American Welding Society classification system for filler metals. The ASME IX procedure and welding qualifications systems give in general a wide scope of validity for the base materials (P) but the validity becomes more restraint with the F numbers.
It can be said that the filler metals are considered more important than the base metals.

At present, there is in the SS-EN (ISO) qualification system a coarser classification for consumables. The classification is not based on the European standards for welding consumables. The covered welding electrodes are classified based on the covering type: A (acid), R, RA, RB, RC, RR (rutile), C (cellulosic) and B (basic). The welding rods are classified as S (solid), M (Metal cored), P and V (rutile cored), W and Y (basic cored) and Z (other types).
Tables are decisive for determining the scope of validity for procedure and for welder qualifications.
It can be said that the base materials prevail on the welding consumables in the current SS-EN (ISO) standards.

Note that in the previews of the future standards SS-EN ISO 9606-1 for welder qualification and the proposal for the new SS-EN ISO 15614-1 the grouping of consumables is classified different (FM1 to FM6) and more similar to the ASME system.

5.10. Non Destructive Testing (NDT)

Both ASME IX and SS-EN (ISO) welding qualification standards require multiple nondestructive testing (NDT) on the qualification test coupon. A remarkable difference is the interpretation.

Section IX of the ASME B&PV Code requires that the NDT methods (procedures) shall meet the requirements of Section V [3]. For the acceptance criteria, all limits and ranges of validity are fully described in the ASME IX with references to the dimensions of the indications.

EN (ISO) welding qualifications standards require NDT methods according to several European standards. These NDT standards introduce other standards which describe different grades or classes for the interpretation of the found indications. However, the SS-EN (ISO) welding qualification standards require the interpretation to be in compliance with SS-EN ISO 5817:2007 [37] which uses the dimension of the imperfection in the actual dimension. This means that the as-found dimension is required to be converted to the real dimension by using SS-EN ISO 17635:2010, *Non-destructive testing of weld – general rules for metallic materials* [38].

Below are some extracts from SS-EN ISO 17635:2010

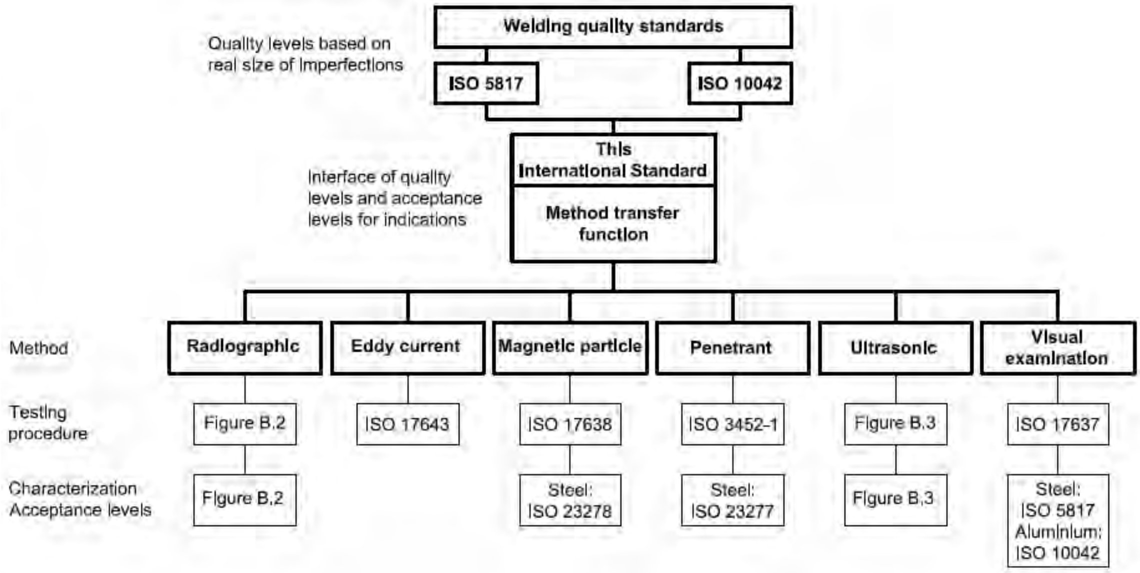


Figure 1: Graph of standard context

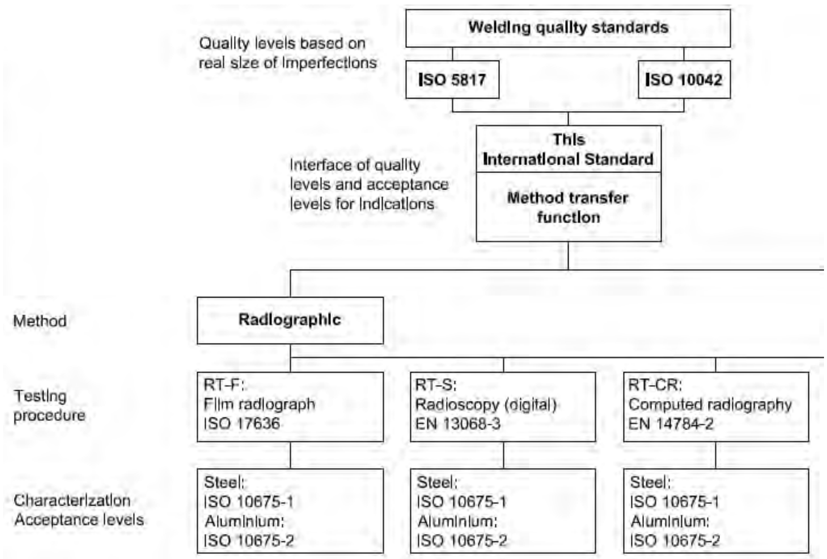


Figure 2: Graph of standard context for radiography

Note: "This International Standard" in Figure 2 is SS-EN ISO 17635:2010

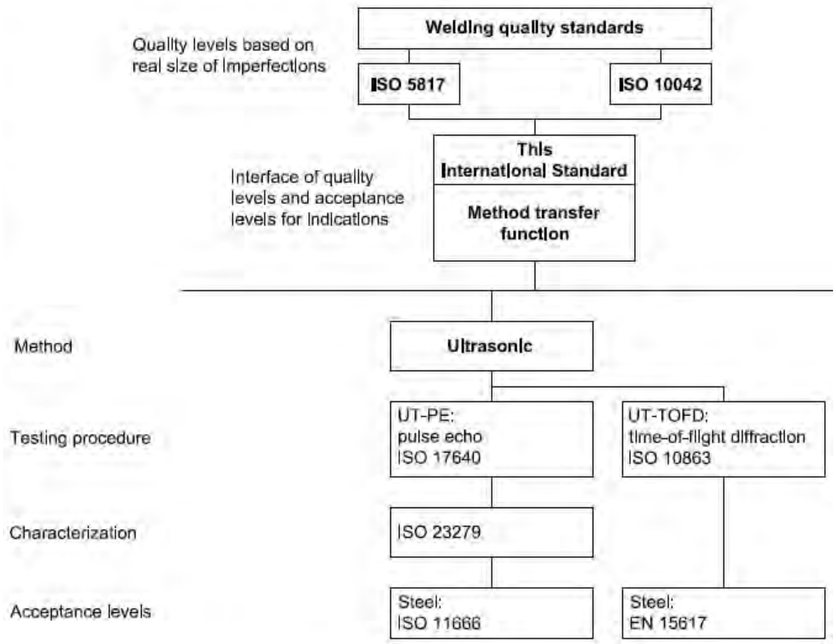


Figure 3: Graph of standard context for ultrasonic methods

Note: "This International Standard" in Figure 3 is SS-EN ISO 17635:2010

5.11. Destructive testing

Both ASME IX and SS-EN (ISO) welding qualification standards require several destructive tests on the qualification test coupon. ASME IX refers to the SA370 Specification [39] for the method of testing. The SS-EN (ISO) standards refer to different European standards for destructive testing. As a consequence, it must be taken into account of the different dimensions for the test pieces.

The calibration for the equipment can also be different. For example, the equipment for the Charpy-V notch test is different for what concerns the radius of the striker (see Figure 4 below).

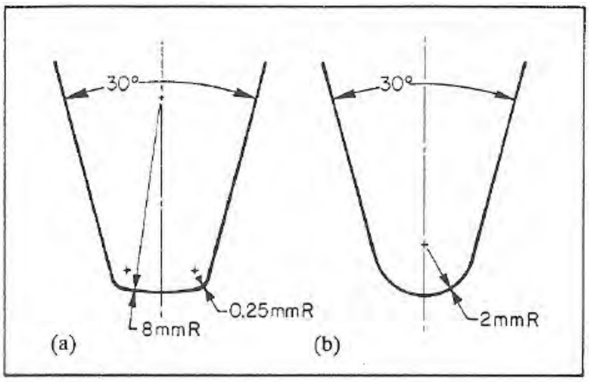


Figure 4: Schematic drawing of the (a) ASTM (8 mm radius) and (b) ISO (2 mm radius) striker

For welding qualifications that must meet ASME IX and SS-EN (ISO) requirements simultaneously, the test needs normally to be performed twice. Some manufacturers are used to demonstrate the technical equivalence of the different destructive testing methods. However such demonstration is not formally accepted.

5.12. Welding processes

There is a difference in the nomination for the different welding processes.

In ASME IX, the welding processes are determined with abbreviations from the American Welding Society (AWS). Examples: SMAW, GTAW, GMAW, LBW, …
The semi-automatic welding (arc welding with gas protection and automatic supply of filler wire) is grouped in function of the used filler metal, like solid wire for GMAW (Gas metal arc welding) and cored wire for FCAW (flux cored arc welding), regardless the type of gas.

The SS-EN (ISO) refers to SS-EN ISO 4063:2010, *Welding and allied processes. Nomenclature of processes and reference number*. Examples: 111, 141, 135, 138, 521, …
The semi-automatic welding is grouped in function of the used gas (inert gas for MIG = 131, 132, 133 and mixed Argon/CO_2 gas for MAG = 135, 136, 138) regardless the kind of solid or cored filler.

5.13. Nomenclature for the type of weld

ASME IX covers two different types of weld: groove welds and fillet welds.
A groove weld is defined in QW/QB-492 of ASME IX as *a groove formed within a single member or between two members to be joined*. When the members are aligned

in the same plane, he joint can be referred to as a butt joint. (a butt joint is considered a groove weld).
A fillet weld is defined in QW/QB-492 as *a weld of approximately triangular cross section joining two surfaces approximately at right angles to each other in a lap joint, tee joint, or corner joint*. ASME IX does not use abbreviations for the type of weld and a groove weld qualifies the Fillet weld but not vice versa.

The SS-EN (ISO) standards use abbreviations for the type of weld: BW for a butt weld and FW for a fillet weld. A written definition for a FW (fillet weld appeared for the first time in the SS-EN 287-1 edition 2011 [21] and is a copy of the above mentioned ASME IX definition for filet weld. The definition for a Butt Weld is provided: a weld other than a fillet weld. It can be considered that a BW is the equivalent of a groove weld. In contrast to ASME IX, the SS-EN 287-1 Standard mentions that, for the qualification of welders, a test coupon with a BW is only valid for a BW and a FW is only valid for FW.
SS-EN (ISO) defines also abbreviations for the weld details, which are used in tables to determine the scope of validity. Example: bs, lw, mb, ml, nb, rw, sl, ss (and in the future also fb, ci, gb).

5.14. Welding positions

ASME IX defines the positions in Subsubarticle QW-120 and QW-461 figures.
For groove welds we have flat-1G, horizontal-2G, vertical-3G, overhead-4G, and multiple-5G and 6G. For fillet welds we have 1F, 2F, 2FRotated, 4F and 5F. For stud welds we have the positions 1S, 2S and 4S. All positions are defined with orientation, inclination and rotation. For the test positions during qualifications, the indications 1G, 6G, 2F, etc. are used. To indicate the production welding positions we use F (flat), V (vertical), O (overhead) etc…

The positions in SS-EN ISO 15614-1 [28] are taken from SS-EN ISO 6947 [42] (flat-PA, horizontal vertical-PB, horizontal-PC, horizontal overhead PD, overhead PE, vertical up PF, vertical down-PG, pipe upwards-PH and pipe downwards-PG, multiple HL045 (upwards 45°) and JL045 (downwards 45°). All positions are defined with slope, rotation and inclined angle.
These defined angles (and positions) are indicated in degrees and are different for welding qualification positions (small tolerances) and for working positions (broader tolerances).

Figure 5 below provides a comparison of international, European and US designations:

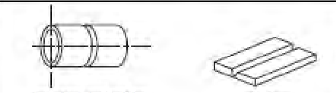
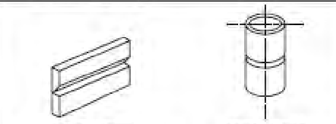
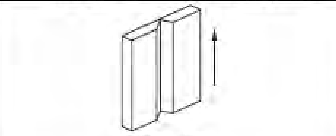
Illustration	Welding position according to AWS A3.0[4] ASME Section IX[7]	Welding position according to this International Standard
 flat position (pipe rotating) flat position	1G	PA
 horizontal position horizontal position	2G	PC
 vertical up position	3G uphill	PF

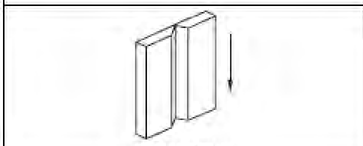
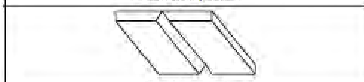
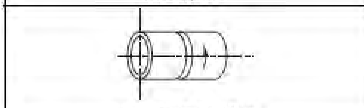
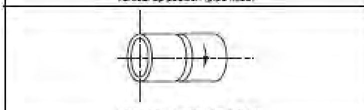
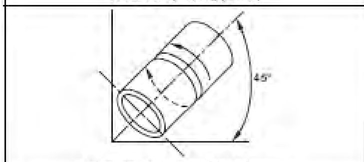
Illustration	Welding position according to AWS A3.0[4] ASME Section IX[7]	Welding position according to this International Standard
 vertical down position	3G downhill	PG
 overhead position	4G	PE
 vertical up position (pipe fixed)	5G uphill	PH
 vertical down position (pipe fixed)	5G downhill	PJ
 inclined position (pipe fixed) welding upwards	6G uphill	H-L045

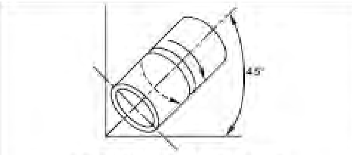
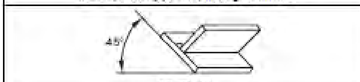
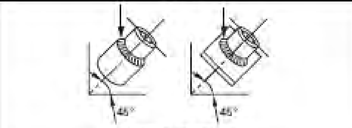
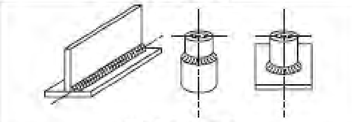
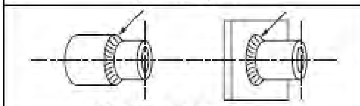
Illustration	Welding position according to AWS A3.0[4] ASME Section IX[7]	Welding position according to this International Standard
 inclined position (pipe fixed) welding downwards	6G downhill	J-L045
 flat position	1F	PA
 flat position (pipe rotating)	1FR	PA
 horizontal vertical position	2F	PB
 horizontal vertical position (pipe rotated)	2FR	PB

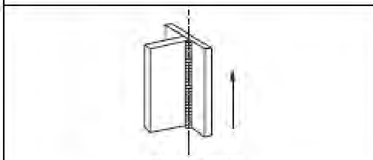
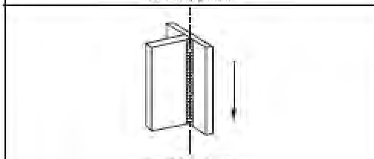
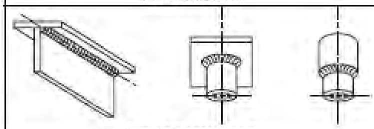
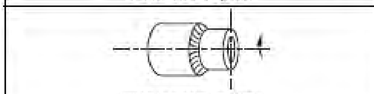
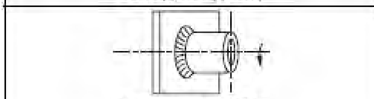
Illustration	Welding position according to AWS A3.0[4] ASME Section IX[7]	Welding position according to this International Standard
 vertical up position	3F uphill	PF
 vertical down position	3F downhill	PG
 horizontal overhead position	4F	PD
 vertical up position (pipe fixed)	5F uphill	PH
 vertical down position (pipe fixed)	5F downhill	PJ

Figure 5: Comparison of international, European and US designations

5.15. Conversion of values

As evidence, the SS-EN (ISO) standards use the metric values (SI units).
ASME IX uses the US Customary units. The SI units are placed in parentheses after the US customary units in the text. It is described for instance in Appendix G to Section IX [4], *Guidance for the use of US customary and SI units in the ASME boiler and pressure vessel code*. The suffix M for metric is sometimes is added. In most cases, conversions of units are done using hard SI conversion practices, with some soft conversions on a case-by-case basis, as appropriate. Example: 3/16" (5 mm) but in "exact" or soft conversion is this only 4.76mm. This can make a problem if the defect is for example 4.9mm, and the limit was recorded 3/16". For this reason there must be agreed in advance which conversion will be used before starting the construction activities.

