Assessment of Safety Equivalency

EN 13445 – ASME B&PV Section VIII Div.1

Pressure Vessels

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George Antaki, PE, Fellow ASME

Pressure Equipment Engineering LLC

gaa1951@outlook.com

Contents

1 Purpose

To assess whether European vessel construction Code EN 13445 (2021, the latest edition at the time of this writing) provides an equivalent level of safety as the ASME Boiler and Pressure Vessel Code (B&PVC) Section VIII (2023, the latest edition at the time of this writing).

2 Assessment Method

EN 13445 is compared to ASME VIII Division 1 for a series of key attributes that covers the safety attributes for the construction of new pressure safety for pressure vessels:
1. Materials.
2. Code design.
3. Fabrication.
4. Examination.
5. Testing.
6. Over-pressure protection.
7. Inspections and certifications.

3 Conclusions on Safety Equivalency

The comparative review of attributes in ASME VIII Div.1 (2023) and EN 13445 (2021), which have been grouped into 7 categories ((1) materials, (2) Code design, (3) fabrication, (4) examination, (5) testing, (6) over-pressure protection, and (7) inspections and certifications), indicates that EN 13445 provides an equivalent level of safety against failure (leaks or ruptures of the pressure boundary) as ASME VIII Div.1, except for the following attributes that must be addressed by the user of an EN 13445 vessel, where they apply:

3.1 Layered vessels

Attribute 6.8: Layered vessels are addressed in ASME VIII Part ULW and are not addressed in EN 13445.

Suggestion: The owner-user of a layered vessel is to assess the EN 13445 in accordance with ASME VIII ULW for materials, design, fabrication, examination, testing, and over-pressure protection of layered vessels.

3.2 Temper bead welding

Attribute 7.9: Temper bead is not addressed in EN 13445.

Suggestion: If temper bead is applied in post-weld heat treatment of ferritic steel welds of EN 13445 vessels, the temper bead procedure is to be reviewed against ASME VIII UCS-56.

3.3 Rupture discs

Attribute 10.2: EN 4126-2 does not address bursting disc (rupture disc) set pressure tolerances.

Suggestion: The owner-user must verify the equivalency of sizing and set points of EN 13445 vessel rupture discs against ASME VIII/XIII.

3.4 Non-CE stamped vessels

Attribute 11.6: ASME VIII requires the involvement of the Authorized Inspector for ASME VIII vessels. EN 13445 permits self-declaration of conformity by the manufacturer, without Notified Body oversight, but only for Category SEP (sound engineering practice) vessels.

Suggestion: If the vessel is (a) not CE stamped, or (b) classified as Category SEP (sound engineering practice) vessels, the user must review the application of the PED directive to confirm that the vessel was correctly categorized as SEP, before the vessel is installed.

3.5 Leak Test at Startup

The construction codes focus on pressure or leak testing of the final assembled vessel upon completion of fabrication and assembly. However, the vessel may not be operated for a long period of time after the construction pressure or leak test was completed. It is even possible that mechanical joints (bolted flanges, groove couplings, swaged joints, etc.) may have been assembled and re-assembled during transport, storage, or pre-operational checks.

Suggestion: For newly received pressure vessels, ASME VIII or EN 13445, in toxic, flammable, explosive, or otherwise dangerous service, it is a good practice for the owner-user to perform a low-pressure leak test of the vessel system to assure that the joints (welded or mechanical) are tight and do not leak. This pre-operational leak test is not addressed in either ASME VIII or EN 13445, because these Codes rely on the manufacturer Code pressure test (hydrostatic, pneumatic, or leak test) conducted at end of fabrication.

4 Scope

4.1 ASME VIII Div.1 Code

ASME VIII consists of three Divisions:

- Division 1 Rules for Construction of Pressure Vessels.
- Division 2 Rules for Construction of Pressure Vessels – Alternative Rules (design by detailed analysis).
- Division 3 Rules for Construction of Pressure Vessels – Alternative Rules for Construction of High Pressure Vessels (typically 10,000 psi and above).

This report addresses ASME VIII Div.1, the most common of the pressure vessel Divisions used in industry and in the DOE complex. In this report, reference to ASME VIII means ASME VIII Div.1. Reference to ASME VIII Div.2 will be identified accordingly.

The ASME VIII Div.1 Code is the commonly used Code for the construction of pressure vessels at the DOE facilities. The term “construction” means that the Code addresses the following activities for the production of a new pressure vessel:

1) Materials
2) Code Design
3) Fabrication
4) Examination
5) Testing
6) Over-pressure protection

7) Inspections and Certifications

ASME VIII does not address post-construction activities, which are typically:

1) Periodic inspections and tests of operating pressure vessels.
2) Fitness-for-service assessment (remaining life assessment, run-or-repair decisions) based on the results of the inspections and tests, i.e., based on the type and extent of damage identified.
3) Repairs, replacements, alterations based on the outcome of the fitness-for-service assessment.

For oversight and Code conformance, the ASME VIII Code relies on an Authorized Inspection Agency (AIA) as addressed in module 11 of this report.

4.2 EN 13445

4.2.1 The European Pressure Equipment Directive (PED)

An EU Directive is a legislation that sets out requirements products must meet in order to sell them throughout the EU. A manufacturer of pressure equipment or related components (boilers, vessels, piping, valves, etc.) wishing to enter the European market must certify their pressure equipment according to the European Pressure Equipment Directive (PED).

The original PED 97/23/EC became mandatory in the European Union in May of 2002, and updated as PED 2014/68/EU. Along with the Simple Pressure Vessel Directive 2009/105/EC and directives addressing portable pressure vessels and aerosol cans, PED 2014/68/EU sets mandatory requirements for pressure vessels in EU member countries. The PED directive establishes high level Essential Safety Requirements (ESRs).

Pressure equipment in the scope of the PED are (1) pressure vessels, (2) boilers, (3) Piping systems, and (4) pressure accessories (such as valves); which (a) are over 1 liter in volume (compare to 6 in. max dimension in ASME VIII) and (b) have a maximum pressure exceeding 0.5 bar gauge (7.3 psig, compare to 15 psig for ASME VIII).

a. The PED is mandatory throughout the EU, for pressure vessels, piping systems, and boilers and supersedes national regulations.
b. The PED covers a large range of equipment (pressure cookers to chemical reactors). The PED does not apply to nuclear power plants and waterworks which have their own regulations.
c. The European Norm (EN) standards such as EN 13445 for pressure vessels and EN-13480 for piping systems, provide detailed implementation requirements to meet the PED. The EN standards are not mandatory. But, compliance to the EN standards is presumed to comply with the ESR of the PED, without further justification.
d. National standards (such as PD5500 in the UK, CODAP in France, AD 2000 in Germany) can be used if it is established that they meet the ESRs of the PED.
e. The ESRs take a hazard-based approach, based on the consequence of failure in terms of (1) the size of the vessel or piping system, (2) its contents (gas or liquid), (3) its pressure, and (4) its contents (Group 1 toxic, flammable, explosive, etc.) and Group 2 (not Group 1). Hazard Categories range from 0 (not subject to the ESRs) up to IV.
f. Each PED equipment, if it is to receive the CE mark, is subject to a Conformity Assessment Procedure, performed by a Notified Body or by applying an approved Quality Assurance procedure, the extent of which depends on the Hazard Category. Pressure equipment and piping that complies with the PED bears the CE marking.

4.2.2 EN 13445 Outline

Regarding the implementation of the PED, the Committee for European Standardization (CEN) establishes EN and ISO standards, which are then adopted by all EU member countries. The EN standards, such as EN 13445 for pressure vessels, provide the construction details to comply with the PED and receive the CE or "Conformité Européenne" stamp.

The European vessel construction Code EN 13445 “Unfired Pressure Vessels” consists of the following ten parts:

1) Part 1 General
2) Part 2 Materials
3) Part 3 Design
4) Part 4 Fabrication
5) Part 5 Inspection and testing
6) Part 6 Spheroidal graphite cast iron vessels
7) Part 7 Use of conformity assessment procedures
8) Part 8 Aluminum and aluminum alloy vessels
9) Part 9 Conformance of EN 13445 to ISO 16528
10) Part 10 Nickel and nickel alloys vessels

As is the case for ASME VIII, EN 13445 does not address post-construction activities.

For oversight and Code conformance, the EN 13445 Code relies on a Notified Body as addressed in module 11 of this report.

4.2.3 Quotes

Quotes from the Codes and standards are reported in italic.

5 Materials

The key attributes for materials are:

5.1 Listed materials (base metals, weldments, bolts)

5.1.1 ASME VIII DIV.1

Material for vessels is to be ASME II, with exceptions.
UG-4 GENERAL
(a) Material subject to stress due to pressure shall conform to one of the specifications given in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3, including all applicable notes in the tables, and shall be limited to those that are permitted in the applicable Part of Subsection C, except as otherwise permitted in UG-9, UG-10, UG-11, UG-15, Part UCS, Part UIG, and the Mandatory Appendices.

UG-10 (a) Identified Material with Complete Certification From the Material Manufacturer. Material identified with a specification not permitted by this Division and identified to a single production lot as required by a permitted specification may be accepted as satisfying the requirements of a specification permitted by this Division, provided the following conditions are satisfied: …

5.1.2 EN 13445

EN 13445-1 Para.A.4 Only materials which are qualified for pressure equipment may be used. The qualification of materials can be made in three different ways:

- European harmonized standard EN 13445-2 Para.4.3.1 and Annex E.
- European approved materials (EAM) EN 13445-2 Para. 4.3.2.
- Materials with a particular material appraisal (PMA) by the manufacturer EN 13445-2 Para.4.3.3.