5.16. Use of standard WPS

Both ASME IX and SS-EN ISO standards describe the use of permitted standard welding procedure specification (Mandatory Appendix E to Section IX and SS-EN ISO 15612 [43]).
A manufacturer with previous experience may buy a proposed qualified welding procedure without executing the tests, but there are restrictions.
AWS (American Welding Society) has about 30 qualified welding procedures to sell to manufacturers holding an ASME stamp (quality system assured).
These American procedures exist only for normal thicknesses and not for special welding processes.
The restrictions in SS-EN ISO 15612 are that the manufacturer needs to have a SS-EN ISO 3834 quality system, needs to have coordination personnel conform to SS-EN ISO 14731 [44] and only valid for thicknesses from 3 mm to 40 mm and materials group 1 and 8 (+ 21 and 22).
A usability test for proving that the welding procedure can be used adequately in the organization of the manufacturer is also necessary.

6. Welding Procedure Qualifications

6.1. Standards

Section IX of the ASME B&PV Code provides, in one standard only, qualification requirements for welding and brazing procedures, welders, brazers, and welding and brazing operators.

In the SS-EN ISO approach for the procedure qualifications, 26 different standards are involved (see Table 3 below), depending of the objectives (writing a WPS or welding qualification test), weld process (arc, beam, …) or base material (steel, nickel, castings …). The general rules and guidelines for grouping system (rows 1 and 2 In Table 3) are in principle always used. The mentioned WPS standards (row 3 in Table 3) should be mentioned in the welding specification by welding process qualifications without testing. The series of SS-EN ISO15610 up to 15613 are welding procedure “acceptances”. The procedure Qualification Record can be achieved without welding a test piece or without performing all the tests. These are normally not used for pressure retaining components, with one exception in SS-EN ISO 15613. This construction standard for metallic industrial piping has, in function of the fluid, fluid group and criteria as pressure and diameter, divided the piping system in different piping classes 0, I, II and III. For the piping class 0 (which is largely equivalent with risk category “Article 3 paragraph 3” or sound engineering practice” of the PED) the welding procedures approvals by SS-EN ISO 15610 up to SS-EN ISO 15613 could be used.

Table 3: Details of the SS-EN ISO standards dealing with specification and approval of welding procedures

Process	Arc Welding	Gas Welding	Electron Beam Welding	Laser Beam Welding	Resistance Welding	Stud Welding	Friction Welding
General rules	EN ISO 15607						
Guidelines for a grouping system	CR ISO/TR 15608				Not applied	CR ISO/TR 15608	
WPS	EN ISO 15609-1	EN ISO 15609-2	EN ISO 15609-3	EN ISO 15609-4	EN ISO 15609-5	EN ISO 14555	EN ISO 15620
Approved consumables	EN ISO 15610		Not applied				
Previous welding experience	EN ISO 15611					EN ISO 15611 EN ISO 14555	EN ISO 15611 EN ISO 15620
Standard procedure	EN ISO 15612				Not applied		
Pre-production test	EN ISO 15613					EN ISO 15613 EN ISO 14555	EN ISO 15613 EN ISO 15620
Welding procedure test	EN ISO 15614 Part 1: Steel/Nickel Part 2: Aluminium Part 3: Cast iron Part 4: Finishing welding of aluminium castings Part 5: Titanium/zirconium Part 6: Copper Part 7: Surfacing Part 8: Tube to tube sheet Part 9: Wet hyperbaric Part 10: Dry hyperbaric	EN ISO 15614 Part 1: Steel/nickel Part 3: Cast iron Part 6: Copper Part 7: Surfacing	EN ISO 15614 Part 7: Surfacing Part 11: Electron beam/ laser beam		EN ISO 15614 Part 12: Spot, seam and projection Part 13: Flash and butt	EN ISO 14555	EN ISO 15620

The following paragraphs in this chapter mainly deal with the differences between ASME IX and SS-EN ISO 15614-1 [28].

6.2. Responsibility

ASME IX

Each manufacturer or contractor (installer, assembler, …) is responsible for the welding done by his organization. It is not permissible for the manufacturer or contractor to have the supervision and control of welding performed by another organization. This means that the WPS and PQR documents are only valid in the organization under the full supervision and control of the manufacturer. Effective operational control of welding procedure qualifications, as described in QW-201, may allow that the procedure should be used by two companies with different names on condition they both describe this in their Quality Control System and/or Quality Assurance Program.
When a manufacturer or contractor is acquired by a new owner, the PQRs and WPSs may be used by the new owner without requalification, provided that the new owner takes responsibility for the WPSs and PQRs and the source of the PQRs is identified as being from the former manufacturer.

SS-EN ISO 15614-1

A qualification of a pWPS by a welding procedure test obtained by a manufacturer is valid for welding in workshops or sites under the same technical and quality control of the manufacturer.(definition without extension).
Welding is under the same technical and quality control when the manufacturer who performed the welding procedure retains complete responsibility for all welding carried out to it.

6.3. Terms and definitions

There are some contradictions and a lot of differences in terms and abbreviations between ASME IX and SS-EN ISO 15614-1 [28].
Table 4 below summarizes the terms and abbreviations as used in ASME IX and SS-EN ISO 15614-1
This can sometimes be confusing and many mistakes are still being made. In particular, the following should be emphasized:

- Thickness of base material ‘T’ and ‘t’
- Thickness of weld deposit ‘t’ and ‘s’ (‘s’ definition thickness of weld metal excluding any reinforcements)
- Thickness for determining PWHT is ‘T’ and ‘W’ (see also chapter 4 of this report)
- Type of weld ‘Groove weld’ and ‘BW’
- Grouping of Classification for base materials ‘P-numbers’ and ‘Group numbers’
- Sub-classification (important in case of KcV) ‘Group numbers’ and ‘sub-group numbers’

Table 4: Summary of the terms and abbreviations used in welding procedure qualification

Attention not to merge different abbreviations			
	ASME	EN ISO	Remarks
Thickness of base metal	T	t	
Thickness of weld deposit	t	s	s = excluding reinforcements
Thickness to take in account for PWHT (see also §4 of this report)	T	W	W = controlling weld thickness
Weld type indication	Groove	BW	
Grouping numbers for base materials	P + Gr	Gr + $_{Sub}$Gr	
Welding procedure specification	WPS	WPS	
Welding procedure qualification report	PQR	WPQR	
Welding performance qualification record (certificate)	WPQR	WAR	
Criteria	indication	imperfection	See chapter 5.10

6.4. Test piece for procedure qualification

The dimensions of the four proposed test coupons in the SS-EN ISO 15614-1 are minimum dimensions. The possible coupons are plate or pipe, BW or FW and a BPC (Branch Pipe Connection).
It is specified that the material thicknesses of the two parts to be welded shall be the same (except for BPC and fillet welds).
If it turns out that one of the four proposed test coupons does not result in a scope of validity to achieve the production welding, the qualification standard SS-EN ISO 15613:2004 [45] shall be used. The validity is then limited to weld only the realized weld.

ASME IX gives no dimensions for the test coupons. The dimensions of the test coupon shall be sufficient to provide the required test specimen. ASME IX leaves the choice that the test coupon may consist of either plate, pipe or other product form. (Qualification in plate also qualifies for pipe and vice versa – this only in ASME)

6.5. Welding procedure test

For ASME IX and SS-EN ISO, welding is to be carried out in compliance with the written instructions pWPS and under the general conditions of welding in production which they shall represent. (e.g., protective precautions against climatologic conditions).
The welding is to be realized under the full responsibility of the manufacturer. If subject to PED regulation, it may be required that the Notified Body is also present as examiner or examining body. During the test, all the real used welding data will be recorded and all essential variables are to be mentioned on the PQR (PQR is a true record of the real variables). The welding position is not important if no KcV notch test is required.

EN ISO 15614-1 [28] adds that there is a limitation for the angle of slope and rotation of the test piece in accordance with SS-EN ISO 6947 [42] (see also welding positions for welders in chapter 3 of this report).
EN ISO 15614-1 also recommends that if tack welds are to be fused in the final joint, they shall be included in the test piece.

ASME IX requires that the variables, as stated on the WPS, be rigorously met but a nonessential variable may be modified.

6.6. Examination and testing

ASME IX describes all possible tests in Article 1 of Part QW (General Welding Requirements).
It concerns the mechanical tests to be performed like tension test, guided bend test, fracture test, macro examination, notch toughness test, stud weld test, tube to tube-plate test, and also radiographic or ultrasonic inspection, liquid penetrant examination, resistance weld test, laser beam welding joint test, flash welding test, corrosion tests and visual examination.

For a normal ASME IX procedure qualification, to prove the quality of the weld, the type and number of test are laid down in Tables QW-451 and only 2 tension tests and four bend tests are necessary for qualifying a groove weld. A fillet weld is submitted to 4 or 5 macro examinations in function of the form of the test coupon. Every other test is supplementary required by the provisions from other standards than the qualification standard. The notch toughness test for example is mandatory when the base metal has notch toughness requirements, or if it is required by the design and construction code, or if it is required due to the working conditions.

The SS-EN ISO 15614-1 Standard requires significantly more testing for BW and FW. All tests shall be in accordance with European standards. There are some supplementary rules for test describes in Clause 7 of the standard. Example the place of the hardness measurement points, number of lines for hardness depending on the thickness, tables for the admitted remaining hardness in the heat affected zone, …

Table 5 below provides a summary of the comparison between the requirements of Section IX and SS-EN ISO 15614-1 related to the tests for welding procedure qualification

Table 5: comparison of test requirements for welding procedure qualification

Comparison of test for welding procedure qualifications		
	ASME IX	**SS-EN ISO 15614-1**
Testing BW	2 tensions tests 4 bend test	Visual Radiographic or ultrasonic Surface crack detection Transverse tensile test Transverse bend test Impact test ( ) Hardness test Macro examination
Testing FW	4 or 5 macro examinations	Visual Surface crack detection

Comparison of test for welding procedure qualifications		
	ASME IX	SS-EN ISO 15614-1
		Hardness test Macroscopic examination
Supplementary tests and other possible tests	Visual examination Notch toughness test Longitudinal bend test Stud weld test Tube to tube-plate test Radiographic examination Ultrasonic examination Liquid penetrant examination Resistance weld test Laser beam welding joint test Flash welding test Corrosion tests Chemical analysis Cobalt content Macro examination *…	Longitudinal weld test All weld metal bend test Corrosion test Chemical analysis Micro examination Delta ferrite examination Cruciform test *…

*… Specific service-, material- or manufacturing conditions may require more comprehensive testing than is specified by the welding qualification standard in order to gain more information and to avoid repeating the welding procedure test at a later date just to obtain additional test data.

This table indicates that the number of mandatory tests has an impact not only for the dimensions of the test coupon but also for the cost of the welding procedure qualification.
Note that the visual and radiographic examinations are not required by ASME IX. Nevertheless, in practice, they will be performed before machining the destructive tests specimens to be sure that there are no detrimental defects in the test piece.

6.7. Location and taking of test specimen

Both ASME IX and SS-EN ISO 15614-1 provide figures on which the distribution of the test pieces out of the test bock should be done. The ASME IX figures and the SS-EN ISO 15614-1 figures are not the same. Generally it can be said that they are technically equivalent. For instance, the hardness test piece is extracted where the lowest welding energy was and the impact test piece is extracted where the highest welding energy was.

6.8. Acceptance criteria

All the acceptance criteria for the tests and examinations required by ASME IX are specified in the Subarticles spread in Section IX volume, sometimes in the test description and sometimes in Tables. As mentioned in paragraph 5.10 above, the acceptability is based on the size of the as-found indications.

The SS-EN ISO 15614-1 Standard refers to the SS-EN ISO 5817 Standard [37]Depending on the type of imperfection, quality B (highest level) or C (intermediate level) shall apply. As mentioned in paragraph 5.10 above, the acceptability is based on the real size of the imperfection.

6.9. Re-testing

If any required test fails to meet the applicable criteria the test coupon shall be considered as failed. In case of failure, ASME IX allows an immediate retest. When it can be determined that the cause of failure is not related to welding parameters, another test coupon may be welded using the same parameters. Alternatively additional test specimens may be removed as close as practicable to the original specimen location to replace the failed test specimen. When it has been determined that the failure is caused by a variable, a new test coupon may be welded with appropriate changes of the concerned variable.

The approach used in SS-EN ISO 15614-1 is almost similar. If a required test specimen fails due to imperfection, two (2) supplementary test specimens shall be tested for each initial test specimen that failed. These additional test specimens can be taken from the same test piece (if there is sufficient material). If one of this additional test pieces does not comply with the requirements, the welding procedure test has failed. Same reasoning for additional test specimen exists for tensile test, hardness measurements and Charpy impact test.

6.10. Range of qualification

As a first general statement, changes outside the ranges specified in the scope of validity of the qualification require a new welding procedure test.

6.10.1. Related to the manufacturer

By the definition of the manufacturer's or contractor's responsibility, as defined in the ASME Code, the qualified welding procedure is only valid under the full supervision and control of that manufacturer or contractor.
SS-EN ISO 15614-1 defines the range of qualification related to the manufacturer in Clause 8.2 as follows: *a qualification of a pWPS by a welding procedure test according to this standard obtained by a manufacturer is valid for welding in workshops or sites under the same technical and quality control of the manufacturer*.

6.10.2. Related to the welding process

The qualifications are only valid for the welding process(es) used in the welding procedure test.

ASME IX defines the scope of validity in Tables for each welding process. All possible applicable variables from QW-400 for that process are mentioned. (see also paragraph 5.7 above). This has for result that the welding process, as defined in ASME IX, is an essential variable. A change from manual to automatic is for common welding processes a nonessential variable. Example: a procedure qualification for manual SMAW or GTAW or GMAW/FCAW can be used for mechanical welding.

EN ISO 15614-1 considers the welding process also as an essential variable so a qualification is also only valid for the welding process(es) used in the welding procedure test. In contrast to ASME IX, the SS-EN ISO Standard requires that each degree of mechanization shall be qualified independently (manual, partly mechanized, fully mechanized and automatic). For this reason, different SS-EN ISO standards exist for the qualification of mechanized or automatic welding processes such as SS-EN ISO 15614-11 [46] (laser beam welding) and SS-EN ISO 15614-8 [47] (tube to tube sheet welding)

Combination of welding procedures is allowed by both ASME IX and SS-EN ISO 15614-1: multiple WPS with one PQR or multiple PQR for one WPS as long as there is compliance with all the essential variables.
However, in ASME IX, the qualification range is more restrictive related to the thickness of the coupon and the root layer (QW-200.4). In SS-EN ISO 15614-1 it is not allowed to use a multi-process procedure test to qualify a single process unless all testing carried out on all processes.

EN ISO 15614-1 covers in Clause 8 some variables (written in text) in relation to specific welding processes. These additions come mainly in line with the listed ASME IX variables per process, e.g. the transfer mode and wire system when semi-automatic welding is used. SS-EN ISO 15614-1 admits a slight variation in the specified percentage composition of shielding gas mixture for semi-automatic processes (for instance10% for CO_2 inside the grouping of SS-EN ISO 14175, see Clause 8.5.2

in SS-EN ISO 15614-1) ASME IX allows only variations for plasma-arc welding gas.

6.10.3. Related to the base material

As mentioned in paragraph 5.8of this report, base materials have assigned P-numbers (as per QW-422 in ASME IX) or Group numbers (as per CEN ISO/TR 15608 [35])

Subsubarticle QW-424 in ASME IX explains that a base metal used for procedure qualification coupon qualifies other base metals.

Some examples are provided in Table 6 below:

Table 6: extract/reproduction of QW-424 in ASME IX

Base metal(s) used for procedure qualification coupon	Base metals qualified
One metal for a P-number to any metal from the same P-number	Any metal assigned that P-number
One metal from a P-number to any metal from any other P-number	Any metal assigned the first P-number to any metal assigned the second P-number
… … …	… … …
One metal from P-No.5A to a metal from P-No.4, or P-No.3, or P-No. 1	Any P-No.5 metal to any metal assigned to P-No.4, 3 or 1
… … …	… … …
Any unassigned metal to the same unassigned metal	The unassigned metal to itself

Note that when notch toughness is required, the supplementary essential variables become mandatory. This concerns not only the group numbers for materials but influences also the thickness ranges of the base materials.
The final range of validity for the PQR becomes sometimes very narrow, so that multiple procedure qualifications are necessary.

EN ISO 15614-1 presents tables for the range of qualification for the groups and the sub-groups. There are tables for steel, nickel alloys and dissimilar joints. These tables do not always cover the entire mentioned group but only the steels of that group equal or lower specified yield strength. For stainless steel (group 8) the qualification range is limited to the same subgroup and lower subgroups within the same steel (even when there is no notch toughness test).
Separate welding procedure qualifications are required for each parent material or parent material combinations not covered by the grouping system.
Table 7 below provides some examples taken from Table 3 of SS-EN ISO 15614-1.