5.1.3 Conclusion

For ASME VIII and EN 13445 permitted vessel pressure boundary materials are in accordance with are in accordance with written consensus material standards and the listed standards have the same mechanical and metallurgical properties. Therefore, the two codes are equivalent for this attribute.

5.2 Allowances for unlisted materials.

5.2.1 ASME VIII DIV.1

See 5.1 (reference to UG-10), unlisted materials are allowed under certain conditions.

5.2.2 EN 13445

Materials with a PMA by the manufacturer EN 13445-2 Para.4.3.3.

A Particular Material Appraisal (PMA) is the process by which the pressure equipment manufacturer demonstrates that each proposed material that is not referenced in a harmonized standard or covered by a European Approval for Materials (EAM) conforms to the applicable Essential Safety Requirements (ESR). A Particular Material Appraisal is therefore a "description of the solutions adopted to meet the

essential requirements of the directive where the standards referred to in Article 5 have not been applied" and forms part of the Technical Documentation for the pressure equipment.

5.2.3 Conclusion

For ASME VIII and EN 13445 unlisted materials are allowed under certain conditions and therefore the two codes are equivalent for this attribute. The conditions of use of unlisted materials include verification of their mechanical properties, chemistry, heat treatment, etc.

5.3 Responsibility for material selection and corrosion allowances.

5.3.1 ASME VIII DIV.1

UG-4 (f) It is recommended that the user or his designated agent assure himself that materials used for the construction of the vessels will be suitable for the intended service …

5.3.2 EN 13445

EN 13445 does not address material selection; it is therefore the responsibility of the owner or designee.

5.3.3 Conclusion

Neither ASME VIII nor EN 13445 select materials. In both cases it is the responsibility of engineering and therefore the two codes are equivalent for this attribute.

5.4 Material used within the lower temperature limits.

5.4.1 ASME VIII DIV.1

Toughness testing is imposed for low temperature operation of ferritic steels.
UG-84 CHARPY IMPACT TESTS
(a) General. Charpy V-notch impact tests in accordance with the provisions of this paragraph shall be made on weldments and all materials for shells, heads, nozzles, and other vessel parts subject to stress due to pressure for which impact tests are required by the rules in Subsection C. / Subsection C requirements pertaining to classes of materials / Part UCS requirements for pressure vessels constructed of carbon and low alloy steels

UHA-51 IMPACT TESTS - Impact tests, as prescribed in (a), shall be performed on materials listed in Table UHA-23 for all combinations of materials and minimum design metal temperatures (MDMTs) except as exempted in (d), (e), (f), (g), (h), or (i) …

5.4.2 EN 13445

EN 13445-2 mandatory Annex B provides the requirements for toughness testing by material specification and grade, as a function of thickness.

Specified minimum impact energy (Charpy-V), at a test temperature in accordance with Annex B but not higher than 20°C: $\geq$ 27 J ferritic steels, steels with 1.5 - 5.0 % Ni; and $\geq$ 40 J other (35 J for some austenitic steels). There are also requirements for testing welded test plates in 13445-4.

5.4.3 Conclusion

Toughness testing is required in ASME VIII and EN 13445, with small differences in threshold temperature and energies and therefore the two codes are equivalent for this attribute.

5.5 Material used within the maximum temperature limits.

5.5.1 ASME VIII DIV.1

Maximum temperature limits are specified in ASME II Part D for all materials.

5.5.2 EN 13445

EN 13445-1 Table 4.2-1 provides reduction factors on yield strength up to 300^{o}C.

5.5.3 Conclusion

ASME VIII is more explicit regarding maximum permitted temperature for a material. This goes back to the fact that the allowable stresses in ASME VIII refer to ASME II which is explicit for every metal, whereas allowable stresses are not provided for each metal in EN 13445. EN 13445 requires the designer to refer to the material specification for allowable stress at temperature. However, the temperature limits apply in both Codes and therefore the two codes are equivalent for this attribute.

5.6 Unknown or reclaimed materials used within allowances.

5.6.1 ASME VIII DIV.1

UG-4 (d) Materials other than those allowed by the rules of this Division shall not be used. Data for new materials shall be submitted to and approved by the ASME Boiler and Pressure Vessel Committee on Materials in accordance with Section II, Part D, Mandatory Appendix 5.

5.6.2 EN 13445

Unknown materials are not permitted.

5.6.3 Conclusion

Both codes prohibit unknown materials and therefore the two codes are equivalent for this attribute.

5.7 Elevated temperature material testing.

5.7.1 ASME VIII DIV.1

Per ASME II Part D Appendix 1, Para.1-100, *(b) At temperatures in the range where creep and stress rupture strength govern the selection of stresses, the maximum allowable stress value for all materials is established by the Committee not to exceed the lowest of the following:*
(1) 100% of the average stress to produce a creep rate of 0.01%/1,000 hr
(2) 100 Favg % of the average stress to cause rupture at the end of 100,000 hr
(3) 80% of the minimum stress to cause rupture at the end of 100,000 hr

5.7.2 EN 13445

EN 13445-3 Para.19 provides stress limits for creep. EN 13445-2 Annex B addresses creep strength of weldments. They are both based on a fraction of creep rupture or 1% mean creep strain for a lifetime or 100,000 hours.

5.7.3 Conclusion
Material allowable stress in the creep regime are different, but both are conservative, resulting in a small creep strain during the design life, and therefore the two codes are equivalent for this attribute.

5.8 Allowance for brittle materials.
5.8.1 ASME VIII DIV.1
Part UCI applies for the construction of cast iron vessels.

5.8.2 EN 13445
Cast iron is permitted and has its own requirements in 13445-6.

5.8.3 Conclusion
The permission to use cast iron vessels applies in both Codes and therefore ASME VIII and EN 13445 are equivalent for this attribute.

5.9 Suitability of non-metallic materials.
5.9.1 ASME VIII DIV.1
ASME VIII permits certain non-metallic pressure boundaries, such as UIG for impregnated graphite, and *MANDATORY APPENDIX 48 VESSELS WITH ACRYLIC CYLINDRICAL SHELLS (c) The acrylic shell section of pressure vessels constructed to this Appendix shall be cylindrical acrylic windows constructed to the requirements of ASME PVHO-1 and the requirements of this Appendix. (1) The allowable window configuration is limited to cylindrical windows, ASME PVHO-1, Figure 2-2.2.1-3(b).*

5.9.2 EN 13445
Non-metallic materials are not addressed in 13445 (excluding coatings and gaskets).

5.9.3 Conclusion
The treatment of non-metallic materials such as viewing windows is lacking in both Codes. When using ASME VIII for non-metallic windows, other than impregnated graphite, and when using EN 13445, the user must verify the adequacy of non-metallic pressure boundaries such as windows, for example by proof testing of a prototype. Therefore, the two codes are equivalent, being silent regarding most non-metallic pressure boundaries such as observation windows.

5.10 Qualification of material suppliers.
5.10.1 ASME VIII DIV.1
Material suppliers do not have to be authorized by ASME, or otherwise certified. It is up to the owner-user to verify the quality of the materials (base metals and weld filler metals) used to fabricate the pressure vessel.

5.10.2 EN 13445
Material suppliers have to meet the technical delivery requirements of European Standards EN 10028 (plate), EN 10222 (forging), EN 10216 (seamless pipe), EN 10217 (welded pipe), EN 10269 (fasteners), and EN 12074 and EN 13479-1 for welding consumables.

5.10.3 Conclusion
EN 13445 is stricter than ASME VIII regarding material suppliers.

5.11 Quality control of materials.

5.11.1 ASME VIII DIV.1

UG-10 (1) Documentation is provided [by the material supplier] *to the Certificate Holder demonstrating that all applicable requirements (including, but not limited to, melting method, melting practice, deoxidation, chemical analysis, mechanical properties, quality, and heat treatment) of the specification permitted by this Division, to which the material is to be recertified, have been met.*

UG-93 Inspection of Materials requires material test reports.

5.11.2 EN 13445

EN 13445-2 Para.4.1, 4.2, 4.3 has strict conditions for the use of materials (base metal and weldments) and their "technical delivery".

5.11.3 Conclusion

ASME VIII and EN 13445 both require documentation of the quality control of materials. The required documentation for EN 13445, although different than ASME VIII, is comprehensive. Therefore, the two codes are equivalent for this attribute.

5.12 Material traceability.

5.12.1 ASME VIII DIV.1

UG-77 MATERIAL IDENTIFICATION (SEE UG-85)

(a) Material for pressure parts preferably should be laid out so that when the vessel is completed, one complete set of the original identification markings required by UG-94 will be plainly visible. The pressure vessel Manufacturer shall maintain traceability of the material to the original identification markings by one or more of the following methods …

5.12.2 EN 13445

EN 13445-2 Para.4.4 requires markings and traceability.

5.12.3 Conclusion

ASME VIII and EN 13445 require material traceability. Therefore, the two codes are equivalent for this attribute.

5.13 Material test reports.

5.13.1 ASME VIII DIV.1

See 5.12.

5.13.2 EN 13445

EN 13445 Para.4.1.2 requires material certificates; and certificates of special control for vessels designed by analysis.

5.13.3 Conclusion

ASME VIII and EN 13445 require material certificates. Therefore, the two codes are equivalent for this attribute.

6 Code design

The following reports are valuable resources in comparing the Code design attributes of EN 13445 to ASME VIII:

- ASME PTB-10-20 “Guide for ASME VIII Division 1 Stamp Holders”, ASME Standards Technology LLC, 2015.
- STP-PT-007 « Comparison of Pressure Vessel Codes ASME Section VIII and EN 13445 », ASME Standards Technology LLC, 2006.
- WRC Bulletin 435, “Evaluation of Design Margins for Section VIII Div.1 and 2 of the ASME Boiler and Pressure Vessel Code”, E. Upitis and K. Mokhtarian, September 1998.
- ASME PVP2009-77273 “Cross Comparison of European and American Pressure Vessel Standards in the Design of the Main Pressure Vessel Components, F. Lidonnici, ASME Pressure Vessel and Piping Conference, 2009.

The key attributes for design are:

6.1 Scope exclusions and boundaries of the vessel or piping.

6.1.1 ASME VIII DIV.1

U-1 Scope places the vessel boundary at:

(-a) the welding end connection for the first circumferential joint for welded connections [see UW-13(i)];
(-b) the first threaded joint for screwed connections;
(-c) the face of the first flange for bolted, flanged connections;
(-d) the first sealing surface for proprietary connections or fittings;

6.1.2 EN 13445

EN 13445-1 “Introduction” defines the scope of the pressure vessel to go to the nozzle flange or first circumferential weld.

6.1.3 Conclusion

The scope boundaries of ASME VIII and EN-13445 are identical. Therefore, the two codes are equivalent for this attribute.

6.2 Selection of the design pressure and temperature.

6.2.1 ASME VIII DIV.1

UG-21 DESIGN PRESSURE
Each element of a pressure vessel shall be designed for at least the most severe condition of coincident pressure (including coincident static head in the operating position) and temperature expected in normal operation.

6.2.2 EN 13445

Pressure at the top of the component is chosen for the derivation of the pressure at each component.

6.2.3 Conclusion

ASME VIII and EN 13445 require static head to be included in the pressure design. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.3 Allowances for over-pressure and over-temperature.

6.3.1 ASME VIII DIV.1

UG-153 OVERPRESSURE LIMITS
(a) Other than unfired steam boilers, when a pressure relief device is provided, it shall prevent the pressure from rising more than 10% or 3 psi (20 kPa), whichever is greater, above the maximum allowable working pressure, except as permitted in (1) and (2) and UG-154(c).
(See UG-155 for pressure settings.)
(1) When multiple pressure relief devices are provided … rising more than 16% or 4 psi (30 kPa), whichever is greater, above the maximum allowable working pressure.
(2) When a pressure vessel can be exposed to fire or other unexpected sources of external heat … from rising more than 21% above the maximum allowable working pressure. …

6.3.2 EN 13445

EN 764-7 Para.6.1.4

- For a single relief device, the over-pressure limit of 10% over the MAWP or 0.1 bar (1.45 psig) whichever is greater. EN13445 is therefore more restrictive on over-pressure allowance during relief device discharge.
- For multiple relief devices the over-pressure limit of 10% over the MAWP or 0.1 bar (1.45 psig) whichever is greater. EN13445 is therefore more restrictive on over-pressure allowance during relief device discharge.
- For the case of an external fire, the over-pressure limit is to be based on a consequence analysis, or 10% over-pressure may be used as a conservative limit.

PED (2014) Para.2.11.2. *Pressure limiting devices. These devices shall be so designed that the pressure will not permanently exceed the maximum allowable pressure PS; however a short duration pressure surge in keeping with the specifications laid down in point 7.3 is allowable, where appropriate.*

PED (2014) Para.7.3. *Pressure limiting devices, particularly for pressure vessels. The momentary pressure surge referred to in point 2.11.2 shall be kept to 10 % of the maximum allowable pressure.*

6.3.3 Conclusion

EN 13445 limits the over-pressure to 10% even with multiple relief devices while ASME VIII permits 21%. Therefore EN 13445 is more restrictive then ASME VIII for this attribute.

6.4 Loads to be considered in the design.

6.4.1 ASME VIII DIV.1

ASME VIII does not specify the loads and load combinations to be used in design.

U-2 General
(2) User's Design Requirements Form
(-a) A User's Design Requirements Form, or other document with equivalent information, shall be provided when any of the following conditions is a design requirement:
(-1) superimposed static reactions [see UG-22(c)]
(-2) cyclic or dynamic reactions [see UG-22(e)]
(-3) loadings due to wind, snow, or seismic reactions [see UG-22(f)]
(-4) impact reactions [see UG-22(g)]
(-5) temperature effects [see UG-22(h)]
(-6) abnormal pressures [see UG-22(i)]
(-b) Sample User Design Requirements forms and guidance on their preparation are found in Nonmandatory Appendix KK.

UG-22 LOADINGS
The loadings to be considered in designing a vessel shall include those from:
(a) internal or external design pressure (as defined in UG-21);
(b) weight of the vessel and normal contents under operating or test conditions;
(c) superimposed static reactions from weight of attached equipment, such as motors, machinery, other vessels, piping, linings, and insulation;
(d) the attachment of:
(1) internals (see Nonmandatory Appendix D);
(2) vessel supports, such as lugs, rings, skirts, saddles, and legs (see Nonmandatory Appendix G);
(e) cyclic and dynamic reactions due to pressure or thermal variations, or from equipment mounted on a vessel, and mechanical loadings;
(f) wind, snow, and seismic reactions, where required;
(g) impact reactions such as those due to fluid shock;
(h) temperature gradients and differential thermal expansion;
(i) abnormal pressures, such as those caused by deflagration;
(j) test pressure and coincident static head acting during the test (see UG-99).

6.4.2 EN 13445

EN 13445 Para.5.3 lists examples of loads to take into consideration in design.

6.4.3 Conclusion

ASME VIII and EN 13445 are equivalent in mentioning loads to be considered in design. However, neither code has mandatory load requirements, in both cases it is up to the owner-user and designer to define the loads. Therefore, the two codes are equivalent for this attribute.

6.5 Margins of basic allowable stress against ultimate and yield.

6.5.1 ASME VIII DIV.1

ASME VIII Div. 1 and ASME VIII Div. 2 apply different design factors against the minimum specified ultimate strength of the metal, while they have the same design factor against minimum specified yield strength.

- ASME VIII Div.1 Rules for Construction of Pressure Vessels
  ASME VIII Div.1 allowable stress has a design factor of 1/1.5 against yield (90% of yield for certain stainless steel applications) and 1/3.5 against ultimate.

- ASME VIII Div.2 Rules for Construction of Pressure Vessels Alternative Rules
  ASME VIII Div.2 has the same 1/1.5 design factor against yield, but two design factors against the ultimate strength:
  ASME VIII Div.2 Class 1 vessels **1/3** ultimate (ASME II Part D, Subpart 1, Tables 2A and 2B)
  ASME VIII Div.2 Class 2 vessels **1/2.4** ultimate (ASME II Part D, Subpart 1, Tables 5A and 5B)
  The extent of design analysis is different for ASME VIII Div.2 Class 1 and Class 2.

User Design Specification (UDS): ASME VIII Div.2 Class 1 and Class 2 require the user to develop a UDS which provides all the loads and load combinations, including fatigue cyclic loads. This input is more detailed than ASME VIII Div.1 which focuses on internal pressure and the range (maximum and minimum) of temperature.

Class 1: The UDS does not have to be PE certified unless fatigue analysis is required.
Class 2: The UDS must be PE certified.

Design Analyses:

- Class 1: Part 4 of Section VIII, Div. 2 Design by Rule, i.e., design by formulas, are used in the design of Class 1 pressure vessels. If design rules are not provided in Part 4, Design by Analysis, i.e., typically design by finite element analysis, (Part 5 of Section VIII, Div. 2) is used.
- Class 2: Design by Analysis (Part 5) is required when design rules are not provided in Part 4. Components for Class 2 pressure vessels may be designed using a combination of Part 4 or Part 5. Part 5 (Design by Analysis) may be used to establish design thickness and/or configuration in lieu of Part 4 (Design by Rule) for any geometry or loading conditions. Thickness can be less than that determined using Part 4.

Manufacturer's Design Report (MDR):

ASME VIII Div.2 Class 1 and Class 2 require the manufacturer to prepare an MDR.

- Class 1: The MDR must be independently certified when (a) a fatigue analysis applies; (b) Part 5 (Design by Analysis) rather than Part 4 (Design by Rule) is used to determine thickness of

pressure parts when design rules are not provided in Part 4; (c) a quick-actuating closure is designed using Part 4.8; and (d) a dynamic seismic analysis is performed

- Class 2: The MDR must be PE certified in all cases.

6.5.2 EN 13445

EN 13445 Para.6.2.1 specifies the allowable stress as the smaller of $S_{yield}/1.5$ and $S_{ultimate}/2.4$.

6.5.3 Conclusion

While different design factors are used throughout ASME VIII depending on differences in the level of design analysis rigor, the minimum basic design factor allowed in EN 13445 and in ASME BPVC is $S_{yield}/1.5$ or $S_{ultimate}/2.4$ is the same. Therefore, the two codes are equivalent for this attribute.