Table 7: SS-EN ISO 15614-1 Table 3 (extract)

Material (sub) group of test piece	Range of qualification
1 - 1	1^a – 1 (^{a} = lower R_{eh} of the same group)
… … …	… … …
8 - 8	8^b – 8 (^{b} = same subgroup and lower subgroup)
10 - 8	10b – 8^c (^{c} = same subgroup)
… … …	… … …

Note that in both ASME IX and SS-EN ISO 15614-1, a dissimilar weld is to be qualified separately. A process piping line, changing from carbon steel to stainless steel needs three different procedure qualifications: carbon/carbon, carbon/stainless and stainless/stainless.

6.10.4. Related to the thickness

The range of validity is not always qualified to 2 times the parent metal thickness as it is usually thought

First of all, the thickness to be considered can be different (the thinner or thickest). ASME IX works with ‘T’ = thickness of base metal and at the same time with ‘t’ = thickness of deposited weld metal (The weld deposit is here by definition inclusive the reinforcements). Otherwise when two welding processes are used, ‘t’ will determine de two corresponding thickness ranges.
EN ISO 15614-1 describes which material thickness ‘t’ is to be considered. It is different for butt welds or fillet weld, branch pipe connections set-on or set-up. For multi-process qualification, the recorded thickness contribution for each process shall be used as a basis for the range of qualification for the individual welding process. In fact they could use the value ‘s’ = by definition the thickness of the weld metal excluding any reinforcement. For the future proposed standard (ISO 9606-1) the tables use the value ‘s’ instead of ‘t’.

Tables in ASME IX give an overview of the qualified thicknesses
Table QW-452 qualifies from a minimum ‘T’ to 2T or from a minimum value to 2T. All this is in function of the thickness of the weld coupon. The qualified weld deposit thickness starts from 0 to 2t. Only for thicknesses over 150 mm, the range is limited to 1.33T. But there are a lot of exceptions (who are sometimes forgotten) explained in the variables. Example: if welded with short circuit transfer mode of the gas metal arc process (semi-automatic welding), there is a limitation to 1.1 x T, when the thickness of the weld coupon is less than 13mm thick. (QW-403.10)
If the thickness t of one pass is greater than 13mm, the qualification range is also limited to 1.1 times the thickness T of the qualification coupon. (QW-403.9)
The minimum qualified thicknesses shall change if notch toughness is required.
If the thickness of the test coupon T is less than 16 mm, the qualified thickness starts at 16 mm. If T is between 6 mm and 16 mm the welded thickness is the lower bound. When T is smaller than 6 mm, the range is from 1/2T to 2T. (QW-410.6)
ASME IX provides Tables with the specific indicated variables to allow the determination of the range of validity.
The different tables in SS-EN ISO 15614-1 are simpler at first sight. Table 8 below provides a copy of Table 5 in SS-EN ISO 15614-1 for butt welds in function of the thickness t of the test coupon

Table 8: Copy of Table 5 in SS-EN ISO 15614-1

Table 5 — Range of qualification for butt welds material thickness and weld deposit thickness

Dimensions in millimetres

Thickness of test piece t	Range of qualification	
	Single run	**Multi-run**
$t \leq 3$	0,7t to 1,3t	0,7t to 2t
$3 < t \leq 12$	0,5t (3 min.) to 1,3t [a]	3 to 2t [a]
$12 < t \leq 100$	0,5t to 1,1t	0,5t to 2t
$t > 100$	Not applicable	50 to 2t

[a] when impact requirements are specified the upper limit of qualification is 12 mm unless impact testing has been performed.

Note that these table could be modified in the future where ‘s’ replaces ‘t’.

There is also a second table (Table 6 in SS-EN ISO 15614-1) for fillet welds, based on the value t and that gives the range for material thickness and also for a (throat thickness) in case of single run.

It should be noted that ASME IX and SS-EN ISO 15614-1, for the same thickness of a test piece, provide a different qualified thickness range.

6.10.5. Related to the diameter

ASME IX is relatively flexible for diameters in welding procedure qualifications. QW-211 defines that the base metal may consist of either plate, pipe or other product forms. Qualification in plate also qualifies for pipe and vice versa. As a result, most ASME IX test coupons are plates, which qualify all diameters.
Type and dimensions of groove welds are not essential variables and diameters are less important for the qualification of the procedure. It should be emphasized that this is not the case for welders qualifications.

SS-EN ISO 15614-1 limits the range of qualification in a table. A test coupon with an outside diameter D smaller than 25 mm qualifies from 0.5D to 2D. A test piece with an outside diameter greater than 25 mm qualifies from 0.5D (minimum 25mm). Qualification given for plates also covers pipes when the outside diameter is > 500 mm or > 150 mm depending on the welding position.

As far as the diameter is concerned, the ASME IX is less restrictive than the SS-EN ISO standard for welding procedure qualifications.

6.10.6. Related to the welding position

ASME IX defines the positions in Subarticle QW-120 (flat-1G, horizontal-2G, vertical-3G, overhead-4G, and multiple-5G, 6G). In most of the Tables for welding variables, the position is nonessential. It should be emphasized that this is only valid for procedure qualification.
This means that the vertical position qualifies vertical up and vertical down. Only when notch toughness is required, a change from the vertical down to vertical up-hill progression shall require requalification.

A manufacturer who needs to make weld in a particular difficult situation (near wall, between other pipes, …) shall qualify his procedure in that particular position.

The positions in SS-EN ISO 15614-1 are taken from SS-EN ISO 6947 [42] (flat-PA, horizontal vertical-PB, horizontal-PC, horizontal overhead PD, overhead PE, vertical up PF, vertical down-PG, pipe upwards-PH and pipe downwards-PG, multiple HL045, JL045) When neither impact nor hardness test requirements are specified, welding in any position qualifies for welding in all positions.
To satisfy both hardness and impact requirements two test pieces in different positions (PC for hardness and PF for impact) are required.

Descriptions of welding positions have similar definitions for slope, rotation and inclined angle in both ASME IX and ISO 15614-1.

6.10.7. Related to the type of weld

The type of joint in ASME IX is a nonessential variable for procedure qualifications. This concerns the groove design, backing, root spacing retainers. A qualification with a groove weld covers all fillet sizes for all base metal thicknesses and all diameters. When using a fillet weld test coupon, the range is only limited to all fillet welds (no groove welds) but this can be done by a production assembly mock up.

SS-EN ISO 15614-1 is more restrictive for the type of weld. A procedure qualification with butt weld qualifies fillet welds and branch connections with an angle ≥ 60°. A procedure qualification with a fillet weld qualifies fillet welding only. There are restrictions for both side welding, backing gouging and especially is it not permitted to change a multi run deposit into a single run (or a single run on each side) or vice versa for a given process.

6.10.8. Related to the filler material

The size of the filler metal is in ASME IX a nonessential variable. But the type is very important. Type means the F-number (see paragraph 5.9, above), the A-number (related to the chemical composition of the weld deposit), and the classification (AWS SFA 5.xx number). With or without filler metal is an essential variable and a change in the deposited weld metal thickness t beyond the range qualified needs a new qualification. The type of filler metal product form is also limiting the range of qualification.

The SS-EN ISO 15614-1 Standard qualifies other filler materials as long as they have equivalent mechanical properties, same covering, same composition and same hydrogen content or lower (should be the same nominal designation). The size of the filler material may change as long as the heat input limitations are satisfied.
But when impact testing is required, the range of validity is restricted to the manufacturer and trade name of the filler metal used for qualification. It is only permissible to change the specific make of the filler metal to another with the same compulsory part of the designation when an additional test piece is welded. This test piece shall be welded using the identical welding parameters as the original test and the weld metal impact tests shall be tested.

6.10.9. Related to the type of current

Most electrical characteristics in ASME IX are nonessential except when notch toughness requirements are specified. Then the heat input and the type of current and polarity become supplementary essential variables.
EN ISO 15614-1 states that the qualification is only valid for the type of current and polarity used during qualification. Only for metal-arc welding with covered electrode, alternating current also qualifies direct current (both polarities) when impact testing is not required.
Both ASME IX and SS-EN ISO 15614-1 mention for semi-automatic welding that a change from globular, spray or pulsed transfer welding to short circuiting transfer welding or vice versa requires a new qualification.

6.10.10. Related to the heat input

In the ASME IX there are several formulas to calculate the heat input in function of the waveform, instantaneous measurements, mechanical and automatic welding. The SS-EN ISO 15614-1 Standard refers only to the formula in the SS-EN 1011-1 Standard [48].
In ASME IX, only an increase in the heat input or an increase in volume of weld metal deposited per unit length of weld requires a new qualification.
The SS-EN ISO 15614-1 Standard allows a change in energy of 25% higher or 25% lower than the energy used when welding the test piece, depending on the impact or hardness requirements: *when impact requirements apply, the upper limit of heat input qualified is 25 % greater than that used in welding the test piece; When hardness requirements apply, the lower limit of heat input qualified is 25 % lower than that used in welding the test piece*. It is not a general rule but the variation in heat input for ASME IX usually is ± 10% and for SS-EN ISO 15614-1is ± 25%.
ASME IX takes into account a lot of possible energy variables as power ratio, pulsing frequency, dwell time, flashing time, etc… which are considered as a part of the welding process in the SS-EN ISO 15614-1 Standard.

6.10.11. Related to the heat treatment

Compared to the values used in the qualification, the heat treatment conditions in ASME IX do not allow:

a) a decrease of preheat temperature,
b) a change in the maintenance or reduction of the preheat,
c) an increase of the interpass temperature.

For the post weld heat treatment (PWHT), a separate procedure qualification is required. A welding procedure qualification with PWHT can only cover a WPS with PWHT and a qualified procedure without PWHT can only cover WPS's without PWHT. In this case it must be evaluated if PWHT is mandatory by other Sections of the ASME Code and great importance should be devoted to the material thicknesses. A change in temperature and time range of the PWHT can require a new welding qualification.

SS-EN ISO 15614-1 specifies that when preheat is required the lower limit of qualification is the nominal preheat temperature applied at the start of the welding procedure test. The upper limit of qualification of the interpass temperature is the temperature reached during the test.
If post heating for hydrogen release (diffusion) is done, the temperature and holding time shall not be reduced. Post heating shall not be omitted but may be added. The addition or deletion of PWHT is not permitted (same as in ASME IX).
A change in the initial heat treatment conditions prior to welding for precipitation hardenable materials is not permitted.

It can be stated that both ASME IX and SS-EN ISO 15614-1 follow approximately the same reasoning for the heat treatments, which are required by other specifications.

6.10.12. Related to other variables

1. Validity for used protection gas and backing gas:
   A procedure qualification according to ASME IX is only valid for the same chemical composition of the used gas. The SS-EN ISO 15614-1 reasoning is almost equivalent but it refers to the grouping of gas (EN ISO 14175 [49]) and lets the composition of CO2 vary inside the group. For gases that are not covered by the SS-EN ISO 14175, the nominal composition of the used gas is an essential requirement.

2. Validity in time:
   In both ASME IX and SS-EN ISO 15614-1 Standard the validity of the welding procedure qualification is the same. The PQR remains valid as long as nothing is changed to the essential variables.

3. Validity for submerged arc welding:
   The used and unique combination of filler metal and flux is an essential variable in both ASME IX and SS-EN ISO 15614-1 Standard. Even in the SS-EN ISO 15614-1 Standard the qualification given for the flux is restricted to the make and designation used in the welding procedure test.

4. Other welding processes:
   ASME IX also describes other more non-conventional welding processes, while in the European context these processes are described in separate standards. Examples: Stud welding (SS-EN ISO 14555 [50]), Resistance welding (SS-EN ISO 15614-12), Laser beam welding (SS-EN ISO 15614-11 [51]), Tube to tube sheet welding (SS-EN ISO 15614-8 [47]), Flash welding (SS-EN ISO 15614-13 [52]) and even Temper bead welding, for which no equivalent European qualification standard exists.

7. Qualification of welders

7.1. Standards

Section IX of the ASME B&PV Code and the SS-EN ISO standards have the same philosophy to qualify a welder or a welder operator with a test, but the conditions and method is different.

ASME IX of the ASME B&PV Code [4] provides in one volume the requirements for welder performance qualifications using manual welding, semi-automatic welding or automatic welding in all techniques (even diffusion welding).

EN (ISO) has separate standards for qualification testing of welders. Table 9 below provides some of the SS-EN (ISO) standards applicable to the qualification of welders.

Table 9: SS-EN (ISO) standards applicable to the qualification of welders

SS-EN 287-1 [21]	Qualification of welders – fusion welding- part 1: Steel
SS-EN ISO 9606-2 [53]	Qualification of welders – fusion welding- part 2: Aluminium and aluminium alloys
SS-EN ISO 9606-3 [54]	Qualification of welders – fusion welding- part 3: Copper and copper alloys
SS-EN ISO 9606-4 [55]	Qualification of welders – fusion welding- part 4: Nickel and nickel alloys
SS-EN ISO 9606-5 [56]	Qualification of welders – fusion welding- part 5: Titanium and Zirconium and alloys
SS-EN ISO 14732 [57]	Welding personal – approval testing of operators for fully mechanized and fully automatic

The personnel qualifications for other welding processes are integrally included in the corresponding standards for the welding procedure qualifications. For instance, the qualification of the welder for tube-to-tube plate is described in SS-EN ISO 15614-8 [47] and the qualification of the operator for laser beam welding in SS-EN ISO 15614-11 [46].

The SS-EN 287-1 [21] has had an eventful development since 1992. To obtain international recognition (and to be adapted to the technical evolution), the standard SS-EN 287-1 that is used today may change in the near future. The final changes and innovations can only be explained upon publication, and especially after approval of the SS-EN ISO 9606-1 Standard [58], which is not yet released. Only the version ISO 9606-1 [59] exists but without SS-EN approval).

It should also be emphasized that the SS-EN 287-1 Standard enables the qualification of welders for the fusion welding of steels independently of the type of product. On the other hand ASME IX treats only the welder performance qualification for pressure components constructed in accordance with the ASME B&PV Code.

7.2. Responsibility

ASME IX defines in a QW-300.2 the responsibility for the manufacturer to qualify his welders by testing a weld coupon welded using an already qualified WPS.
The welders qualification is only valid in the organization of that manufacturer.
A welder who leaves his employer cannot use his qualification in another organization or employer.

The SS-EN 287-1 Standard describes also the qualification test but there is no need to weld the weld coupon with a qualified WPS. In some cases a welder can be qualified on the basis of a preliminary WPS and a PQR is not always required.
It is not clear whether a welder qualified in an organization of the manufacturer is allowed to weld within his qualification limits for another organization of a second manufacturer. Unless this second manufacturer confirms that he approves and accepts the certificate (This in the European spirit of common market of goods, persons, established in The Treaty of 1957).

Note that both ASME IX and SS-EN 287-1 Standard define welding qualifications and not certifications.
The qualification report is referred to in ASME IX (see Form QW 484A) as the *Welder Performance Qualification (WPQ) Record*. On the other hand, the SS-EN 287-1 Standard designates his report as *Welder qualification test certificate*. To the opinion of the Authors, this designation is ambiguous because it could lead to use inappropriately the term "certification" to designate the qualification of a welder. Certification of persons should require certification commissions and organizations to SS-EN ISO 17024 [60] and this is not the common way for the welder qualification.[12]

7.3. Terms and definitions

SS-EN 287-1:2011 [21] describes in Clause 3 a lot of terms and defines the abbreviations in Clause 4, These terms and abbreviations are more numerous than in the SS-EN ISO 15614-1 Standard [28]. These descriptions are not comparable with the definitions provided in Subsubarticle QW-492 in ASME IX.

[12] Notified Bodies and recognized third party organizations are assigned by the European Member States. These designations must comply with the minimum criteria of Annex IV of the Directive. Despite the recommendations from the European Commission accreditation is not (yet) an obligation. Some member states do not apply accreditation and some apply one or more of the accreditation standards of the SS-EN ISO 17000 series.
It is the opinion of the authors that an SS-EN ISO 17024 accreditation for Notified Bodies is not necessary for the following reasons :

- Welders are not supposed to act in an autonomous way. Their qualification is linked to an organization (their employer) and to welding procedures qualified within that organization.
- The Directive does not use the terms certificate and certification. Operating procedures and personnel must be approved.
- Checking compliance and acceptance of welding procedures and welders belongs to the core activities of inspection agencies and should be covered by their notification conditions as inspection body.
- The added value of an SS-EN ISO 17024 accreditation is questionable.