6.6 Burst Prevention Design

6.6.1 ASME VIII DIV.1

Minimum thickness formulas for shells, heads, and nozzles are provided in UG-27 and 27 and 32 through 34.

6.6.2 EN 13445

EN 13445 is more comprehensive in providing design equations for calculating wall thickness.

6.6.3 Conclusion

EN 13445 is more comprehensive in providing design formulas for various part shapes.

6.7 Allowance for pressure design by proof testing.

6.7.1 ASME VIII DIV.1

ASME VIII permits establishing the rated pressure by proof testing.

UG-101 PROOF TESTS TO ESTABLISH MAXIMUM
ALLOWABLE WORKING PRESSURE

(2) The maximum allowable working pressure P in pounds per square inch (kilopascals) at test temperature for parts tested under this paragraph shall be computed by one of the following equations:
(-a) parts constructed of materials other than cast materials: $P = (B/4)(S_{\mu}E/S_{\mu.avg})$

6.7.2 EN 13445

EN13445-3 Para.T.4.4 addresses qualification by proof testing, with a design factor of 5, i.e. B/5.

6.7.3 Conclusion

EN 13445 is more conservative regarding this attribute.

6.8 Allowance for layered vessels.

6.8.1 ASME VIII Div.1

PART ULW requirements for pressure vessels fabricated by layered construction

6.8.2 EN 13445
EN 13445 does not apply to Multilayered, auto-frettage or pre-stressed vessels.

6.8.3 Conclusion
Layered vessels are addressed in ASME VIII Part ULW and are not addressed in EN 13445.

Suggestion: The owner-user of a layered vessel is to assess the EN 13445 in accordance with ASME VIII ULW for materials, design, fabrication, examination, testing, and over-pressure protection of layered vessels.

6.9 Special rules for the design of heat exchangers.
6.9.1 ASME VIII Div.1
PART UHX provides the rules for shell-and-tube heat exchangers.

6.9.2 EN 13445
Heat exchangers are addressed in EN 13445-3 Para.13, with similar design rules as ASME VIII.

6.9.3 Conclusion
ASME VIII and EN 13445 have similar rules for the design of heat exchangers. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.10 Plastic instability prevention design.
6.10.1 ASME VIII DIV.1
ASME VIII Div.1 permits plastic analysis by reference to ASME VIII Div.2, under certain conditions.
MANDATORY APPENDIX 46 rules for use of section VIII, Division 2
The design-by-analysis requirements in Division 2, Part 5 may be used to design the components for a Division 1 pressure vessel provided the following conditions are met regarding the allowable stress and the weld joint efficiency factor.

6.10.2 EN 13445
13445-3 addresses design by analysis, using the direct method (Annex B, i.e. plastic analysis) or stress categories (Annex C, i.e. elastic stress linearization). The methods are different from ASME VIII Div.2 in terms of design factors and strain limits, but the same failure modes are addressed.

6.10.3 Conclusion
The methods of plastic stress/strain analysis have different design factors and strain limits, but they protect against the same failure modes. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.11 Fatigue cracking prevention design.
6.11.1 ASME VIII DIV.1
Division 1 is silent regarding rules for fatigue design, but Appendix 46 refers to ASME VIII Div.2 that has a full treatment of fatigue (cyclic loads).

6.11.2 EN 13445
EN 13445 Clauses 17 and 18 address fatigue design. The fatigue analysis methods in Clauses 17 and 18 are comprehensive and equivalent to ASME VIII Div.2, and includes additional considerations such as weld peaking or misalignment.

6.11.3 Conclusion
ASME VIII Div.1 refers to ASME VIII Div.2 for fatigue design. The fatigue design of EN 13445 is equivalent to ASME VIII Div.2. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.12 Buckling prevention design.
6.12.1 ASME VIII DIV.1
Appendix 1 supplementary design formulas has buckling formulas for certain vessel heads.

ASME VIII Div.1 evaluates buckling from axial compression and external pressure. The code procedure varies depending on the equipment geometry and loading, but the underlying method is the same.

ASME VIII Div.2 assesses collapse from buckling using three types of analysis: Type 1: Elastic stress analysis without geometric nonlinearities; Type 2: Elastic-plastic stress analysis with non-linear geometry; Type 3: Collapse analysis with imperfections explicitly considered.

Therefore, for the analysis of gross plastic deformation, ASME VIII Div.2 permits the use of elastic-perfectly plastic or strain hardening material models and small or large deformation theory.

6.12.2 EN 13445
EN 13445-3 addresses buckling throughout. The margins are different from ASME VIII.

For the analysis of gross plastic deformation, EN13445 specifies an elastic-perfectly plastic material model but requires large (second order) deformation effects to be considered for vessels or components exhibiting geometric weakening.

The slenderness ratio of ASME II-D Figure G and EN-13445-3 come from the same references and match well.

6.12.3 Conclusion
EN-13445-3 and ASME VIII and ASME II Part D have different formulation of buckling analysis. Both Codes are based on elastic and elastic-plastic analysis, equivalent in their general approach to buckling. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.13 Bearing stress failure prevention.
6.13.1 ASME VIII DIV.1
UG-23 MAXIMUM ALLOWABLE STRESS VALUES
(h) Maximum bearing stress shall be limited to 1.60 times the values in Section II, Part D, Subpart 1, Table 1A, Table 1B, or Table 3.

6.13.2 EN 13445
EN 13445-3 Para.11 limits the bearing stress to 1.50 the allowable stress.

6.13.3 Conclusion
The bearing stress limits are equivalent. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.14 Margins on stress limits for load combinations.

6.14.1 ASME VIII DIV.1

Endnote 15 UG-23(d) permits an increase in allowable stress when earthquake or wind loading is considered in combination with other loads and pressure defined in UG-22. The 1.2 increase permitted is equivalent to a load reduction factor of 0.833. Some standards which define applicable load combinations do not permit an increase in allowable stress, however a load reduction factor (typically 0.75) is applied to multiple transient loads (e.g., wind plus live load, seismic plus live load, etc.).

6.14.2 EN 13445

EN 13445 does not address an increase for allowable stresses where earthquake or wind applies.

6.14.3 Conclusion

EN 13445 does not provide an increase in allowable stresses where earthquake or wind applies. However, the design margins are different, with the margin of 2.4 in EN-13445 and margins from 3.5 to 2.4 in ASME VIII Div.1 or Div.2 refer to Para.6.6. Allowing a 1.2 increase in allowable stress corresponds to a margin of 3.5/1.2 = 2.9 compared to 2.4 for EN-13445. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.15 Weld joint efficiency factors.

6.15.1 ASME VIII DIV.1

UW-12 provides a table of weld joint efficiency from 1.0 to 0.45 factors as a function of the type of weld (butt, one-sided or two-sided) and full or spot or no radiography.

6.15.2 EN 13445

EN 13445-3 Table 5.6-1 provides joint coefficients, from 1.0 to 0.7, i.e. do not permit joints that have a low coefficient (such as the 0.45 in ASME VIII).

6.15.3 Conclusion

EN 13445-3 is more restrictive.

6.16 External pressure design.

6.16.1 ASME VIII DIV.1

UG-28 thickness of shells and tubes under external pressure; and UG-29 stiffening rings for cylindrical shells under external pressure.

Until the 2023 edition, there were shortcomings in the buckling prevention design of ASME VIII Div.2 pressure vessels. In the 2023 edition, ASME VIII Div.1 issued a Code Case similar to Div.2 Part 4 (Design by rule), with a margin of 2.5 for elastic analysis when imperfections are accounted for and 1.67 for elastic plastic analysis. These Div.2 Part 4 rules are based on experimental work and the theoretical equations were modified to match the experimental work. The design margins in Div.2 Part 5 (Design by analysis) are similar to Div.2 Part 4.

6.16.2 EN 13445

EN 13445-2 Para.8 provides design methods for buckling similar to the current ASME VIII Div.2 see attributes 6.13.

6.16.3 Conclusion
The design methods for buckling prevention are similar in ASME VIII Div.2 and EN 13445. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.17 Nozzle reinforcement design.
6.17.1 ASME VIII DIV.1
UG-36 addresses openings in pressure vessels; UG-37 addresses reinforcement required for openings in shells and formed heads; and UG-45 addresses nozzle neck thickness provide reinforcement rules based on area reinforcement.

6.17.2 EN 13445
EN 13445-3 Para.9 Openings in shells, addresses the area reinforcement rule, in a more explicit manner, but equivalent to the area replacement method.

6.17.3 Conclusion
The area reinforcement rules for openings are equivalent. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.18 Permitted and prohibited weld details.
6.18.1 ASME VIII DIV.1
UW-9 DESIGN OF WELDED JOINTS (a) Permissible Types provides rules for vessel welds, including the requirement that butt welds be full penetration.

6.18.2 EN 13445
13445-3 Annex P addresses the different types of welds for limits on the stress range.

6.18.3 Conclusion
ASME VIII and EN 13445 provide acceptable weld details that are equivalent. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.19 Allowances and prohibitions for types of mechanical (non-welded, non-bolted) joints.
6.19.1 ASME VIII DIV.1
MANDATORY APPENDIX 24 DESIGN RULES FOR CLAMP CONNECTIONS, states that *Clamp hub friction shall not be considered as a retainer method.*

6.19.2 EN 13445
EN 13445-3 Para.17.6.1.1.2 refers to clamping joints. EN 13445-5 Para.C.5.4 permits screw clamps for flange assemblies.