7.4. Essential variables and range of qualification

Section IX of the ASME B&PV Code, as mentioned in paragraph 5.7, presents per welding process a table with the possible essential variables for that process, that have an impact on the qualification of welders (verification of craftsmanship and possibility to make a sound weld). The most common variables are joints, base metals, filler metals, position, gas and electrical for FCAW (Flux-Cored Arc Welding) and GTAW (Gas Tungsten Arc Welding) ASME IX contains a summary table with the essential variables in Table QW-416 for the most common welding processes. Variables for the other processes are mentioned in Subarticles QW-360 and QW-380.
There are no supplementary or non-essential variables. All what is not mentioned may change inside the range of approval.

The SS-EN 287-1 Standard specifies the 8 variables, such as described in the procedure qualifications, which are treated in tables. Other (sometimes hidden) variables can be found in texts scattered in the standard.

7.4.1. Related to the welding process

Both ASME IX and SS-EN 287-1 Standard specify that each qualification test normally qualifies only one welding process. A change of welding process requires a new qualification test.

There are exceptions in the SS-EN 287-1 Standard: the change from welding process 135 (semi-automatic welding with solid wire) to 138 (semi-automatic welding with metal cored wire) or vice versa does not require a new qualification. And TIG welding with filler (welding processes 141, 143 or 145) qualifies for 142 (without filler) but not vice versa.

However, in both ASME IX and SS-EN 287-1 Standard, it is permitted for a welder to be qualified for two or more welding processes by welding a single test piece (multi process joint) or by two or more qualification tests pieces. The ranges of qualification concerning the deposited thickness of the weld metal for each welding process used in the multi process joint for butt welds must comply with the values of the table on the thicknesses (see paragraph 7.4.6below).

7.4.2. Related to the product type

This product type is not mentioned as a variable in ASME IX. A qualification of a welder on plate also qualifies him on pipes, but sometimes limited in different positions (see paragraph 7.4.7 below) and diameters (see paragraph 7.4.3 below).

In SS-EN 287-1, when pipes are welded, they only qualify plates when the outside diameter is greater than 25 mm. Welding of plates only qualifies pipes from outside diameter 150 mm or 500 mm depending the welding position. SS-EN 287-1 is therefore more restrictive than ASME IX.

7.4.3. Related to the type of weld

In ASME IX qualifying for a welder for groove welds qualifies him for all type of groove welds and also all fillet welds (in all base material thicknesses, fillet sizes and diameters), but qualifying for fillet welds qualify the welder for all fillet welds only.
An important essential variable for the joint is the deletion of a backing.

SS-EN 287-1 has another approach. Butt welds cover butt welds and branch pipe connections (max 60°). Butt welds do not qualify fillet welds or vice versa.
A special qualification method (by welding a supplementary test piece) is proposed to cover fillet weld in the validity range of butt welds. This method is not common because two separate qualifications (one for butt welds and one for filler welds) result in an even greater scope of validity.

7.4.4. Related to the parent material group

SS-EN 287-1 uses a table (Table 2) with references to the material groups from CEN ISO/TR 15608 [35]. A copy of this table is provided in Table 10 below. The underlying principle is that the welding of any metal in a material group covers qualification of the welder for the welding of all other metals within the same material group as well as other material groups mentioned in that table.
Note that carbon steel (Group 1) mainly qualifies only carbon steel. Stainless steel (Group 8) mainly qualifies only stainless steels and nickel (Group 9). Only one test piece with a dissimilar joint can qualify both carbon steels and stainless steels.
It is noteworthy to mention that, when US carbon steels is used with higher % of carbon (see paragraph 5.8 above), the material is group 11, which gives a wider scope of materials (plus 1.3 and 11) than using European carbon steel from group 1.

Table 10: SS-EN 287-1 Table 2: Range of qualification for parent metal

Material group [a] of the test piece		Range of qualification												
		1.1 1.2 1.4	1.3	2	3	4	5	6	7	8	9: 9.1	9: 9.2 + 9.3	10	11
1.1, 1.2, 1.4		×	–	–	–	–	–	–	–	–	–	–	–	–
1.3		×	×	×	×	–	–	–	–	–	×	–	–	×
2		×	×	×	×	–	–	–	–	–	×	–	–	×
3		×	×	×	×	–	–	–	–	–	×	–	–	×
4		×	×	×	×	×	×	×	×	–	×	–	–	×
5		×	×	×	×	×	×	×	×	–	×	–	–	×
6		×	×	×	×	×	×	×	×	–	×	–	–	×
7		×	×	×	×	×	×	×	×	–	×	–	–	×
8		–	–	–	–	–	–	–	–	×	–	×	×	–
9	9.1	×	×	×	×	–	–	–	–	–	×	–	–	×
9	9.2 + 9.3	×	–	–	–	–	–	–	–	–	–	×	–	–
10		–	–	–	–	–	–	–	–	×	–	×	×	–
11		×	×	–	–	–	–	–	–	–	–	–	–	×

[a] Material group according to CEN ISO/TR 15608.

Key

× indicates those material groups for which the welder is qualified.

– indicates those material groups for which the welder is not qualified.

ASME IX adopts another approach for the base materials. A welder using P-No.1 through P-No.15F, P-No.34, and P-No.41 through P-No.49 is qualified to weld the full scope all these material groups (restriction will be imposed later by the filler metal).
Unassigned materials (not listed in QW-422) for the qualification of the welder are not to be considered because the unassigned metals may be considered as having the same P-number as an assigned metal provided it meets the mechanical and chemical requirements of the assigned metal.
On the other hand, SS-EN 287-1 requires a separate qualification test if the welding parent materials is outside the grouping system CEN ISO/TR 15608.

Related to the parent material, it may be concluded that the SS-EN 287-1 is very restrictive when compared to Section IX

7.4.5. Related to the filler material

EN 287-1 limits the range of qualification with tables.
Table 3 in SS-EN 287-1 concerns the range by type of covering for covered electrodes (111) divided in rutile, basic and cellulosic covering. Table 4 in SS-EN 287-1 concerns the wire electrodes divided into solid wires, metal cored wires and flux cored wires.
For some welding processes the welding with filler material qualifies also welding without but not vice versa.

ASME IX places a higher value on the filler metal. The F number, related to the AWS classification (see paragraph 5.9 above) limits the range of qualification for the welder (QW-433) For example, using a F-No.3 electrode on a weld without backing allows to weld with a F-No.1 electrode only with backing, a F-No.2 electrode only with backing and a F-No.3 electrode with and without backing. Any F-No6 electrode (e.g., austenitic stainless steel) covers only all F-No. 6 electrodes. Referring to paragraph 7.4.4 above, it could be thought that a welder using a stainless steel test piece is allowed to weld also carbon steel to carbon steel. It is indeed the case but the use a stainless steel filler metal is required.
It should be emphasized that the A-Number (chemical composition of the weld deposit) which was important for the procedure qualification (see paragraph 6.10.8 above), does not play any role in the welder qualification.

7.4.6. Related to the dimensions

The SS-EN 287-1 Standard defines the range of qualification for welders with tables (Tables 5 and 6 in SS-EN 287-1for butt welds and Table 7 in EN287-1 for fillet welds) for thicknesses (base metal thickness ‘t’ or weld deposit thicknesses ‘s’ in case of a multi-process welding qualification) and diameters. A note states that *it is not intended that material thickness or outside pipe diameters should be measured precisely but rather the general philosophy behind the values given in Tables 5 and 6 should be applied.* Tables 5, 6 and 7 in SS-EN 287-1 are reproduced in Tables 11, 12, and 13 below.

Table 11: SS-EN 287-1 Table 5: thickness (mm) for butt welds

Dimension in millimetres

Thickness[a] t	**Range of qualification**
$t < 3$	t to $2 \times t$ [b]
$3 \le t \le 12$	3 to $2 \times t$ [c]
$t > 12$	≥ 5

Table 12: SS-EN 287-1 Table 6: Range of qualification for outside pipe diameter

Dimension in millimetres

Outside pipe diameter of test piece D	**Range of qualification**
$D \le 25$	D to $2 \times D$
$D > 25$	$\ge 0,5 \times D$ (25 mm min.)

Table 13: SS-EN 287-1 Table 7: Thickness (mm) for fillet welds

Dimension in millimetres

Material thickness of test piece t	**Range of qualification**
$t < 3$	t to 3
$t \ge 3$	≥ 3

Note some lower limit of thickness as 't' itself, 3 mm and 5 mm and the upper limits as the double of the used thickness.
Note specially the upper limit as the double for the outside diameter (this includes no plates if the diameter was ≤ 25 mm).

Note that in the future SS-EN ISO 9606-1 [58] all values of 't' will be replaced by 's'

ASME IX specifies in 5 tables (QW-452.x) the ranges for thicknesses and diameters. Reworked versions of these Tables are provided in Tables below.

Table 14: For groove welds (reworked table)

Thickness weld deposit 't'	Thickness of weld metal qualified
all	*2t*
13mm (minimum 3 layers)	*Maximum to be welded*

Table 15: For fillet welds (reworked table)

Thickness of test coupon 'T'	Qualified range
5 mm or greater	*All thicknesses, sizes and Ø ≥ 73 mm*
Less than 5 mm	*T to 2T, T max size and Ø ≥ 73 mm*

Table 16: For fillet welds qualified by butt welds (reworked table) (don't exist in SS-EN ISO)

Type of joint	Thickness of coupon 'T'	Qualified range
Any groove	*All thicknesses*	*All thicknesses, sizes and all Ø*

Table 17: Groove weld diameter limits (reworked table)

Outside diameter test coupon	Outside diameter qualified
Less than 25 mm	*Size welded up to unlimited*
From 25 mm to 73 mm	*25 mm up to unlimited*
Over 73 mm	*73 mm um to unlimited*

Table 18: Small diameter fillet weld test (reworked table)

Outside diameter test coupon	Diameter qualified	Thickness qualified
Less than 25 mm	*Minimum size welded*	*All*
From 25 mm to 73 mm	*Minimum 25 mm*	*All*
Over 73 mm	*Minimum 73 mm*	*All*

Note that in ASME IX there is no minimum thickness for qualification of welder
Note that there is no upper limit for diameter so that plate is included.
Note the wide range for fillet weld when qualified by groove weld.

When comparing with the qualification ranges set forth in SS-EN 287-1, it may be seen that the ranges of thicknesses and diameters are different and mostly larger in ASME IX.

7.4.7. Related to the welding positions

The welding positions used in both ASME IX and SS-EN 287-1 (see paragraph 5.14 above) give a validity range as good as similar. The reason behind this is that a welder who realizes successfully a weld piece without defects in a difficult position, is assumed to succeed in an easier position.

The European standard SS-EN ISO 6947 [42] defines qualification positions (PA, PB, … or HL045) with small tolerances and defines the working positions (also PA, PB, … or HL045) but with greater tolerances.
Vertical up (PF or PH) and vertical down (PG or PJ) are included in the positions.

ASME IX defines the qualification positions (1G, 2F, … and 6G) and the working positions for which the welder is qualified as F (flat), H (Horizontal) V (Vertical), O (overhead).
Vertical up or vertical down are not specified with a position but they are for all welder qualification tests an essential variable.

7.4.8. Related to the weld details

In SS-EN 287-1, the weld details which influence the range of welder qualification are: single side or double side welding, welding with or without backing, welding from both sides, single- and multi-layer, rightwards and leftwards welding. Depending on these weld details, the ranges of qualification are shown in tables 9 and 10 in SS-EN 287-1.

In ASME IX, welding details are divided between the large number of variables listed in Article QW-400. These are only to be used if required by QW-300 (depending on the welding technique and welding process) and by the essential variables in the qualification tables (e.g., the already mentioned QW-416, see paragraph 7.4 above).

7.5. Welding the test piece

The dimensions of the test blocks should have as a minimum a 150 mm controlled weld length, otherwise multiple test pieces shall be welded. This reasoning is basically the same for both ASME IX and SS-EN 287-1 Standard, although the minimum dimensions in SS-EN 287-1 are imposed.
Also the welding should be performed in a time corresponding with a normal required working time. The welding is witnessed by the examiner who verifies that the variables of the qualified WPS (ASME IX) or the pWPS (EN287-1) are respected.
EN 287-1 defines clearly that all test pieces should have at stop and re-start in the root run and the capping run (the welder must also prove that he is capable to weld a stop/start without errors). In ASME IX only a test coupon for fillet weld needs a stop/start as required by figure QW-462.
Prior to any testing the test piece should be cleaned (no slag, no spatter, not grinding of the weld metal). A PWHT can be omitted at the discretion of the manufacturer because this is not an essential variable for welders' qualification.

7.6. Examination and testing

ASME IX is very precise and detailed with the testing while SS-EN 287-1 offers a wide range of possible test scenarios. Tables 19, 20, and 21 below provide some details about the requirements for examination/testing.

Table 19 compares the requirements of ASME IX and SS-EN 287-1 for examination/testing of welder performance test blocks.

Table 19: General compared test table

	Section IX	EN 287-1
Groove weld / Butt weld.	Visual Bend test [a)]	Visual Radiographic (or UT) Bend test Fracture test
Fillet welds	Macro test Fracture test	Visual Fracture (or macro)

A large number of foot notes can make this tests pretty complex

More details about the requirements are given in Table 20 for Section IX and in Table 21 for SS-EN 287.

Table 20: Section IX examination/testing requirements

Section IX provisions	
Small groove welds (< 19 mm)	Visual + 1 x root bend + 1 x face bend [a)]
Thick groove welds (≥ 19 mm)	Visual + 2 x side bend [a)]
Fillet welds	Macro + fracture

Table 21: SS-EN 287-1 examination/testing requirements

EN 287-1 provisions	
Butt welds	Visual + Radiographic
Butt welds (ferritic and t ≥ 8 mm)	Visual + Ultrasonic
Butt welds	Visual + 100% bend
Butt welds	Visual + 100% texture
Butt welds (131, 135, 138, 311)	Visual + Radiographic + (2 or 4)[b)] additional bend
Butt welds (131, 135, 138, 311)	Visual + Radiographic + (2 or 4)[b)] additional texture
Butt welds (131, 135, 138, 311 + ferritic and t ≥ 8 mm)	Visual + Ultrasonic + (2 or 4)[b)] additional bend
Butt welds (131, 135, 138, 311 + ferritic and t ≥ 8 mm)	Visual + Ultrasonic + (2 or 4)[b)] additional texture
Fillet welds	Visual + fracture
Fillet welds	Visual + macro

a) ASME IX describes also an alternative for the bend test. These can be replaced by volumetric non-destructive examination (NDE) when using the common welding processes SMAW, SAW, GTAW, PAW, GMAW. But this is not valid for GMAW in the short circuit mode, where bend test are the only way to qualify the welder. Volumetric NDE is either radiography or ultrasonic.
A second alternative, which exists only in ASME IX, is that the welder can be qual-

ified by examination of the first 150 mm length of his first production weld. Examination is hereby of course the proposed NDE.
A welder cannot be qualified by a production weld in SS-EN 287-1 where a test piece is mandatory.

b) in function of welded position 2 additional test for PA and PC, 4 additional test for other positions.

All tests have to be realized in conformity with the non-destructive standards.

7.7. Acceptance criteria

The acceptance criteria for the ASME IX performance qualification are well determined in Article QW-100. The acceptability is based on the size of the found indications.

In analogy with the procedure qualifications, the SS-EN 287-1 Standard refers to the standard SS-EN ISO 5817 [37]. Depending on the type of imperfection, quality B (highest level) or C (intermediate level) is required. As already mentioned, the acceptability is based on the real size of the imperfection.

ASME IX describes a possible ‘immediate retest’ and SS-EN 287-1 gives the welder the opportunity to repeat the qualification test. Nevertheless, it is not intended to try and retry until the welder succeeds.
If the indications or imperfections in the welder’s test piece exceed the permitted maximum specified, the welder is supposed to have failed the test.

7.8. Period of validity and prolongation

An ASME IX qualification for a process expires in time when a welder has not welded with that process during a period of six months.
This requires the manufacturers to keep logbooks, follow up systems for welders, to prove that the welder did weld within the period of six months with that process.
When there is a specific reason to question his ability to make welds that meet the specification, the qualification can be revoked.
Renewal of performance qualification for a specific process can easily be done by welding a single test coupon of either plate or pipe, of any material, thickness or diameter, in any position (see QW-322.2) with the process.
Acceptable tests on that coupon will renew the welder previous qualifications for that process.

The procedure in SS-EN 287-1- is a little more complex. The welder qualification is valid for two years providing that the manufacturer can confirm that the welder has welded within the initial range of qualification, every six months.
This looks similar to ASME IX and can be fulfilled by the same follow up system for welders. Differences are that the evaluations must be done every six months. As an example: it is possible that the welder has welded in the beginning of the second six monthly period and at the end of the third six monthly period, even if there are eight months between, he remains qualified in SS-EN 287-1 but not in ASME IX.
However the biggest difference is that, in SS-EN 287-1, the welder should weld within the initial range of his qualification to confirm the validity. This is to be evaluated for every qualification and in ASME IX for every process only.