6.19.3 Conclusion
ASME VIII would not permit friction clamps. The only clamps mentioned in EN 13445 are screw clamps for flanges that do not rely on friction. Therefore, ASME VIII and EN 13445 are equivalent and do not permit friction clamps.

6.20 Design of flanges and bolted joints.
6.20.1 ASME VIII DIV.1
The design of bolted flanged joints is addressed in the following ASME VIII sections:

- UG-44 Flange and pipe fittings *(b) External loads (forces and bending moments) may be evaluated for flanged joints with welding neck flanges chosen in accordance with (a)(2), (a)(9), and (a)(10), using the following requirements: …*
- Mandatory Appendix 2 Rules for Bolted Flange Connections with Ring Type Gaskets; for the design of custom (non-B16) bolted flange connections.
- Nonmandatory Appendix S Design Considerations for Bolted Flange Connections; rules of good practice to supplement Appendix 2.
- Nonmandatory Appendix Y Flat Face Flanges with Metal-to-Metal Contact Outside the Bolt

6.20.2 EN 13445
EN 13445-3 Para.11 addresses the design of flanges. The method of flange design by analysis is comprehensive but differs from ASME VIII.

6.20.3 Conclusion
ASME VIII and EN 13445 provide different flange design analysis formulations, but the two methods provide a safe design of bolted flange joints. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.21 Bolting design.
6.21.1 ASME VIII DIV.1
UG-12 BOLTS AND STUDS, UCS-10 (carbon steel) bolt materials, and UNF-12 (non-ferrous) provide the requirements for bolts and studs.

6.21.2 EN 13445
EN 13445-3 Para.11 addresses the design of flange bolts. The method of flange bolt design is comprehensive but differs from ASME VIII.

6.21.3 Conclusion
ASME VIII and EN 13445 provide different flange bolt design analysis methods, but the two methods provide a safe design of bolted joints. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.22 Design of cladding and weld overlays.
6.22.1 ASME VIII DIV.1
PART UCL requirements for welded pressure vessels constructed of material with corrosion resistant integral cladding, weld metal overlay cladding, or applied linings provides the requirements for the design of cladding and weld overlays. The cladding may be credited for thickness design: *"the design calculations may be based on a thickness equal to the nominal thickness of the base material plus S_c/S_b times the nominal thickness of the cladding after any allowance provided for corrosion has been deducted, …"*

6.22.2 EN 13445
EN 13445-3 Para.B.7.2 addresses cladding. Structural strength can be attributed to cladding only for plastic deformation assessment.

6.22.3 Conclusion
EN 13445-3 is more restrictive for this attribute.

6.23 Design of blanks and flat heads.

6.23.1 ASME VIII DIV.1

UG-34 UNSTAYED FLAT HEADS AND COVERS *(a)* The minimum thickness of unstayed flat heads, cover plates and blind flanges shall conform to the requirements given in this paragraph.

6.23.2 EN 13445

EN 13445-3 Para.10 addresses flat ends. The method of flat end design is comprehensive but differs from ASME VIII.

6.23.3 Conclusion

ASME VIII and EN 13445 provide different blank and flat head formulas, but the two methods are equivalent.

6.24 Design of catalog specialty items.

6.24.1 ASME VIII DIV.1

U-2 NOTE: The term "applicable design calculations" means that all pressure-retaining components covered by the Certification Mark stamping are supported by calculations and/or proof tests that comply with the requirements of this Division.

UG-101 PROOF TESTS TO ESTABLISH MAXIMUM ALLOWABLE WORKING PRESSURE provides the option of setting the MAWP by proof testing at a value P = (B(burst pressure)/4)($S_{\mu}E/S_{\mu.avg}$).

6.24.2 EN 13445

EN13445-3 Para.T.4.4 addresses qualification by proof testing, with a design factor of 5, i.e. B/5.

6.24.3 Conclusion

For qualification of items by proof testing, EN 13445 is more conservative by 5/4 = 1.25.

6.25 Design of support structures.

6.25.1 ASME VIII DIV.1

UG-54 SUPPORTS (a) All vessels shall be so supported and the supporting members shall be arranged and/or attached to the vessel wall in such a way as to provide for the maximum imposed loadings (see UG-22 and UG-82). (b) Nonmandatory Appendix G contains suggested rules for the design of supports.

6.25.2 EN 13445

EN 13445 Para.16.8 covers horizontal vessels on saddle supports; Para.16.9 on stiffening ring supports; Para.16.10 vertical vessels on bracket supports; Para.16.11 on legs; Para.16.12 on skirts; Para.16.12.5.2 anchor bolts; etc. More comprehensive than ASME VIII.

6.25.3 Conclusion

EN 13445-3 is more comprehensive than ASME VIII for the design of vessel support structures and anchorage to concrete.

6.26 Allowance for design by finite element analysis, and stress or strain limits.

6.26.1 ASME VIII DIV.1

ASME VIII Div.1 permits design by finite element analysis by reference to ASME VIII Div.2 *MANDATORY APPENDIX 46 RULES FOR USE OF SECTION VIII, DIVISION 2 Para. 46-4 DESIGN BY ANALYSIS "The design-*

by-analysis requirements in Division 2, Part 5 may be used to design the components for a Division 1 pressure vessel provided the following conditions are met …"

6.26.2 EN 13445

13445-3 addresses design by analysis, using the direct method (Annex B, i.e. plastic analysis) or stress categories (Annex C, i.e. elastic stress linearization). The methods are different from ASME VIII Div.2 in terms of design factors and strain limits, but the same failure modes are addressed.

6.26.3 Conclusion

For design by detailed finite element analysis, ASME VIII Div.1 refers to ASME VIII Div.2 Part 5, while EN 13445-3 provides Annexes B and C. The methods are different but both address the same failure modes. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.27 Fracture mechanics in design, flaw tolerance.

6.27.1 ASME VIII DIV.1

There is no option in ASME VIII Div.1 for design by fracture mechanics.

6.27.2 EN 13445

EN 13445-3 Para.C.7.5 permits fracture mechanics as an alternative to tri-axial stress limit. EN 13445-3 Para.M.3 permits fracture mechanics in estimating periodic inspections for remaining life in fatigue (i.e., post-construction).

6.27.3 Conclusion

EN 13445 addresses fracture mechanics in limiting tri-axial stresses in design, while ASME VIII is silent. EN 13445 is more explicit and more complete for fracture prevention analysis.

6.28 Graded approach to design based on consequence of failure.

6.28.1 ASME VIII DIV.1

Pressure vessels in ASME VIII categorizes vessels as lethal or non-lethal service. *When a vessel is to contain fluids of such a nature that a very small amount mixed or unmixed with air is dangerous to life when inhaled, it shall be the responsibility of the user and/or his designated agent to determine if it is lethal.*

Lethal service vessel will have supplementary requirements for design (ERW pipe cannot be used as a shell, etc.), weld NDE, and pressure testing.

6.28.2 EN 13445

The ESRs of the PED take a hazard-based approach, based on the consequence of failure in terms of (1) the size of the vessel or piping system, (2) its contents (gas or liquid), (3) its pressure, and (4) its contents. Hazard Categories range from 0 (not subject to the ESRs) up to IV.

EN-13445-7 defines Group 1 vessels as those containing "dangerous fluids" such as explosive, extremely flammable, toxic, oxidizing.

6.28.3 Conclusion

ASME VIII Div.1 differentiates vessels containing lethal fluids from non-lethal. EN-13445-7 has a similar differentiation between vessels containing hazardous fluids and non-hazardous. In addition, EN-13445 differentiates by pressure-volume of the vessel, i.e. its energy release in case of a rupture.

Therefore, EN-13445 introduces an energy-based classification in addition to ASME VIII's hazard level of the contents.

6.29 Design of closures.

6.29.1 ASME VIII DIV.1

The design for closures is addressed in UG-35.2 Quick-Actuating Closures and UG-35.3 Quick-Opening Closures.

6.29.2 EN 13445

EN 13445-5 requires access openings in vessels, with several types of closures. Para.C.5.3 requires they be designed to EN 13334-3.

6.29.3 Conclusion

Equivalent rules for closures, with EN 13445 being more explicit.

6.30 Design of vessel internals.

6.30.1 ASME VIII DIV.1

Nonmandatory Appendix D Suggested Good Practice Regarding Internal Structures (a) Connections to the vessel wall should be designed to prevent excessive tensile stress outward from the wall face due to the connection. (See UG-55.)

6.30.2 EN 13445

EN 13445-3 points out the need to address stresses caused by internal structures.

6.30.3 Conclusion

No explicit design rules provided in either Code. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

6.31 Design of attachment to the support structure.

6.31.1 ASME VIII DIV.1

Nonmandatory Appendix G Suggested Good Practice Regarding Piping Reactions and Design of Supports and Attachments

(a) *All supports should be designed to prevent excessive localized stresses due to temperature changes in the vessel or deformations produced by the internal pressure.* No explicit design rules are provided.

6.31.2 EN 13445

EN 13445-3 addresses the design of vessel support structures, and Para.16 addresses forces at attachments, and Para.18 addresses attachment welds.