The prolongation in SS-EN 287-1 is to be performed after two years by the examiner or examining body. The examiner has to verify all records and evidences used to support prolongation for traceability to the welder and to the WPS used in production.
The examiner should find evidence (volumetric examination or destructive testing) that proves that in the last six months, two welds were produced by that welder, similar to the original test conditions, except for thickness and outside pipe diameter. The test results on those two welds shall be conform to SS-EN ISO 5817. Examinations in accordance with the design and construction codes or standards are not enough.
In practice a few manufacturers are found that realize a 100% conform evaluation and prolongation system responding the SS-EN 287-1 requirements. Complete new qualification for the expired qualification is more a normal way of working.
Fulfilling the ASME IX requirements for prolongation is less complex if it is well followed up by the manufacturers.

Note that the period of validity, with the confirmations every six months and the prolongation after two year, shall change thoroughly in the future ISO 9606-1. There will be a choice between:

1. A validity range for three years with every three years a new qualification.
2. A system identical to the current requirements.
3. A prolongation system equivalent to the ASME IX procedure provided that some additional conditions are fulfilled.
   Example: the welder continues to work for the same manufacturer, the manufacturer has an approved by verification ISO 3834 quality program and an adequate system for tracking the welders data and the quality of the production welds based on the application standards.

7.9. Reports

The reporting of the performance qualification has already been discussed in paragraph 7.2 above and is completed hereafter.

ASME IX and SS-EN 287-1 present suggested formats for reporting the performance qualification. All formats refer to the used WPS during qualification, the PQR which covers this WPS, unambiguous identification of the welder, actual values of the essential variables during welding and range qualified. Also the test results are mentioned.
Section IX has only one suggested format (QW-484A) named *Welder Performance Qualification record*.

EN (ISO) has multiple examples of reports depending on the different standards for welders' qualification. These documents have the same content as the ASME IX reports.

7.10. Verification of competence

The verification of competence does not exist in ASME IX but the SS-EN 287-1 Standard provides for the possibility of a job knowledge test. It is recommended, not mandatory (see Annex C in SS-EN 287-1).
The welder must prove that, by his former training and experience, he has a sufficient welding knowledge and can assure that procedures are followed and common practices are complied with. In practice, the welder is subject to some twenty multiple choice questions, for which he must obtain minimum 15/20 marks.

8. Preheating and Post Weld Heat treatment

8.1. Heat treatments to be considered

Heat treatment is an operation that is both time consuming and costly. It can affect the strength and toughness of a welded joint, its corrosion resistance and the level of residual stress but is also a mandatory operation specified in many construction Codes and Standards. In addition it is an essential variable in welding procedure qualification specifications.

Various definitions relative to heat treatment are given below:

- Solution treatment is carried out at a high temperature and designed to take into a solution elements and compounds which are then retained in solution by cooling rapidly from the solution treatment temperature. This may be done to reduce the strength of the joint or to improve its corrosion resistance
- Annealing consists of heating a metal to a high temperature, where recrystallization and/or a phase transformation take place, and then cooling slowly, often in the heat treatment furnace. This is often carried out to soften the metal after it has been hardened
- Normalizing is a heat treatment that is carried out only on ferritic steels. It comprises heating the steel to some 30-50°C above the upper transformation temperature (for a 0.20% carbon steel this would be around 910°C) and cooling in still air. This results in a reduction in grain size and improvements in both strength and toughness.
- Quenching comprises a rapid cool from a high temperature. A ferritic steel would be heated to above the upper transformation temperature and quenched in water, oil or air blast to produce a very high strength, fine grained martensite. Steels are never used in the quenched condition, they are always tempered following the quenching operation.
- Tempering is a heat treatment carried out on ferritic steels at a relatively low temperature, below the lower transformation temperature; in a conventional structural carbon steel this would be in the region of 600-650°C. It reduces hardness, lowers the tensile strength and improves ductility and toughness. Most normalized steels are tempered before welding
- Ageing or Precipitation hardening is a low temperature heat treatment designed to produce the correct size and distribution of precipitates, thereby increasing the yield and tensile strength.
- Stress relief is a heat treatment designed to reduce the residual stresses produced by weld shrinkage. It relies upon the fact that, as the temperature of the metal is raised, the yield strength decreases, allowing the residual stresses to be redistributed by creep of the weld and parent metal. Cooling from the stress relief temperature is controlled in order that no harmful thermal gradients can occur.
- Pre-heating of the base metal prior to welding. There are four primary reasons to utilize preheat: (1) it lowers the cooling rate in the weld metal and base metal, producing a more ductile metallurgical structure with greater resistant to

cracking (2) the slower cooling rate provides an opportunity for any hydrogen that may be present to diffuse out harmlessly without causing cracking (3) it reduces the shrinkage stresses in the weld and adjacent base metal, which is especially important in highly restrained joints and (4) it raises some steels above the temperature at which brittle fracture would occur in fabrication. Additionally, preheat can be used to help ensure specific mechanical properties, such as notch toughness.

- Preheating temperature depends on a number of factors, such as the chemical analysis, degree of restraint of the parts being joined, elevated temperature, physical properties and material thicknesses.
- Preheating temperature is always a minimum temperature.
- Interpass temperature is the highest temperature in the weld joint immediately prior to welding, or in the case of multiple pass welds, the highest temperature in the section of the previously deposited weld metal, immediately before the next pass is started. Interpass temperature is important with regard to the mechanical and microstructural properties of welds. High temperatures reduce the weld metal strength and higher temperatures provide a finer grain structure.
- Interpass temperature is always a maximum temperature.
- Post heating is a low temperature heat treatment carried out immediately on completion of welding by increasing the preheat by some 100°C and maintaining this temperature for 3 or 4 hours. This assists the diffusion of any hydrogen in the weld or heat affected zones out of the joint and reduces the risk of hydrogen induced cold cracking.
- Post heating is not necessary for most applications. The need assumes a possible hydrogen induced cracking problem (sensitive microstructure, high hydrogen and high stresses). Post heating may be a code requirement for example: ASME III requirement for P No.1 materials is 230 to 290°c for a minimum of two hours. Post heating is also often required for critical repairs (to avoid hydrogen cracking).
- Post Weld Heat Treatment (PWHT) is a heat treatment to improve the properties of the weld and that is carried out when welding is complete.
  The effects are to increase the resistance to brittle fracture and relaxing residual stresses. Other results are hardness reduction and material strength enhancements.

The necessity of performing a PWHT is mostly a function of the composition and structure of the material, the thickness of the material and the operating conditions (temperatures, stresses, ...). The content of the alloying elements and previous heat treatment of the base metal can also give rise to PWHT. The properties of quenched and tempered alloy steels can be adversely affected by PWHT if the temperature exceeds the tempering temperature of the base metal. The filler metal composition is also important. After heat treatment, the properties of the deposited weld can be considerably different than the “as-welded” properties (usually strong reduction of specified tensile strength).
Particularly when constructing a pressure equipment in accordance with the pressure vessel codes such as Section III of ASME B&PV Code, SS-EN 13445 Standard or Section VIII of ASME B&PV Code, the PWHT could be mandatory. In this case the construction standard specifies when and how.

8.2. Construction code requirements for PWHT

ASME B&PV Code and SS-EN ISO construction standard specify not only "when" PWHT is to be done but, in that case, also "how" to perform the PWHT.
The Code/Standard require to heat uniformly the structure to a sufficient high temperature (but below the transformation temperature range) to hold that temperature during a specific time and then to cooling it uniformly. Articles and tables in the construction codes determine the values. For example, Table NB-4622.1-1 in Section III, Subsection NB of the ASME B&PV Code , Table 9.14.1-1 in SS-EN 13480-4 [20] or Table 10.1-1 in SS-EN 13445- [29] specify for what kind of material (P-number or Group number), and from which thickness PWHT is required or not.
Also the holding temperature range is indicated as well as the minimum holding time at temperature in function of the weld (or base metal) thickness.

The ASME B&PV Code refers also to alternate temperatures, temper bead welding (conditions for making repairs without PWHT) and the exemptions to mandatory PWHT.
For stainless steel PWHT is neither required nor prohibited.
There are some materials which almost always require PWHT. For example chrome-molybdenum steels usually need stress relieving at 675 to 700°C temperature range.

The tables in SS-EN standards are similar, but there are also important differences:

- As already mentioned (see paragraph 5.8 above), the base metal grouping system is different. An US material P-No.4 could be a European Group 4 material. So the PWHT requirements could be really different.
- The thickness to be considered in ASME B&PV Code is always the "t", the base material thickness. This material thickness, which is of course known before welding, determines the possible PWHT or not.
  The thickness to be considered in SS-EN 13480-4 is the controlling thickness "W" (example for a butt weld the thickest part of the welded joint). As a result, the possible PWHT should be evaluated after the welding, when the thickness of the welding can be measured. Such a situation has already caused problems.
- The minimum PWHT holding times as required in the SS-EN (ISO) standards are noticeably lower than in ASME.
- There are also slight differences in the proposed method (procedure) for PWHT concerning calibration, the gradual cooling and warming speed, numbers and location of thermocouples, …
- Currently the SS-EN (ISO) standards do not provide rules for operating temperatures in the creep range and do not take into account the nuclear irradiation (e.g. neutron fluence) on the materials. These rules are included in Section III of the ASME B&PV Code.

8.3. Influence on the welding qualifications

Both ASME IX and SS-EN (ISO) welding qualification standards for welding procedure qualifications consider the PWHT as an essential variable. A qualified welding procedure with PWHT is always to be used with PWHT and a qualified welding procedure without PWHT is always to be used without PWHT.

This has an influence on the qualified thicknesses. “With PWHT” could mean that the range under the minimum required thickness for PWHT cannot be used (unless PWHT is also performed on these thin thicknesses) or vice versa: a procedure without PWHT cannot be used for thicknesses higher than the minimum required thickness for PWHT.
PWHT is not an essential variable for qualification of welders in accordance with ASME IX and SS-EN 287-1 Standard. Nevertheless the SS-EN 287-1 standard mentions in Clause 6.3 that *any post-welded heat treatment required in the pWPS or WPS can be omitted at the discretion of the Manufacturer.*

ASME IX considers in various Subsubarticles the performance of PWHT above the upper transformation temperature (normalization or solution heat treatments) and below the lower transformation temperature.
ASME IX allows a change of 25% difference of the aggregate times at temperature (QW-407.2). ASME IX requires (QW-407-4) that if the PWHT is realized above the upper transformation temperature or if there is a solution heat treatment, the thickness range will be limited to 1.1 x the thickness of the test coupon (this is not a rule in SS-EN ISO).
For the procedure qualification of weld corrosion-resistant overlay, ASME IX considers (QW-407.9) in addition to the requirements of QW-407.1 specific requirements which ask for a separate procedure qualification depending on the A-No of the filler metal. For instance, for weld overlay with A-No 8 on all base material, when the total time of the PWHT in fabrication exceeds 20 hrs, a separate procedure qualification is required in case of a increase of 25% or more in total time at postweld heat treating temperature.

EN ISO qualifications are less technically supported with respect to the influence of PWHT. The validated temperature range is the holding temperature used in the welding procedure test ± 20°C unless otherwise specified. When required, the holding time, heating rates and cooling rates shall be related to the product.
On the other hand, the SS-EN (ISO) welding qualification standards describe requirements for other heat treatment parameters as the interpass temperature (always maximum), the post heating for hydrogen release (temperature and duration not reduced), the initial heat treatment (initial heat conditions prior to welding of precipitation hardenable materials is not permitted) and the preheat temperature (not below the lower limit of qualification). This last point means that if no preheat is realized during the qualification, preheat may be added in production without requalification.

8.4. Where should the temperature be measured?

There is also a subtle difference in the measurement points for temperature between the ASME B&PV Code and the EN(ISO) standards.
According to AWS D1.1 [61][13] temperature measurement points must be taken at a distance at least equal to the thickness of the thickest welded part (but not less than 3” (75 mm) in all directions from the point of welding.
Specific industries in US have adopted self-imposed regulations like 1” (25 mm) away from the weld toe and within the first foot (300 mm) of its start. In this particular case, the preheat is applied from the back side of the joint so as to completely “soak” the base metal. This last reasoning is been used in the nuclear requirements.

[13] ASME Code does not refer to AWS D1.1, though this measurement technique is common in USA and it is referred to in construction codes.

SS-EN ISO standard refers to the SS-EN ISO 13916 [64]. For small thicknesses (< 50 mm) the measurement points are 4 x the thickness measured from the border of the weld preparation. For lager thicknesses, the measurement points are at 75 mm form the edge of the weld preparation, measured at the opposite side of the warming-up side.

9. Rules and requirements concerning the quality system for welding companies

This chapter completes chapter 3 above. Some duplication could not been avoided.

9.1. In the scope of the ASME Code, Section III

Section III of the ASME Code requires obtaining an N certificate and to establish, maintain and document a quality assurance program. (NCA-3520 in NCA Subsection of Section III [8]).
The quality assurance requirements as such are introduced by Article NCA 4000,"*Quality Assurance*" in Subsection NCA.
Subsubarticle NCA-4110 in Subsection NCA sets forth the requirements for planning, managing, and conducting Quality Assurance Programs for controlling the quality of activities performed under Section III and the rules governing the evaluation of such programs prior to the issuance of certificates for the construction, fabrication, manufacture, and installation of ASME Class 1, 2, and 3 components, Class MC (Metal Containment), and Core Support structures (CS).
Subsubarticle NCA 4110 requires also that N-type Certificate Holders (what means practically all manufacturers, engineering organizations and installers of equipment subject to Section III) shall also comply with the requirements of Part I in ASME-NQA-1 [23], *Quality Assurance Requirements for Nuclear Facilities Applications*,
The quality assurance requirements related to welding activities are addressed in Subparagraph NCA-4134.9, *Control of processes*.
This subparagraph requires that the Certificate Holder shall prepare instructions, procedures, drawings, checklists, travelers, or other appropriate documents, including the document numbers and revisions to which the process conforms, with space provided for reporting results of completion of specific operations at checkpoints of fabrication, manufacture, or installation. The documents must include space for: a signature, initials, or stamp; the date that the activity was performed by the Certificate Holder's representative; the Authorized Nuclear Inspector's signature, initials, or stamp; and the date on which those activities were witnessed.
This Subsubparagraph also introduces the (additional) provisions of NQA-1- Requirement 9 that must be applied.

NQA-1 Requirement 9: Control of special processes.
This requirement starts with identifying what processes are to consider as special:

- *Welding, heat treatments, non-destructive examination shall be performed by qualified personnel using qualified procedures in accordance with specified requirements.*

Other requirements from Requirement 9 are:

- *Special processes shall be controlled by instructions, procedures, drawings, checklists, travelers, or other appropriate means. Special process instructions shall include or reference procedures, personnel and equipment qualification requirements. Conditions necessary for accomplishment of the process shall be included. These conditions shall include proper equipment, controlled parameters of the process, specified environment and calibration requirements.*

- *The requirements of applicable code and standards, including acceptance criteria for the process shall be specified or referenced in procedures or instructions.*
- *It is the responsibility of the organization performing the special process to adhere to the approved procedures and processes.*
- *Records shall be maintained as appropriate for the currently qualified personnel, processes, and equipment of each special process.*

The survey[14]:
It is an ASME III requirement that a Certificate Holder must operate a quality assurance program that has been evaluated and accepted by the (ASME) Society.
Based on this evaluation, the Society will grant the Certificate Holder the authorization to use the official certification mark (the Stamp) for a period of three years.
The quality assurance program is evaluated every three years by the Society. However, Certificate Holders shall possess an agreement[15] with an Authorized Inspection Agency to provide inspection and audit services.[16]

The survey activities of the Certificate Holder's Quality Assurance program by the Authorized Inspection Agency are required by:

- NCA-5220 Duties of inspector and categories of inspector's duties:
  - *Monitoring of the Certificate's holder Quality Assurance program including subcontracted activities*
- NCA-5300 Responsibilities of the Authorized Inspection Agency:
  - *Provide for participation in the Society's review of the applicant's Quality Assurance program*
  - *Provide for the review and acceptance of any proposed modifications to Quality Assurance manuals before they are put into effect.*

9.2. In the EN/PED scope

The SS-EN design and construction standards (EN 13445 [19], SS-EN 13480 [20], SS-EN 12952 [65], SS-EN 12953 [66]…) and the Pressure Equipment Directive EC 97/23 [5] itself do not require manufacturers to operate a quality system or a quality assurance program.
For sure, many manufacturers are certified ISO 9001. However experience from the field showed that this standard is often misused and the resulting quality systems are seldom effective and able to satisfy and to demonstrate the applicable technical and regulatory criteria and requirements. As examples, E/E1, D/D1, and H/H1 approvals are "sold" together with an ISO 9001 approval as a package while the assessors are not or not sufficiently familiar with the regulation, standards and the design and/or manufacture of pressure equipment, resulting in:

- NDT operators are approved and qualified but the control procedure is not able to detect the flaws.

[14] Survey means monitoring of the quality assurance program in addition of the detailed inspections in compliance with Section III the inspector will witness and verify.
[15] Certificate holders must notify the Society whenever their agreements with an Authorized Inspection Agency are cancelled or changed ….(NCA-8130).
[16] An agreement under the form of a contract between the manufacturer/certificate holder and the Authorized Inspection Agency. The manufacturer pays the assessments made by the AIA.

- Use of S (structural) steel instead of P (pressure) steels. For both economic and lack of competence reasons.
- Lack of correct assessment of assemblies.
- Use of material with incorrect, incomplete or false material certificates (between 20 and 30%, based on actual results after an "upgrade" from 3.1 to 3.2 certificate on several tenths of pressure retaining material items and fittings).

Article 10 and Annex III of the PED are offering a set of conformity assessment procedures. These procedures are selected by the manufacturer based on the risk category of the equipment and are used by the notified body (for those applications subject to the involvement of a third party) for demonstrating that the equipment concerned is in full compliance with the Directive and his essential safety requirements.
Some of these procedures are based on the quality system approach. However, it is not an obligation to apply the quality system route since for each risk category the PED offers also the traditional product assessment or inspection route based on formal design approval (in categories III and IV) and on product inspection (in all categories).
Depending on the risk category the quality system assessment procedures are more or less conservative and strict. The PED is still using the terms product quality assurance (modules E and E1), production quality assurance (modules D and D1) and full quality assurance (modules H and H1), similar compared to the former editions (1994 edition) of the ISO 9001 standard, ISO 9003, ISO 9002 and ISO 9001.

The fact that the SS-EN system does not systematically require a qualification or accreditation of the manufacturer’s quality system is confirmed and illustrated by some PED Guidelines, e.g. Guideline 6/9 (see paragraph 4.4 above).

9.3. Additional remarks

The following remarks are to be made.

1. The ESPN Order [15] (French regulation for nuclear pressure equipment), based on a modified and amended transposition of the PED into the French regulation requires for nuclear safety level 1 (N1) equipment a combination of the PED modules H and G: full quality assurance in combination with EC unit examination, which is comparable to the ASME III approach.

2. When considering welding and quality assurance, attention should also be paid to the SS-EN ISO 3834 Standard, *Quality requirements for fusion welding of metallic materials [67]*
   Despite the fact that SS-EN ISO 3834 certificates are issued this standard is not a quality system standard intended to take the place of SS-EN ISO 9001, but it is rather a useful, additional tool for use when SS-EN ISO 9001 is applied by manufacturers, in which case the meeting of its detailed requirements needs to be recorded in certificates or documentation. However, SS-EN ISO 3834 can also be used independently of SS-EN ISO 9001.
   The SS-EN ISO 3834 standard is not a legal requirement but may be a contractual requirement.
   One of the aims of SS-EN ISO 3834 is to define requirements in the field of

welding so that contracting parties or regulators do not have to do these themselves. A reference to a particular part of SS-EN ISO 3834 should be sufficient to demonstrate the capabilities of the manufacturer to control welding activities for the type of work being done.

SS-EN ISO 3834 has the advantage, compared to other quality assurance standards such as SS-EN ISO 9001, NCA 4000, NQA-1 and the quality system requirements of the PED, that all quality criteria related to welding are explicitly identified and split up in three “grades” –read: three quality levels-: the comprehensive (part 2), the standard (part 3) and the elementary (part 4) quality requirements.

Quality systems based on SS-EN ISO 9001, ASME NQA-1 or on the quality system requirements of the PED Directive however can be developed and implemented with the same effectiveness and efficiency as an SS-EN ISO 3834 based system.

10. Rules and requirements for surveillance and inspection of welding processes during fabrication of pressure equipment

10.1. In the ASME Code context

As mentioned in paragraph 9.1 above, under the rules of the ASME Code Section III, and in addition to all inspections and surveillance required by the respective Subsections, the welding operations, amongst all other construction activities, are subject to a quality assurance program.
The quality assurance program of the manufacturer is subject to periodic assessments (audits) by the (ASME) Society as well as by the monitoring by the Authorized Inspection Agency involved in the inspection of the equipment.

Under the requirements of the ASME Code Section III, the inspection and surveillance by the Authorized Inspector are governed by Subarticle NCA-5200 of Subsection NCA [8], and in particular by Subsubarticle NCA 5220 that specifies the duties of the Inspector (see paragraph 9.1 above) and by NCA-5270 that states: *The Inspector shall witness in-process fabrication, non-destructive examinations and destructive tests, when feasible; alternatively, he shall check the examination and test records to determine the acceptability of the items involved.*

The NDT examination program depends on the ASME Code Class of the pressure equipment (i.e., the applicable ASME Code Subsection) and, within a particular Subsection, on several other parameters.

Examples:

For Subsections NB, NC and ND (vessels, piping, pumps and valves…) the type and extent of nondestructive examination depends on the category of welded joint.
The welded joint categories are determined by Figures NB/NC/ND-3351-1. Figure 6 below provides a copy of Figure NB-3351-1 applicable to ASME Code Class 1 pressure components.

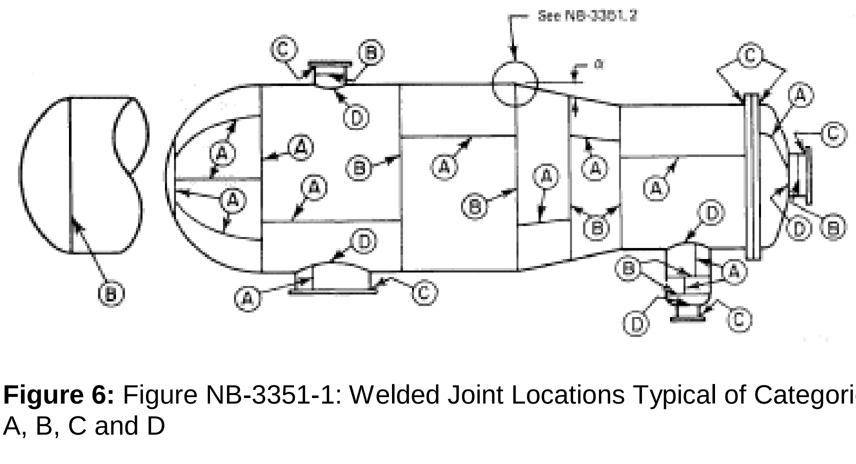


Figure 6: Figure NB-3351-1: Welded Joint Locations Typical of Categories A, B, C and D

The welded joint category defines the location of a joint in a pressure vessel, but not the type of joint. Within a specific welded joint category, several types of welds may therefore be present, such as full penetration butt welds, full penetration corner welds, socket welds…
A few examples are given below:

- For ASME Code Class 1 pressure vessels, Subsubarticle NB-5230,, *Category C vessel welded joints and similar welded joints in other components*, specifies the various types of welded joints within category C and the required NDT examinations:
    - *Category C full penetration but welded joints in vessels and similar welded joints in other components shall be examined by a volumetric and either the liquid penetrant or magnetic particle method*
    - *Category C full penetration corner welded joints and similar welded joints in other components shall be ultrasonically or radiographically examined and either liquid penetrant or magnetic particle examined*.
    - […]

- For ASME Code Class 3 pressure vessels, Subsubarticle ND-5230,, , specifies the various types of welded joints within category C and the required NDT examinations:
    - Vessels:
        - *Category C full penetration welds shall be fully radiographed when:*
            - *The thickness exceeds the requirements of ND-5211.2 or ND-5211.3*
            - *They are butt welds in nozzles or communicating chambers attached to vessel sections or heads that rare required to be fully radiographed and exceed NPS 10 (DN 250) or $1^1/_8$ in. (29 mm) wall thickness*
            - *The welds are made by the electroslag process*
        - *Any category C butt weld not required to be fully radiographed by thickness or location using the joint efficiency of ND-3352.3 (a) shall meet the requirements of ND-5221(b)*
        - *[...]*
    - Piping, Pumps and valves:
        - *The requirements for welded joints similar to Category C shall be the same as given in ND-5222, i.e.,*
          Circumferential welded joints in piping, pumps and valves greater than NPS 2 (DN 50) shall be examined by either the magnetic particle, liquid penetrant, or radiographic methods.

- For supports of ASME III pressure vessels, no welded joint category is defined in Subsection NF of ASME III.
  The required Non Destructive examinations depend on other parameters such as:
    - the ASME Code Class(1, 2, 3, MC…) of the supported equipment
    - Primary or secondary member welded joints
    - Full penetration or other welded joints

- So for example, a full penetration butt welded joint in a primary member of a Code Class 1 support must be examined by the radiographic method.
  All welded joints in secondary members of class 3 supports shall be examined by the visual method.

10.2. In the PED/EN context

Under the requirements of the PED, the survey is indirectly governed by the PED and directly by the assessment procedure(s) selected by the manufacturer. Survey of the welding activities through the assessment of the quality system is only applicable and possible when the manufacturer selects such an approach. Otherwise the inspection route applies (procedures A1, C1, F and G).

More in particular the assessment procedure G (EC unit verification for category IV equipment) requires the notified body to (see Annex III of the PED):

- *Examine the technical documentation with respect to the design and manufacturing procedures.*
- *Assess the materials used where these are not in conformity with the relevant harmonized standards […] and check the certificate issued by the material manufacturer […].*
- *Approve the procedures for permanent joining of parts or check that they have been previously approved […].*
- *Verify the qualifications or approvals required [for the personnel in charge of the permanent joining and the personnel in charge of the non-destructive tests of permanent joints in categories III and IV].*
- *Carry out the final inspection […] and perform or have performed the proof test […] and examine the safety devices if applicable.*

Related to Non Destructive examinations and for illustrating the SS-EN approach it is here referred to the product standard SS-EN 13445[19] for design and construction of unfired pressure equipment.

Clause 6.6.1 in SS-EN 13445-5 specifies the extent of the non-destructive testing of welded joints:
The required extent of non-destructive testing depends both on the testing group and the type of welded joints.

Tables 6.6.1-1 and 6.6.2-1 apply below the creep range. Table F.2-1 in Annex F applies to pressure vessels subject to creep.

According to Clause 6.6.1.1.1 in SS-EN 13445-4, *the testing groups or sub-groups take into consideration the manufacturing difficulties associated with different groups of steel, maximum thickness, welding process, service temperature range and joint coefficient. It is intended that any of the testing groups will provide adequate integrity for typical applications within the limitations contained within Tables 6.6.1-1 and F.2-1.*

The testing group and sub-group is determined based on Table 6.6.1-1 (see copy in Table below)

Table 22: Table 6.6.1-1 – Testing groups for steel pressure vessels

Requirements	Testing group [a]						
	1		2		3		4 [b,j]
	1a	1b	2a	2b	3a	3b	
Permitted materials [g]	1 to 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 9.3, 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 10	1.1, 1.2, 8.1	1.1, 8.1
Extent of NDT for governing welded joints [e,h]	100 %	100 %	100 % - 10% [d]	100 % - 10 % [d]	25 %	10 %	0 %
NDT of other welds	Defined for each type of weld in Table 6.6.2-1						
Joint coefficient	1	1	1	1	0,85	0,85	0,7
Maximum thickness for which specific materials are permitted	Unlimited [f]	Unlimited [f]	30 mm for groups 9.1, 9.2 16 mm for groups 9.3, 8.2 [i], 10	50 mm for groups 1.1, 8.1 30 mm for group 1.2	30 mm for groups 9.2, 9.1 16 mm for groups 8.2, 10	50 mm for groups 1.1, 8.1 30 mm for group 1.2	12 mm for groups 1.1, 8.1
Welding process	Unlimited [f]	Unlimited [f]	Fully mechanical welding only [c]		Unlimited [f]	Unlimited [f]	Unlimited [f]
Service temperature range	Unlimited [f]	Unlimited [f]	Unlimited [f]	Unlimited [f]	Unlimited [f]		Limited to (-10 to +200) °C for group 1.1 (-50 to+300) °C for group 8.1

[a] All testing groups shall require 100 % visual inspection to the maximum extent possible
[b] Testing group 4 shall be applicable only for:
- Group 2 fluids; and
- $P_S \le 20$ bar; and
- $P_S V \le 20\,000$ bar·L above 100 °C; or $P_S V \le 50\,000$ bar·L if temperature is equal or less than 100 °C; and
- maximum number of full pressure cycles less than 500.

If this testing group 4 is chosen, then a higher pressure test (see clause 10) and a lower nominal design stress (See EN 13445-3:2009) shall be used
[c] Fully mechanised and/or automatic welding process (See EN 1418:1997).
[d] First figure: initially, second figure: after satisfactory experience. For definition of "satisfactory experience", see 6.6.1.1.4
[e] Testing details are given in Table 6.6.2-1
[f] Unlimited means no additional restriction due to testing. The limitations mentioned in the table are limitations imposed by testing. Other limitations given in the various clauses of the standard (such as design, or material limitations, etc.) shall also be taken into account.
[g] See EN 13445-2:2009 for permitted materials.
[h] The percentage relates to the percentage of welds of each individual vessel
[i] 30 mm for group 8.2 material is allowed if delta ferrite containing welding consumables are used for depositing filling passes up to but not including the capping run.
[j] Limited to single compartment vessels and single material group.

After determination of the testing group the extent of nondestructive testing can be determined based on Table 6.6.2-1 and figure 6.6.2-3 (see Table and Figure below).

Table 23: Table 6.6.2-1 – Extent of non-destructive testing *(extract)*

TYPE OF WELD [a, p]			TESTING [b]	EXTENT FOR TESTING GROUP [o]						
				1a	1b	2a [i]	2b [i]	3a	3b	4
				EXTENT FOR PARENT MATERIALS [l,m,n]						
				1 to 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 9.3, 10	1.1, 1.2 8.1	8.2, 9.1, 9.2, 10	1.1, 1.2, 8.1	1.1, 8.1
Full penetration butt weld	1	Longitudinal joints	RT or UT MT or PT	100 % 10 %	100 % 10 % [d]	(100-10) % 10 %	(100-10) % 10 % [d]	25 % 10 %	10 % 10 % [d]	0 0
	2a	Circumferential joints on a shell	RT or UT MT or PT	100 % 10 %	25 % 10 % [d]	(100-10) % 10 %	(25-10) % 10 % [d]	10 % 10 %	10 % [c] 10 % [d]	0 0
	2b	Circumferential joints on a shell with backing strip [k]	RT or UT MT or PT	NA NA	100 % 10 %	NA NA	25 % 10 %	NA NA	25 % 10%	0 0
	2c	Circumferential joggle joint [k]	RT or UT MT or PT	NA NA	100 % 10 %	NA NA	25 % 10 %	NA NA	25 % 10%	0 0
	3a	Circumferential joints on a nozzle $d_i > 150$ mm or $e > 16$ mm	RT or UT MT or PT	100 % 10 %	25 % 10 % [d]	(100-10) % 10 %	(25-10) % 10 % [d]	10 % 10 %	10 % [c] 10 % [d]	0 0
	3b	Circumferential joints on a nozzle $d_i > 150$ mm or $e > 16$ mm with backing strip [k]	RT or UT MT or PT	NA NA	100 % 10 %	NA NA	25 % 10 %	NA NA	25% 10%	0 0
	4	Circumferential joints on a nozzle $d_i \leq 150$ mm and $e \leq 16$ mm	RT or UT MT or PT	0 100 %	0 10 %	0 (100-10) %	0 10 %	0 10 %	0 10 %	0 0
	5	All welds in spheres, heads and hemispherical heads to shells	RT or UT MT or PT	100 % 10 %	100 % 10% [d]	(100-10) % 10 %	(100-10) % 10 % [d]	25 % 10 %	10 % 10 % [d]	0 0
	6	Assembly of a conical shell with a cylindrical shell without a knuckle (large end of the cone) [q, r]	RT or UT MT or PT	100 % 100 %	25 % 100 %	(100-10) % 100 %	(25-10) % 100 %	10 % 100 %	10 % 100 %	0 100 %
	7	Assembly of a conical shell with a cylindrical shell without a knuckle (small end of the cone)	RT or UT MT or PT	100 % 10 %	25 % 10 % [d]	(100-10) % 10 %	(25-10) % 10 % [d]	10 % 10 %	10 % 10 % [d]	0 0
Circumferential lapped joints [k]	8a	General application shell to head	RT or UT MT or PT	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	0 0
	8b	Bellows to shell $e \leq 8$ mm	MT ot PT RT or UT	100 % 0 %	100 % 0 %	100 % 0 %	25 % 0 %	25 % 0 %	10 % 0 %	0 0