6.31.3 Conclusion

Neither Code provides a complete set of equations for the design of welded attachments to a vessel. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7 Fabrication

The key attributes for fabrication are:

7.1 Welding program.

7.1.1 ASME VIII DIV.1

ASME VIII requires compliance to a welding program in accordance with ASME IX, which covers:

- Welding procedure specification (WPS) per ASME IX QW-101
- Procedure qualification record (PQR) per ASME IX QW-102
- Welder performance qualification (WPQ) per ASME IX QW-480

ASME VIII supplementary requirements are:

UG-9 Welding Materials Welding materials used for production shall comply with the requirements of this Division, those of Section IX, and the applicable qualified welding procedure specification.

UG-84 Charpy Impact Tests (2) When Required vessel (production) impact test plates shall be made for all joints for which impact tests are required for the welding procedure by UCS-67, UHT-82, or UHA-51 (except where production test plates are specifically exempt by these paragraphs). Test shall be made of the weld metal and/or heat-affected zone to the extent required by the procedure test (see UCS-67 and UHA-51).

UW-26 General (c) No production welding shall be undertaken until after the welding procedures which are to be used have been qualified. Only welders and welding operators who are qualified in accordance with Section IX shall be used in production.

UW-27 Welding Processes The welding processes that may be used in the construction of vessels under this Part of this Division are limited to those listed in Section IX, Article II with the following additional restrictions: …

7.1.2 EN 13445

EN 13445-4 requires compliance to a welding program with:

- WPS per EN ISO 15609
- Welding Procedure Qualification Record (WPQR) per EN ISO 15613 and 15614
- Welder Qualification EN ISO 9606 (welder) and 14732 (welding operator)

EN13445-4 supplementary requirements include production weld testing.

7.1.3 Conclusion

The two Code programs rely on three key documents: The WPS, the PQR (WPQR in EN 13445), and the WPQ; and supplementary quality control requirements. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.2 Welding Procedure Specification (WPS).

7.2.1 ASME VIII DIV.1

For ASME VIII, the WPS refers to ASME Section IX, which in Article V provides standard procedure specifications (SWPSs) which are generated by the American Welding Society (AWS).

There is a SWPS for each arc welding technique which captures essential and non-essential variables. For example, the following variables apply to TIG welding:

- Type of joint (groove design, root spacing, etc.)
- Base metal
- Filler metal
- Position
- Pre-heat
- Post-weld heat treatment
- Shielding gas
- Electrical characteristics (heat input, current and polarity)
- Tungsten electrode
- Welding technique (string or weaving, method cleaning, method back gouging, single or multiple passes, oscillation, etc.)

7.2.2 EN 13445

The WPS is provided in Annex A to EN ISO 15609-1. This document specifies requirements for the content of WPSs for arc welding processes. The EN 13445 WPS captures the following variables, applicable to all the arc welding processes:

- WPS
- WPQR No.
- Method of preparation and cleaning
- Manufacturer
- Parent material designation
- Mode of metal transfer
- Material thickness
- Joint type and weld type
- Outside diameter
- Throat thickness
- Degree of mechanization
- Deposited weld metal
- Weld preparation sketch
- Welding position
- Joint design
- Welding sequence
- Size of filler metal
- Type of current and polarity
- Current
- Voltage
- Wire feed speed
- Runout length
- Travel speed
- Arc energy / heat input
- Filler designation and make
- Special baking and drying
- Designation of shielding gas/flux

- Backing
- Weaving width
- Gas flow rate
- Tungsten electrode type and size
- Distance to work piece
- Preheating temperature
- Torch angle
- Inter-pass temperature
- Post-weld heat treatment, time, temperature, method, heating and cooling rates
- Manufacturer name and signature/date

Unlike ASME VIII, in this list, the variables are not denoted essential or non-essential. The statement is made that “The variables listed in this document are those influencing the quality of the welded joint.”

7.2.3 Conclusion

In ASME VIII and EN 13445 the welding variables in the WPS are nearly identical. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.3 Welding Procedure Qualification Record (WPQR).

7.3.1 ASME VIII DIV.1

The WPQR is a record of variables recorded during the welding of the test coupons. It also contains the test results of the tested specimens. Welding procedure qualification is in accordance with ASME IX QW-200.2. The type of tests to be performed to qualify a WPS depends on the material and thickness of the weld, and includes:

- Tensile testing
- Guided bend test
- Toughness test in some cases

UW-28 QUALIFICATION OF WELDING PROCEDURE

(a) Each welding procedure used in joining pressure parts to pressure parts or joining pressure parts to load carrying non-pressure parts, such as all permanent or temporary clips and lugs to pressure parts, shall be recorded in detail by the Manufacturer and qualified in accordance with the rules of Section IX.

7.3.2 EN 13445

The WPQR for EN 13445 WPS is in accordance with -EN ISO 15609-1; 15611 (based on previous experience); 15612 (standard WPS); 15613 (pre-production welding test); the mechanical tests are similar to ASME IX:

- Tensile tests
- Bend tests
- Toughness tests in some cases, with supplementary toughness requirements of EN 13445 Para.8.3.

7.3.3 Conclusion

The requirement for a WPQR is identical in ASME VIII and EN 13445, with reference to ASME IX and EN ISO 15614 respectively. The weld qualification tests are equivalent in both Codes. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.4 Welder or weld operator qualification.

7.4.1 ASME VIII DIV.1

ASME VIII requires that welders be qualified for the WPS.

UG-90 GENERAL (11) qualification of welders and welding operator and brazers before using the welders or brazers in production work (see UW-29, UW-48, UB-32, and UB-43);

UW-48 CHECK OF WELDER AND WELDING OPERATOR QUALIFICATIONS
(a) The Manufacturer shall certify that the welding on a vessel has been done only by welders and welding operators who have been qualified under the requirements of Section IX and the Inspector shall assure himself that only qualified welders and welding operators have been used.
(b) The Manufacturer shall make available to the Inspector the record of the qualification tests of each welder and welding operator. The Inspector shall have the right at any time to call for and witness tests of the welding procedure or of the ability of any welder and welding operator.

The duration of the welder qualification is addressed in ASME IX QW-322.1 Expiration. *The qualification of a welder or welding operator for a process remains valid provided no more than 6 months have passed since the welder or welding operator last used that process.*

7.4.2 EN 13445

EN 13445-4 Para.8.4 requires that each welder be qualified for the WPS, in accordance with EN ISO 9606 (welders) and ISO 14732 (welding operators).

The duration of the welder qualification is addressed in EN ISO 9606-1. The welder may be

- Retested every 3 years
- Retested every 2 years, if two welds made during the last 6 months of the validity period were satisfactorily tested by radiographic or ultrasonic testing or destructive testing.

7.4.3 Conclusion

While the duration of the welder qualifications varies, both ASME IX and EN ISO 9606 require the welder to be qualified and re-tested periodically. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.5 End preparation.

7.5.1 ASME VIII DIV.1

UW-13 andUW-16 provide acceptable weld bevel details. ASME VIII permits other bevel details provided they are qualified in the WPS.

7.5.2 EN 13445

EN 13445-4 Para.8.6 and EN ISO 15609 Para.4.4.2 address joint preparation but do not specify the shape of the weld bevel which is, similarly to ASME VIII in accordance with the WPS.

7.5.3 Conclusion

Neither ASME VIII nor EN 13445 impose a weld joint profile, and both refer to the weld joint specified in the WPS. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.6 Permitted and prohibited weld details.

7.6.1 ASME VIII DIV.1

Welding details and profile requirements are provided throughout PART UW REQUIREMENTS FOR PRESSURE VESSELS FABRICATED BY WELDING. Full penetration welds and in some cases fillet welds and partial penetration welds are permitted.

7.6.2 EN 13445

Weld details are provided in EN 1708, but the responsibility of weld details is left to the manufacturer, taking into consideration the method of manufacture, the potential for corrosion, the ability to carry on the required NDE. EN 13445 Para.9.4.6 requires “sound penetration”.

7.6.3 Conclusion

ASME VIII typically requires full penetration butt welds, but also permits partial penetration welds in certain cases. EN 13445 gives the manufacturer the responsibility to specify weld penetration, and for the weld procedure qualification to verify sound penetration. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.7 Pre-heating.

7.7.1 ASME VIII DIV.1

Pre-heating the base metal before placing a weld has two advantages: (1) removing moisture (water) from the surface and therefore preventing the formation of atomic hydrogen during welding which can be trapped in the metal, and (2) to slow-down the cooling rate of the weld bead for ferritic welds, preventing the formation of a hard and brittle martensitic microstructure.

For example, Nonmandatory Appendix R Preheating requires

- *P-NO. 1 [carbon steel] GROUP NOS. 1, 2, AND 3 (a) 175°F (79°C) for material which has both a specified maximum carbon content in excess of 0.30% and a thickness at the joint in excess of 1 in. (25 mm); (b) 50°F (10°C) for all other materials in this P-Number.*
- *R-7 P-NO. 8 [stainless steel] GROUP NOS. 1 AND 2: None*

7.7.2 EN 13445

EN 13445-4 Para.8.9 addresses preheat, with recommendations in EN 1011-2. Para.8.3 of EN 1011 does not specify a minimum pre-heat temperature, but refers to the WPS. In all cases, the minimum metal temperature prior to welding is +5^{o}C.