TYPE OF WELD [a, p]			TESTING [b]	EXTENT FOR TESTING GROUP [o]						
				1a	1b	2a [i]	2b [i]	3a	3b	4
				EXTENT FOR PARENT MATERIALS [l,m,n]						
				1 to 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 9.3, 10	1.1, 1.2 8.1	8.2, 9.1, 9.2, 10	1.1, 1.2, 8.1	1.1, 8.1
Assembly of a flat head or a tubesheet, with a cylindrical shell Assembly of a flange or a collar with a shell	9	With full penetration	RT or UT MT or PT	100 % 10 %	100 % 10 % [d]	(100-10) % 10 %	(100-10) % 10 % [d]	25 % 10 %	10 % 10 % [d]	0 0
	10	With partial penetration if $a > 16$ mm (a as defined in figure 6.6.2-1) [j]	RT or UT MT or PT	NA NA	NA NA	NA NA	NA NA	25 % 10 %	10 % 10 %	0 0
	11	With partial penetration if $a \leq 16$ mm (a as defined in figure 6.6.2-1) [j]	RT or UT MT or PT	NA NA	NA NA	NA NA	NA NA	0 10 %	0 10 %	0 0
Assembly of a flange or a collar with a nozzle	12	With full penetration	RT or UT MT or PT	100 % 10 %	100% 10 % [d]	(100-10) % 10 %	(100-10) % 10 % [d]	25 % 10 %	10 % 10 % [d]	0 0
	13	With partial penetration [j]	RT or UT MT or PT	NA NA	NA NA	NA NA	NA NA	0 10 %	0 10 %	0 0
	14	With full or partial penetration $d_i \leq 150$ mm and $e \leq 16$ mm [j]	RT or UT MT or PT	0 10 %	0 10 % [d]	0 10 %	0 10 % [d]	0 10 %	0 10 %	0 0
Nozzle or branch [e]	15	With full penetration $d_i > 150$ mm or $e > 16$ mm	RT or UT MT or PT	100 % 10 %	25 % 10 % [d]	(100-25) % 10 %	(25-10) % 10 % [d]	25 % 10 %	10 % 10 % [d]	0 0
	16	With full penetration $d_i \leq 150$ mm and $e \leq 16$ mm.	RT or UT MT or PT	0 100 %	0 10 %	0 (100-10) %	0 10 %	0 10 %	0 10 %	0 0
	17	with partial penetration for any d_i $a > 16$ mm (see figure 6.6.2-2)	RT or UT MT or PT[j]	100 % 10 %	25 % 10 % [d]	(100-25) % 10 %	(25-10) % 10 % [d]	25 % 10 %	10 % 10 % [d]	0 0
	18	with partial penetration $d_i > 150$ mm. $a \leq 16$ mm.(see figure 6.6.2-2)	RT or UT MT or PT[j]	NA NA	NA NA	NA NA	NA NA	0 10 %	0 10 %	0 0
	19	With partial penetration $d_i \leq 150$ mm. $a \leq 16$ mm.(see figure 6.6.2-2)	RT or UT MT or PT[j]	0 100 %	0 10 %	0 (100-10) %	0 10 %	0 10 %	0 10 %	0 0
Tube ends into tubesheet	20		MT or PT	100 %	100 %	100 %	100 %	25 %	10 %	0
Permanent attachments [f]	21	With full penetration or partial penetration	RT or UT MT or PT	25 % [g] 100 %	10 % [d] 10 %	10 % 100 %	10 % [d] 10 %	10 % 100 %	10 % [d] 10 % [d]	0 0

TYPE OF WELD [a, p]			TESTING [b]	EXTENT FOR TESTING GROUP [o]						
				1a	1b	2a [i]	2b [i]	3a	3b	4
				EXTENT FOR PARENT MATERIALS [l,m,n]						
				1 to 10	1.1, 1.2, 8.1	8.2, 9.1, 9.2, 9.3, 10	1.1, 1.2 8.1	8.2, 9.1, 9.2, 10	1.1, 1.2, 8.1	1.1, 8.1
Pressure retaining areas after removal of temporary attachments	22		MT or PT	100 %	100 %	100 %	100 %	100 %	100 %	0
Cladding by welding [h]	23		MT or PT	100 %	100 %	100 %	100 %	100 %	100 %	0
Repairs	24		RT or UT MT or PT	100 % 100 %	100 % 100 %	100 % 100 %	100 % 100 %	100 % 100 %	100 % 100 %	0 0

[a] See figure 6.6.2-3

[b] RT = Radiographic testing, UT = Ultrasonic testing, MT = Magnetic particle testing, PT = Penetrant testing

[c] 2 % if $e \leq 30$mm and same WPS as longitudinal, for steel groups 1.1 and 8.1

[d] 10 % if $e > 30$ mm, 0 % if $e \leq 30$ mm

[e] Percentage in the table refers to the aggregate weld length of all the nozzles see 6.6.1.2 b).

[f] No RT or UT for weld throat thickness ≤ 16 mm

[g] 10 % for steel groups 8.2, 9.1, 9.2, 9.3 and 10

[h] Volumetric testing if risks of cracks due to parent material or heat treatment

[i] For explanation of the reduction in NDT in testing group 2, see 6.6.1.2

[j] In exceptional cases or where the design or load bearing on the joint is critical, it may be necessary to employ both techniques (i.e. RT & UT, MT & PT). See table 6.6.3-1 for other circumstances for use of both techniques

[k] For limitations of application see EN 13445-3:2009, 5.7.3.2.

[l] The percentage of surface examination refers to the percentage of length of the welds both on the inside and the outside

[m] RT and UT are volumetric while MT and PT are surface testing. When referenced in this table both volumetric and surface are necessary to the extent shown.

[n] NA means "type of joint not allowed" (see EN 13445-3:2009, Annex A).

[o] In case of cyclic loading refer to Annex G.2.

[p] Annex A of EN 13445-3:2009 gives design limitations on welds.

[q] Unless the design is such that the thickness at the weld exceeds 1,4 e_j (See clause 7.6.6 of EN 13445-3:2009). In which case, use NDT of line 2a.

[r] For connections with a knuckle, case 2a applies.

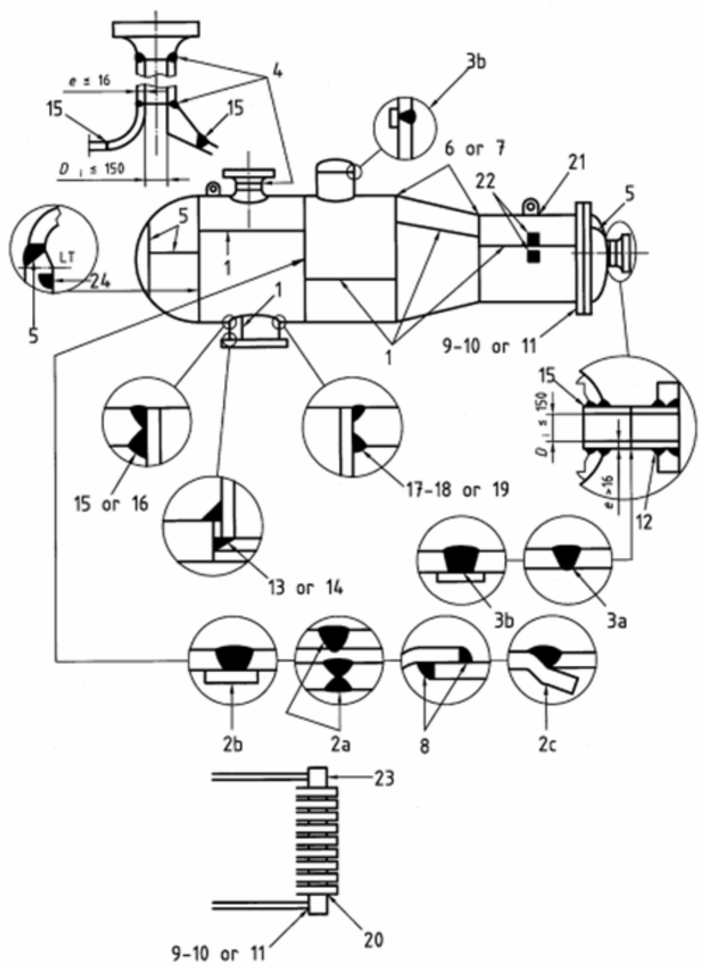


Figure 7: Figure 6.6.2-3 – Type of welds

Other aspects are also contributing to survey of the welding process and the production of sound welds:

- In addition to the NDT examination, some SS-EN standards such as SS-EN 13445-4:2011 in Clause 8.1, require in some conditions the welding of production test plates in order to control the continuing quality of the manufacture and the compliance of the mechanical properties of the welds with the specification.
  Such production test plates in this SS-EN 13445-4:2011 Standard only apply to governing shell-longitudinal and –circumferential welds.
  ASME Code Section III does not require production test plates at all.
- In addition to other requirements related to the weld metal and in order to quarantee the quality of the weld metal and the compliance of the properties of the metal with the specification, both ASME III and SS-EN 13445-4:2011 Standard require an all weld metal tensile test in certain conditions. In ASME Section III Subsection NB (so for ASME Code Class 1,only), this is required by Subsubarticle NB 2430. In the SS-EN 13445-4:2011 standard this is required by Clause 7.3. It should be noted that, when required, the all weld metal tensile test is performed on a coupon for procedure qualification and not on a production weld.

11. Practical experiences of monitoring and supervision of welding processes during fabrication of pressure equipment

11.1. Doel 3 – 1000 MW nuclear PWR plant in Belgium.

All piping systems connected to the reactor coolant loops (Safety Injection, Residual Heat Removal, Surge line,…) are made of austenitic stainless steel with diameters between 2” and 14” and Schedule 160. They belong to ASME Code classes 1 and 2. At the Doel 3 nuclear power plant, surface cracks were detected during the pre-service inspection (ASME Code Section XI) , more in particular after the application of penetrant (dye penetrant examination) for an extra-long period (the operator forgot to clean a weld at the end of his shift) when the operator in the next shift applied the developer. Extension of the examination showed a several hundred of welds with the same type of cracks.
The welded joints were performed using GTAW+SMAW processes. Analysis of the situation revealed a number of common factors. All these welds were welded by the same piping contractor and with the same weld metal (for both GTAW as well as SMAW process).
After review of the material certificates of the filler metal it appeared that the FN (Ferrite number) of the electrodes (SMAW) was not in compliance with the NB requirements, 1 to 2 instead of 5 minimum, which resulted in hot cracking. All these welds involved have been repaired.

11.2. Doel 4-1000 MW nuclear PWR plant in Belgium.

At the Doel 4 nuclear power plants there are socket welds in several piping systems belonging to ASME III Code Classes 1, 2 and 3.
In order to verify the 1.6 mm gap between tube and socket as required by the ASME Code, a few socket welds were subjected to a radiographic examination. For all of them the gap (after welding) was found to be 0 mm
After a significant extension of the examination it appeared that the manufacturer could not be prove that the gap before welding was in compliance with the requirements. As a consequence, about 6000 socket welds have been cut and re-welded.

12. Guidelines and relief of requirements

Neither the PED nor the ASME Code includes provisions on how relief from their requirements might be envisaged. It may however happen that, for a specific application, certain requirements of the PED or ASME Code are impractical as a result of limitations of component design, geometry, or materials of construction. In such a case, any request for relief from requirements should be submitted to the regulatory authority and/or organization performing the conformity assessment (Authorized Inspection Agency or Notified Body). Nevertheless, some documents issued by the ASME Boiler and Pressure Vessel Committee and the European Commission than can provide useful help when difficulties for meeting the requirements are encountered. These documents are the ASME Code Cases and ASME Code interpretations, and the PED Guidelines.

12.1. ASME Code cases

Code Cases are issued by the ASME Boiler and Pressure Vessel Committee to clarify the intent of existing requirements or provide alternatives allowing early and urgent implementation of any revised requirements. These Code Cases appear in the two appropriate Code Cases books: "Boilers and Pressure Vessels" and "Nuclear Components". The "Boilers and Pressure Vessels" Code Cases book is related to Sections I, II, IV, V, VIII, IX, X, and XII of the ASME B&PV Code. The "Nuclear Components" Code Cases book is related to Sections III and XI of the ASME B&PV Code. Since 2006, the ASME Code Cases have no longer an expiration date. They remain therefore in effect until the time that they are annulled by the ASME Boiler and Pressure Vessel Committee because the provisions have been incorporated into the Code, the application for which it was specifically developed no longer exists, or experience has shown that the provisions are no longer adequate. Code Cases can also be superseded through revisions.
Although the “Boilers and Pressure Vessels” Code Cases Code have been adopted by ASME Boiler and Pressure Vessel Committee, they are dealt with on a case-by-case basis with owners and regulatory bodies.

The U.S. Nuclear Regulatory Commission (NRC) evaluates the “Nuclear Components” Code Cases and amends regularly its regulations to incorporate by reference into 10 CFR 50.55a the latest revisions of three regulatory guides (RGs), approving new and revised “Nuclear Components” Code Cases. This action allows nuclear power plant licensees to use the Code Cases listed in these RGs as alternatives to engineering standards for the construction, inservice inspection, and inservice testing of nuclear power plant components. The three RGs are: RG 1.84 [71] (Section III Code Cases), RG 1.147 [72] (Section XI Code Cases), and RG 1.192 [73] (OM Code Cases). The use of “Nuclear Components” Code Cases found acceptable by the NRC may be used as such. The “Nuclear Components” Code Cases found “conditionally acceptable” by the NRC may be used provided they are used with the limitations ASME modifications identified in the applicable RG.

12.2. ASME Code interpretations

The ASME Code interpretations are issued by the ASME Staff on behalf of the ASME Boiler and Pressure Vessel Committee in response to inquiries concerning interpretations of the ASME Boiler and Pressure Vessel Code. An interpretation applies either to the Edition and Addenda in effect on the date of issuance of the interpretation or the Edition and Addenda stated in the interpretation. Subsequent revisions to the Code may supersede the interpretation.
ASME issues written replies to inquiries concerning interpretation of technical aspects of the Code. The interpretations for each individual Section are published separately and included as part of the update service to that Section. Interpretations of Section III, Divisions 1 and 2, are included with the update service to Subsection NCA. Interpretations of the Boiler and Pressure Vessel Code are posted in January and July. These interpretations become all or part of the Interpretations Volume that will be printed with the next Edition of BPVC. The latest editions of the code interpretations can be found on: http://cstools.asme.org/Interpretations.cfm

12.3. PED Guidelines

In order to ensure a coherent application of the Pressure Equipment Directive, Guidelines are developed and agreed by the Commission's Working Group "Pressure" (WGP).
The PED Guidelines are not a legally binding interpretation of the Directive. The legally binding text remains that of the Directive. However, the PED Guidelines represent a reference for ensuring consistent application of the Directive. They represent, unless indicated differently in the respective guideline text, the unanimous opinion of the Member States.

13. Recommendations and conclusions

This chapter provides the recommendations and conclusions of the Authors related to the matters discussed in this report. Some of these are related to specific chapters of the report and are identified as such. The others are referred to as general conclusions or general recommendations as they address the whole report.

1. Related to the surveillance and inspection of the qualification processes of welders, welding operators and welding procedures (see chapter 4).

   a. The approach taken by ASME III and applicable to all design, manufacture, inspection and test activities is characterized by the omnipresence of the quality assurance requirements based on subsection NCA [23] of the ASME B&PV Code, and on ASME NQA-1 Standard [23]. The manufacturer is surveyed by the ASME Society by three yearly assessments and by the monitoring of its Quality assurance program by the Authorized inspection Agency in charge of the inspection of the equipment. These assessments are formalized by the grant of a Certificate of Authorization and the appropriate ASME Code Symbol Stamp(s).This approach makes the ASME system self-certifying or self-qualifying.

      Under the requirements of the PED Directive [5] and SS-EN standards, the survey is indirectly governed by the PED and directly by conformity assessment procedure(s) selected by the manufacturer. Survey of the welding qualification activities based on the assessment of the quality system is only applicable when the manufacturer selects such an approach. Otherwise the traditional inspection routes apply (modules A1, C1, F and G).
      More in particular, the assessment procedure G (EC unit verification for category IV equipment) requires the Notified Body to:

      i. approve the procedures for permanent joining of parts or check that they have been previously approved,
      ii. verify the qualifications or approvals required for the personnel in charge of the permanent joining.

   b. A significant difference is identified between the viewpoint put forward by the ASME Code, which assigns full responsibility, including the certification, to the manufacturer, with merely a supervisory role for the third party (authorized inspector), and the viewpoint of the European SS-EN standards in particular and based on the PED requirements.
      The wording also differs from standard to standard.

      i. ASME IX: the manufacturer qualifies the welding procedures and the performance of welders. He certifies the PQR' (Procedure Qualification Record).
      ii. EN-standards: the welder certificate shall be issued under the sole responsibility of the examiner or examining body.

   c. In the PED the different tasks and duties assigned to the Notified Body are already more explicit than in the SS-EN standards or than in the ASME III but still subject to interpretation.

      i. Example 1: "*The Notified Body or Recognized Third Party Organization must attend part of the different steps in the process for each procedure and for each person*". Does this really mean "part of every step" or only "part of the steps"?

ii. Example 2: "*Some practical tasks concerning the approval of joining operating procedures and personnel may be accomplished by a competent person of a manufacturer according to a quality system*". To the Authors opinion, the extent of such subcontracting should be more explicit.

d. To the Authors opinion, the extent and frequency of inspection and survey of the qualification processes of welders and welding procedures by the third party should be more explicit, in both ASME III and PED approach. This can be improved by:

   i. applying the approach of the French ESPN Order [15] and amend the local regulation by requiring formal quality system approvals through modules E, D or H in addition to the traditional assessment procedures (A1, B1 + F, G, B + F, B + C1).
   ii. For both the ASME III and the PED, applying the approach of the French ESPN Order (e.g. such as proposed in the ASN Guide n°8 [33]) and defining a minimum extent and frequency of inspections of the qualification processes of welders and welding procedures.
   Note: In such situation, it will of course not be possible to accept approvals of qualifications issued and affirmed by other notified bodies.

2. Related to the rules for the qualification of welding procedures (see chapter 6)

   a. Both ASME IX and SS-EN ISO 15614-1 Standard [28] have the same philosophy for qualifying welding procedures but the methods are slightly different.

   b. In the ASME approach Section IX is the basis. But, for nuclear pressure components, Section III is also applicable and introduces additional requirements (depending on the ASME Code Class). While the SS-EN standards do not provide specific rules for design and construction of nuclear pressure equipment.

   c. When considering the intrinsic quality of the procedure qualifications, it can be concluded that both ASME Section IX and the SS-EN series of standards are almost equivalent. The SS-EN standards often require more examinations and tests, but on the other hand most of the SS-EN qualifications cover a larger scope of application resulting in a lower number of procedure qualifications. Since this is very case-related, an economic comparison requires a case by case analysis.

   d. The SS-EN standards are relatively new, but they have the advantage to comply with the essential requirements of the European Pressure Equipment Directive although the PED excludes nuclear pressure equipment. On the other hand Section IX has the advantage to belong to the whole set of the ASME design and construction Codes, for instance Section III, with several decennia of nuclear and industrial experience and a long history of safe use.

   e. Apart from welding-qualification-quality aspects and from economic considerations that seem to have low impact on the choice, it can be recommended to adopt an approach that fits with a design and construction standard or regulation that is applicable to and has a history of safe use in the design and construction of nuclear pressure equipment.
   Potential construction Codes or regulations for nuclear pressure compo-

nents are the French RCC-M Code[17] and the German KTA rules (both having several decennia of experience), and the French ESPN Order (proposing the European harmonized standards to comply with the essential requirements) or other national code and/or regulation.

3. Related to the rules for the qualification of welders and welding operators (see chapter 7).

   ASME IX and SS-EN 287-1 Standard [21] provide requirements for welder qualifications which are more similar than for the welding procedure qualifications.
   The range of approval depends on the essential variables and is sometimes less restricted in ASME IX but sometimes less restricted in SS-EN 287-1.
   In practice, every now and then, it is admitted that an ASME IX qualification is replaced by an SS-EN 287-1 qualification and vice versa. On condition that the manufacturer justifies this by documents to be approved by all other parties concerned. An important item hereby is that the range of approval of the chosen qualification shall cover the welds to be realized in the construction.

4. Related to preheat and post weld heat treatment of welds (see chapter 8).

   Concerning the preheat and PWHT, the ASME and the SS-EN ISO requirements are largely similar. A welding procedure with PWHT is only valid with, and without PWHT is only valid without, also taking into account other consequences, such as the for thickness i.e. a 20 mm thick coupon without PWHT qualifies to 40 mm thick but from the 35mm the PWHT is mandatory by construction code, thus in fact it can only be used to 35 mm.
   Preheating temperature is to be considered as a minimum temperature and addition of preheating is always enabled.
   A small difference is that the ASME describes to a larger extent the technical details (variables) for PWHT than the SS-EN ISO qualification standards do. As a result, a somewhat larger scope of validity is obtained for the welding procedure in the SS-EN ISO versus ASME, in function of the PWHT.

5. Related to the rules and requirements concerning the quality systems for welding companies (see chapter 9).

   Both ASME III and PED/EN quality systems are not really comparable due to the fact that the EN/PED does not require systematically a survey based on quality system or quality assurance program formally approved by a third party, such as required by Section III of the ASME B&PV Code. To make them more or less comparable for these aspects and in order to integrate systematically a quality system or quality assurance survey into the PED/EN approach (in addition to the inspection route), two options apply:

   i. either to make the application of SS-EN ISO 9001(with or without SS-EN ISO 3834 included) in combination with the inspection route pro-

[17] The French design and conception rules for mechanical components of PWR nuclear islands. Note that the requirements related to the qualification of welding procedures and welders (section IV), including destructive and non-destructive testing, refer to and are based on the related SS-EN standards (SS-EN 287-1,SS- EN 288, SS-EN ISO 9606-4, SS-EN 2650…), amended by specific requirements due to nuclear and PWR conditions such as intergranular corrosion, delta ferrite number or ferrite %...so that the scope of this section is consequently wider than the one of section IX of the ASME code, covering aspects contained in other ASME B&PV Code sections (II and III). The objective in the RCC-M code was to provide a single, homogeneous, and complete text including specific processes such as weld overlay or friction welding.
Another difference with the ASME code is the requirement to manufacture production weld test coupons, which is a common practice in Europe.

cedures mandatory and to eliminate the procedures and combinations of procedures based on quality system assessment (D1, E1, B+E, B1+D, B+D, H, H1).

ii. Or to apply the French ESPN Order approach and to amend the local regulation by requiring formal quality system approvals through modules E, D or H above on the traditional assessment procedures (A1, B1+F, G, B+F, B+C).

6. Related to the nuclear specificity of the ASME III/ASME IX (see chapters 2 and 3)

   a. When compared to the assessments of the manufacturer's quality system by the Notified Body in the PED/EN scope, the weight and impact of the assessment of the manufacturer's quality system by a third party (the ASME Society and the Authorized Inspection Agency (AIA)) under the requirements of ASME III are fundamentally different.
   In the scope of ASME Section III the quality assurance system of each manufacturer is subject to a formal approval by the ASME Society and to a survey by the AIA, independently of and in addition to the technical requirements and complementary to the AIA's inspection tasks as stipulated in the respective applicable subsections (NCA, NB, NC, ND, NE…division 2).
   In the scope of the PED regulation and the SS-EN standards, the assessment and the survey of the manufacturer' quality system by the Notified Body is, depend on the risk category and on the manufacturer's choice, not less but not more than an approach in order to assess that the concerned equipment fulfills the essential requirements of the PED Directive. Conformity assessment procedures D, D1, E, E1, H and H1 offer an alternative compared to the "traditional" assessment and inspection tasks such as B/B1+F, G, A1 and C1 but do not provide a complementary assessment above on the inspections by the Notified Body.

   b. Risk categories in the PED and ASME Code Classes in Section III are not comparable. The risk categories in the PED are addressing the structural integrity of the component and are linked to the potential release of stored energy and based on the maximum working pressure, the volume and on the nature of the fluid (dangerous or not).
   The ASME Code Classes in Section III are based on the Rules of the US-NRC, the 10CFR50.55a and Regulatory guide 1.26, and divides equipment in quality groups A, B, C and D. They recognize the different levels of importance associated with the function of each item as related to the safe operation of the nuclear power plant. The ASME Code Classes allow a choice of rules that provide assurance of structural integrity and quality, commensurate with the relative importance assigned to the individual items of the plant.

   c. Nuclear power plants and their components are in the American context subject to the Section XI [10] rules for in-service inspections, repairs and replacements. ASME Section III requires the manufacturers to design and manufacture components in such a way as to allow the in-service inspections and tests required by Section XI. These aspects are missing in the SS-EN context

   d. For some items, such as component supports (Subsection NF), metal containment components (Subsection NE), reactor core support structures (Subsection NG), concrete containment buildings (Division 2), Section III of the ASME B&PV Code provides specific rules. This is not the case for the SS-EN scope since the PED excludes nuclear equipment.

e. ASME III, through NCA 3862.1 and 2, requires the weld material to be supplied with a Certified Material Test Report, which is comparable to the SS-EN 10204 3.2 certificate, while in the PED context (through Guidelines 7/10 and 7/5) for welding consumables, an SS-EN 10204 2.2 test report is sufficient.

f. ASME III requires the filing of “lifetime records” (NCA-4134.17 and Table NCA-4134.17-1) for the lifetime of the power plant and the filing of non-permanent records (Table NCA-4134.17-2) for at least 10 years.
The PED Directive requires the manufacturer to draw up the technical documentation and to keep it at the disposal of the relevant national authorities for inspection purposes for a period of ten years after the pressure equipment has been manufactured.

g. With regard to the “recognition” of the third party involved in the assessment of the equipment (Authorized Inspection Agency in the ASME scope and the Notified Body in the European scope) and compared to the ASME system, the European system does not directly assess the individuals (inspectors and engineers).
The European system is based on the accreditation of the inspection body’s organization. Such an accreditation is pronounced as a result of an assessment and audits by national accreditation bodies based on the SS-EN ISO 17000 series standards such as SS-EN ISO 17020, 17021, 17025, 17024, SS-EN 45011.
These accreditation rules are depending of the scope of activities of the candidate body, but are different from Member State to Member State so that there could be a lack of consistency in the assessments by the Notified Bodies. The knowledge and competence of inspectors and engineers are indirectly assessed through the assessment by the accreditation body of the Notified Body’s quality system in compliance with the applicable standard.
In the ASME system the candidate Authorized Inspection Body is subject to an assessment audit of the Quality Assurance program by the Society and based on the ASME QAI-1 [74] Standard. In addition inspection supervisors and inspectors are subject to training and examinations by the National Board in order to obtain their A, N or NS endorsements as appropriate.

h. Standards (such as SS-EN and ASME standards) should be understood indivisible. The design and manufacture of pressure vessels requires the application of all relevant parts of the standard for the requirements of the standard to be fulfilled. Only in the case that the standard gives no information to specific parts of pressure vessels other standards may be used exceptionally. In such a case, special attention should be paid to ensure that application of such other standard(s) is made consistent with the safety philosophy and the general safety requirements (same nominal design stresses, same safety margins, etc.)…For the same reasons using only the technical requirements of ASME section III, without the formal and administrative requirements (such as the appropriate stamping, survey by an Authorized Inspections Agency, certification by a Registered Professional Engineer (RPE)….) is not a valid option.
Deviations or derogations must be duly justified and alternatives must demonstrate and guarantee an overall equivalent level of safety.

7. Related to rules and requirements for surveillance and inspection of welding processes during fabrication of pressure equipment (see chapter 10).

a. It may be said that the applicable requirements of the ASME Code Section III and SS-EN 13445 Standard for the extent of NDT examination of the welded joints are comparable
However, it should be added that the ASME III takes a complementary parameter into account,i.e., the nuclear safety through ASME Code Class of the concerned equipment.
This means that the European approach does not guarantee that the design, fabrication, erection, inspection and testing is commensurate with the safety function to be performed by the concerned equipment.

b. When comparing NDT extent of the welded joints, , one should also consider and compare the differences in technique between the ASME Code Section V [3] and the several SS-EN standards for examination. For example,for radiographic examination, the required IQI sensitivity (based on the nominal single wall thickness or on the real radiographied thickness) and, for ultrasonic examination, the amplitude based techniques proven by round robin tests (EN 1714 [68] and SS-EN 1712 [69]) or the cascade rule of SS-EN 1713 [70].
Since the result is also depending on the selected acceptation level (in EN) and the type of ultrasonic technique, it is recommended to assess on a case by case base.

c. Other tests and examinations contributing to the demonstration of the weld quality are not always comparable as such.
   i. In the ASME Code, the all weld metal tensile test is required in all cases for ASME Code Class 1 equipment (Subsection NB) while the only criterion in the SS-EN standard is the thickness of 20 mm of the test plate necessary for the qualification of the welding procedure specification.
   ii. The SS-EN standard is requiring production test plates in some conditions while the ASME III code does not.

d. Regarding the survey of equipment subject to the PED by a third party, and due to the lack of details of the number and type of items to assess or to check, but also due to the market conditions and the rough competition, and since the PED Directive does not specify a minimum number of inspection visits, it has been observed that for economic and commercial reasons, Notified Bodies have the tendancy to limit the number and the duration of their inspection visits.
To avoid the result of such a competition in a PED/EN environment, it is recommended to specify the number and the extent of visits and assessments such as in the French ESPN regulation [15] where the ASN specifies in its Guide n°8 [33], for each assessment procedure and for every single aspect, a minimum scope (number, frequency and extent) of inspections to be performed by the Notified Body.

8. General conclusions

a. Comparing ASME III aspects with PED/EN aspects is not possible for all aspects due to the fact that ASME III is considering different ASME Code Classes based on different levels of importance associated with the function of each item as related to the safe operation of the nuclear power plant while the PED/EN is only considering the pressure hazard.
Another fundamental difference between the two approaches is the omnipresence of the required quality assurance program and associated assessments independently of the required survey and inspections of the equipment by the Authorized Inspection Agency while in the PED/EN context

the assessment of the manufacturer's quality system by the Notified Body forms an alternative for product inspection.
Contrary to the equivalent SS-EN standard(s), Section IX has been developed for use in the design and manufacture of pressure equipment and is the result of several tens of years of industrial experience.
Technically spoken the ASME Section IX system is more thorough and up to date compared to the current practices and technological progress.
The ASME Sections (for nuclear applications: III, II, V, IX, XI) form a whole and they prove since many years a high degree of health and safety protection. One practical problem for use in Europe may be the availability of American materials on the European market.

b. There are shortages in the EN/PED context when compared to the ASME context:, such as:

   i. the lack of the double assessment (Quality assurance and Product Inspection) in both, the qualification phase as well as the manufacture phase;
   ii. the lack of experience with "new" or very recent standards;
   iii. the lack of consistency in the assessment of Notified Bodies and related thereto the lack of direct assessment of the individual inspectors/engineers;
   iv. the lack of minimum extent of inspections and assessments;
   v. in some Member States, the lack of survey of the Notified Bodies by the national Authorities;
   vi. the less conservative (read: lighter) certification system of materials, including weld metals explained in § 4.3 of the essential requirements in Annex I of the PED and in Guideline 7/5.
   vii. the fact that the PED and the SS-EN standards are not applicable to nuclear pressure equipment. Neither the PED nor the SS-EN standards take into account the different levels of safe operation of the concerned equipment.

9. General recommendations

a. Based on the comparisons and on the conclusions, the use of the ASME system is recommended for the design and construction of pressure equipment intended for nuclear power plants, in particular for the welding activities.
For use into the Swedish, a non US context, it is necessary to identify conditions in order to transpose and integrate the ASME rules into the local national regulation and laws.
Some examples that may require amendments are:

   i. use of non SA materials
   ii. alternative for Authorized Nuclear Inspection Agency
   iii. alternative for Registered Professional Engineer
   iv. alternative for CMTR (material certification)
   v. introduction and conditions for use of Code Cases, Regulatory Guides, Code Interpretations
   vi. Qualification/Certification system of operators for non-destructive testing
   vii. adding technical requirements, e.g. production test plates, intergranular corrosion testing, Cobalt content, NDT techniques and qualifications, pickling and passivation, cleanliness, …

b. A first alternative is to apply the PED and SS-EN standards and to define additional requirements in order to tackle the shortages identified in the conclusions.
   Some examples are:

   i. To make the application of a quality assurance standard and the assessment of the system by a third party organization mandatory. This can be the ISO 9001 standard, with or without SS-EN ISO 3834 standard included. Better would be the ASME NQA-1 standard or 10 CFR 50 App. B criteria because they are better adapted for the use in the nuclear sector.
   ii. to adopt the ESPN approach by:
      - introducing the nuclear safety philosophy by dividing the equipment in safety levels. Based on the ESPN or even better, based on Regulatory Guide 1.26.
      - defining complementary essential requirements depending on the safety level.
      - reorganizing the application of the PED's assessment procedures.
      - reorganizing, strengthening and adopting the rules for accreditation, notification and survey of the third party in charge of the assessment of this equipment.
      - adopting the French ASN Guide n° 8 [33] specifying amongst others the minimum frequency, extent and number of inspections to carry out by the notified body.
      - including radioprotection requirements.

c. The second alternative is to draw up a specific approach based on the better/best criteria from the several systems (ASME, PED/EN, RCC-M, KTA, ESPN) and on the experience from the past.

14. References

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The Swedish Radiation Safety Authority has a comprehensive responsibility to ensure that society is safe from the effects of radiation. The Authority works to achieve radiation safety in a number of areas: nuclear power, medical care as well as commercial products and services. The Authority also works to achieve protection from natural radiation and to increase the level of radiation safety internationally.

The Swedish Radiation Safety Authority works proactively and preventively to protect people and the environment from the harmful effects of radiation, now and in the future. The Authority issues regulations and supervises compliance, while also supporting research, providing training and information, and issuing advice. Often, activities involving radiation require licences issued by the Authority. The Swedish Radiation Safety Authority maintains emergency preparedness around the clock with the aim of limiting the aftermath of radiation accidents and the unintentional spreading of radioactive substances. The Authority participates in international co-operation in order to promote radiation safety and finances projects aiming to raise the level of radiation safety in certain Eastern European countries.

The Authority reports to the Ministry of the Environment and has around 270 employees with competencies in the fields of engineering, natural and behavioural sciences, law, economics and communications. We have received quality, environmental and working environment certification.

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