7.7.3 Conclusion

ASME VIII is more explicit regarding pre-heating of thick sections of ferritic steels, but both ASME VIII and EN 13445 require pre-heating to be part of the WPS. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.8 Post-Weld Heat Treatment (PWHT)

7.8.1 ASME VIII DIV.1

Table UCS-56-1 provides the PWHT requirements. For example:

- *P-No. 1*[carbon steel] *Gr. Nos. 1, 2, 3 1,100°F (595°C); Up to 2 in. wall 1 hr/in. (25 mm), 15 min minimum ; Over 2 in. wall 2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)*
- P-No. 8 (stainless steel) no PWHT.

7.8.2 EN 13445

EN 13445-4 Table 11.1-1 provides the PWHT requirements, similar to ASME VIII, as a function of the material group and its thickness. The PWHT are tempering treatment, like ASME VIII.

For example, for carbon steel the PWHT temperature is 550°C to 600°C compared to ASME VIII of 595°C.; and for stainless steel PWHT is “generally not applicable” as in ASME VIII.

EN ISO 15609 Para.4.4.15 states *The minimum time and temperature range for post-weld heat treatment or ageing shall be specified or reference shall be made to other standards which specify this information.* Therefore, EN 13445-4 will govern.

7.8.3 Conclusion

The requirement for PWHT and the PWHT temperature is similar in ASME VIII and EN 13445. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.9 Temper bead welding.

7.9.1 ASME VIII DIV.1

UCS-56-Para.(4)(-c) REQUIREMENTS FOR POSTWELD HEAT TREATMENT permits temper bead heat treatment.

7.9.2 EN 13445

Temper bead is not addressed in EN 13445.

7.9.3 Conclusion

Temper bead is not addressed in EN 13445.

Suggestion: If temper bead is applied in post-weld heat treatment of ferritic steel welds of EN 13445 vessels, the temper bead procedure is to be reviewed against ASME VIII UCS-56.

7.10 Backing rings.

7.10.1 ASME VIII DIV.1

Backing strips are addressed for weld joint efficiency factor (Table UW-12), and to permit them in certain configurations (Figure UW-13.2, UHT-18.2).

Appendix 5 flexible shell expansion joints *(c) Nozzles, backing strips, clips, or other attachments shall not be located in highly stressed areas of the expansion joint.*

7.10.2 EN 13445

EN 13445-4 Para.7.3 addresses backing strips. They are permitted if the design is in accordance with EN 13445-3.

7.10.3 Conclusion

Backing strips are permitted under certain conditions in ASME VIII and EN 13445. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.11 Strength of welds.

7.11.1 ASME VIII DIV.1

The strength of welds depends on the type of weld and the extent of NDE. It is addressed in design through the weld joint efficiency factor.

7.11.2 EN 13445

See 6.15.2 which is more restrictive than ASME VIII.

7.11.3 Conclusion

ASME VIII and EN 13445 apply weld joint efficiency factors to reduce the strength of a welded vessel plate. EN 13445-3 is more restrictive.

7.12 Toughness of welds.

7.12.1 ASME VIII DIV.1

UG-84 Charpy Impact Tests (f) Impact Testing of Welds
(1) For steel vessels of welded construction the impact toughness of welds and heat-affected zones of procedure qualification test plates and vessel impact test plates (production impact test plates) shall be determined as required herein …

Toughness is also measured during production welding of the vessel.

Figure UG-84.1M provides minimum toughness values for carbon and low alloy steels, which vary as a function of the yield strength of the metal and its thickness.

7.12.2 EN 13445

EN 13445-4 Table 9.2 addresses impact testing as part of the welding procedure qualification, and refers to EN 13445-2 (materials) for additional requirements.

Toughness is also measured during production welding of the vessel.

- For carbon steel the minimum required toughness (13445-2 Table B.2-13) depends on the material yield strength and varies from 27J (low yield metal) to 40J (high strength metal).
- For stainless steel, with a minimum temperature of -105^{o}C a minimum of 40J toughness at -196^{o}C would be required.

7.12.3 Conclusion

The required minimum toughness values in ASME VIII UG and EN 13445-2 differ. Both Codes require toughness testing on the basis of the material, the thickness, and the minimum operating temperature. The thresholds for toughness tests are expert consensus estimates, so differences are to be expected. The two Codes ASME VIII and EN 13445 have a sound approach to toughness testing. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.13 Brazing and soldering allowances and conditions.

7.13.1 ASME VIII DIV.1

Part UB Requirements for Pressure Vessels Fabricated by Brazing states that brazed vessels shall not be used for services as follows:

(a) lethal services as defined in UW-2(a)

(b) unfired steam boilers [see U-1(g)(1)]

(c) directly fired vessels [see UW-2(d)]

7.13.2 EN 13445

Brazing is addressed in EN 13445-4 Para.8.10.3 with additional examinations by a competent third party.

7.13.3 Conclusion

The competent third-party inspections of EN 13445-4 are an alternative to not permitting brazing in fired applications or lethal service of ASME VIII. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.14 Allowances for weld repairs.

7.14.1 ASME VIII DIV.1

UW-38 REPAIR OF WELD DEFECTS

Defects, such as cracks, pinholes, and incomplete fusion, detected visually or by the hydrostatic or pneumatic test or by the examinations prescribed in UW-11 shall be removed by mechanical means or by thermal gouging processes, after which the joint shall be rewelded [see UW-40(e)].

7.14.2 EN 13445

EN 13445-4 Para.12.2 addresses repairs of weld defects in a manner similar to ASME VIII .

7.14.3 Conclusion

ASME VIII and EN 13445 permit weld repairs during fabrication under similar conditions. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.15 Attachment welds.

7.15.1 ASME VIII DIV.1

UW-15 WELDED CONNECTIONS (b) Strength calculations for nozzle attachment welds for pressure loading are not required for the following …

UW-37 (2) When a multiple number of permanent nonpressure part load bearing attachment welds, nonloadbearing welds such as stud welds, or special welds such as tub-to-tubesheet welds are made on a vessel, the Manufacturer need not identify the welder or welding operator that welded each individual joint provided: …

UW-29 TESTS OF WELDERS AND WELDING OPERATORS (a) The welders and welding operators used in welding pressure parts and in joining load-carrying nonpressure parts (attachments) to pressure parts shall be qualified in accordance with Section IX.

UG-30 addresses attachment welds for stiffening rings.

UW-40 addresses PWHT of attachment welds.

7.15.2 EN 13445

EN13445 Para.8.8 addresses welded attachments and specifies that they have to be welded to a WPS by a qualified welder.

7.15.3 Conclusion

ASME VIII and EN 13445 provide standard attachment weld details, and both Codes require a weld to the pressure boundary to be performed to a qualified welding procedure by a qualified welder. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.16 Bending and forming.

7.16.1 ASME VIII DIV.1

UG-79 FORMING PRESSURE PARTS *(a)* Limits are provided on cold working of all carbon and low alloy steels, nonferrous alloys, high alloy steels, and ferritic steels with tensile properties enhanced by heat treatment [see UCS-79(d), UNF-79(a), UHA-44(a), and UHT-79(a)]. Forming strains or extreme fiber elongation shall be determined by the equations in Table UG-79-1.

UCS-79 (d) Except as addressed in (e) and for materials exempted below, the cold-formed areas of vessel shell sections, heads, and other pressure parts shall be heat treated if the resulting extreme fiber elongation determined in accordance with Table UG-79-1 exceeds 5% from the supplied condition …

7.16.2 EN 13445

EN 13445-4 provides postforming heat treatment as a function of the material and the 5% forming strains, similar to ASME VIII.

7.16.3 Conclusion

ASME VIII and EN 13445 permit bending and forming, with strain-dependent post-bending heat treatment. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.17 Fabrication tolerances.

7.17.1 ASME VIII DIV.1

U-5 TOLERANCES

The Code does not fully address tolerances. When dimensions, sizes, or other parameters are not specified with tolerances, the values of these parameters are considered nominal, and allowable tolerances or local variances may be considered acceptable when based on engineering judgment and standard practices as determined by the designer.

7.17.2 EN 13445

EN 13445-4 Para.6 addresses manufacturing tolerances for weld alignment, diameter ovality, longitudinal axis, local thinning, etc.

EN 13445-4 Annex A provides dimensional tolerances.

7.17.3 Conclusion

EN 13445-4 is more prescriptive than ASME VIII .

7.18 Bolted Flange.

7.18.1 ASME VIII DIV.1

Permitted either as a standard pipe flange (ASME B16.5) or custom flange designed to Appendices 2 and S.

7.18.2 EN 13445

EN 13445-3 Para.11 addresses the design of flanges used in pressure vessels.

7.18.3 Conclusion

ASME VIII and EN 13445 permit the use of standard bolted pipe flanges or custom-designed flanges. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.19 Expansion joints.

7.19.1 ASME VIII DIV.1

Expanded joints are permitted in Table UW-20.1.

7.19.2 EN 13445

EN 13445-3 Para.14 permits expansion bellows and provides the design requirements.

7.19.3 Conclusion

Expansion joints are permitted in ASME VIII and EN 13445. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.20 Traceability of materials.

7.20.1 ASME VIII DIV.1

UG-93 (-b) The handling and storage of the material by the vessel Manufacturer shall be documented in his Quality Control System such that the Inspector can determine

that it is the material identified in (-a) above. Traceability to specific lot, order, or heat is not required. Traceability is required only to material specification and grade and type and class, if applicable.

MANDATORY APPENDIX 10
QUALITY CONTROL SYSTEM

10-6 MATERIAL CONTROL
The Manufacturer or Assembler shall include a system of receiving control which will ensure that the material received is properly identified and has documentation including required Certificates of Compliance or Material Test Reports to satisfy Code requirements as ordered. The required Certificates of Compliance or Material Test Reports may be electronically transmitted from the material manufacturer or supplier to the Certificate Holder. The material control system shall ensure that only the intended material is used in Code construction.

7.20.2 EN 13445
EN 13445-2 Para.4.4 requires markings to provide traceability between the product and the inspection documents, with minimum markings specified.

7.20.3 Conclusion
EN 13445 and ASME VIII require material traceability from material receipt through fabrication. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

7.21 Cleaning.
7.21.1 ASME VIII DIV.1
UW-32 CLEANING OF SURFACES TO BE WELDED
(a) The surfaces to be welded shall be clean and free of scale, rust, oil, grease, slag, detrimental oxides, and other deleterious foreign material. The method and extent of cleaning should be determined based on the material to be welded and the contaminants to be removed. When weld metal is to be deposited over a previously welded surface, all slag shall be removed by a roughing tool, chisel, chipping hammer, or other suitable means so as to prevent inclusion of impurities in the weld metal.

7.21.2 EN 13445
EN 13445-4 Para.8.6 addresses cleanliness in joint preparation for welding.

EN 13445-4 Para.13 requires cleaning as part of the finishing operations.

7.21.3 Conclusion

ASME VIII and EN 13445 address cleaning of the weld joint bevel. Neither Code addresses cleaning the completed vessel. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

8 Examination

The key attributes for examination are:

8.1 Qualifications of NDE personnel.

8.1.1 ASME VIII DIV.1

UW-54 QUALIFICATION OF NONDESTRUCTIVE EXAMINATION PERSONNEL
Personnel performing nondestructive examinations in accordance with UW-51, UW-52, or UW-53 shall be qualified and certified in accordance with the requirements of Section V, Article 1, T-120(e), T-120(f), T-120(g), T-120(i), T-120(j), or T-120(k), as applicable.

8.1.2 EN 13445

EN 1344-5 Para.6.6.3.7 and (by reference) EN ISO 9712 address qualification and certification of NDT personnel as Levels 1, 2, or 3, similar to ASME Section V.

8.1.3 Conclusion

ASME VIII and EN 13445 require certification of personnel performing NDE. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

8.2 Extent and percent of examinations of welds.

8.2.1 ASME VIII DIV.1

UW-11 RADIOGRAPHIC AND ULTRASONIC EXAMINATION
UW-11 (a) Full Radiography. The following welded joints shall be examined radiographically for their full length in the manner prescribed in UW-51:
(1) all butt welds in the shell and heads of vessels used to contain lethal substances [see UW-2(a)];
(2) all butt welds in the shell and heads of vessels in which the nominal thickness [see (g) below] at the welded joint exceeds 1 1/2 in. (38 mm), or exceeds the lesser thicknesses prescribed in UCS-57, UNF-57, UHA-33, UCL-35, or UCL-36 for the materials covered therein, or as otherwise prescribed in UHT-57, ULW-51, ULW-52(d), ULW-54, or ULT-57;
(3) all butt welds in the shell and heads of unfired steam boilers having design pressures …
(4) all butt welds in nozzles, communicating chambers, etc., with the nominal thickness at the welded joint that exceeds the thickness …
(5) all Category A and D butt welds in the shell and heads of vessels where the design of the joint or part is based on a joint efficiency permitted by UW-12(a), in which case:
(-a) Category A and B welds connecting the shell

or heads of vessels shall be of Type No. (1) or Type No. (2) of Table UW-12;
(-b) Category B or C butt welds [but not including those in nozzles and communicating chambers except as required in (4) above] which intersect the Category A butt welds in the shell or heads of vessels or connect seamless vessel shell or heads shall, as a minimum, meet the requirements for spot radiography in accordance with UW-52. Spot radiographs required by this paragraph shall not be used to satisfy the spot radiography rules as applied to any other weld increment.
(6) all butt welds joined by electrogas welding …
(7) all Category A welds in a tubesheet shall be of Type (1) of Table UW-12;
(8) exemptions from radiographic examination for certain welds in nozzles …

UW-11 (b) Spot Radiography. Except when spot radiography is required for Category B or C butt welds by (a)(5)(-b) above, butt-welded joints made in accordance with Type No. (1) or (2) of Table UW-12 which are not required to be fully radiographed by (a) above, may be examined by spot radiography. Spot radiography shall be in accordance with UW-52. If spot radiography is specified for the entire vessel, radiographic examination is not required of Category B and C butt welds in nozzles and communicating chambers that exceed neither NPS 10 (DN 250) nor 1 1/8 in. (29 mm) wall thickness.
NOTE: This requirement specifies spot radiography for butt welds of Type No. (1) or No. (2) that are used in a vessel, but does not preclude the use of fillet and/or corner welds permitted by other paragraphs, such as for nozzle and manhole attachments, welded stays, flat heads, etc., which need not be spot radiographed.

UW-52 (b) Minimum Extent of Spot Radiographic Examination
(1) One spot shall be examined on each vessel for each 50 ft (15 m) increment of weld …

UW-11 (c) No Radiography. Except as required in (a) above, no radiographic examination of welded joints is required when the vessel or vessel part is designed for external pressure only, or when the joint design complies with UW-12(c).
UW-12(c) A value of E not greater than that given in column (c) of Table UW-12 shall be used in the design calculations for welded joints that are neither fully radiographed nor spot radiographed [see UW-11(c)].

UW-53 ULTRASONIC EXAMINATION OF WELDED JOINTS
(a) Ultrasonic examination of welded joints whose joint efficiency is not determined by ultrasonic examinations may be performed and evaluated in accordance with Mandatory Appendix 12.

8.2.2 EN 13445

EN 13445-5 Para.6 addresses the extent of NDE of welds, as a function of testing group, the type of weld, and the assigned joint coefficient. Butt welds are RT or UT, supplemented by PT or MT to some extent. Fillet welds and cladding are MT or PT.

8.2.3 Conclusion

For certain welds EN 13445-5 requires PT or MT in addition to UT or RT, which is more restrictive than ASME VIII.

8.3 Method of examination of welds and acceptance criteria.

8.3.1 ASME VIII DIV.1

UW-11 requires radiographic examination, and for certain welding process (electron beam, bond of integral cladding, etc.) ultrasonic examination.

UW-51 (4) As an alternative to the radiographic examination requirements above, all welds in which the thinner of the members joined is 1/4 in. (6 mm) thick and greater may be examined using the ultrasonic (UT) method specified by UW-53(b) or UW-53(c).

UW-53 ULTRASONIC EXAMINATION OF WELDED JOINTS
UG-103 NONDESTRUCTIVE TESTING
Where magnetic particle examination is prescribed in this Division it shall be done in accordance with Mandatory Appendix 6. Where liquid penetrant examination is prescribed it shall be done in accordance with Mandatory Appendix 8.

UW-42 SURFACE WELD METAL BUILDUP

(1) All weld metal buildup shall be examined over the full surface of the deposit by either magnetic particle examination to the requirements of Mandatory Appendix 6, or by liquid penetrant examination to the requirements of Mandatory Appendix 8.

UCS-56 (3) After removal of the defect, the groove shall be examined, using either the magnetic particle or the liquid penetrant examination methods, in accordance with Mandatory Appendix 6 for MT and Mandatory Appendix 8 for PT.

UCS-68 (-a) fillet welds having leg dimensions not exceeding 3/8 in. (10 mm) attaching lightly loaded attachments,
…
(-b) seal welds.
All such welds as described in (-a) and (-b) shall be examined by magnetic particle or liquid penetrant examination in accordance with Mandatory Appendix 6 or Mandatory Appendix 8.

UNF (non-ferrous) UNF-58 LIQUID PENETRANT EXAMINATION
(a) All welds, both groove and fillet, in vessels constructed of materials covered by UNS N06625 (for Grade 2 only in SB-443, SB-444, and SB-446), UNS N10001, and UNS N10665 shall be examined for the detection of cracks by the liquid penetrant method

8.3.2 EN 13445
EN 13445-5 does not differentiate between volumetric methods (UT or RT).

8.3.3 Conclusion
While ASME VIII relies on RT it also permits UT while EN 13445 does not differentiate between volumetric methods (RT or UT) for the inspection of welds. In both cases the NDE technique is calibrated to detect the flaws that it is examining. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

8.4 Graded approach to examination based on consequence of failure.
8.4.1 ASME VIII DIV.1
See 8.2 for full, spot, and no RT.

UW-11 RADIOGRAPHIC AND ULTRASONIC EXAMINATION
(a) Full Radiography. The following welded joints shall be examined radiographically for their full length in the manner prescribed in UW-51:
(1) all [100%] *butt welds in the shell and heads of vessels used to contain lethal substances [see UW-2(a)]; etc.*

The weld joint efficiency factor used in design reflects the extent of NDE.

8.4.2 EN 13445
EN 13445-5 Para.6.6 determines the extent of weld NDE for each of four testing groups, with testing group 1 (the highest) at 100% RT or UT and 10% MT or PT; and testing group 4 (the lowest) visual only.

The weld joint efficiency factor used in design reflects the extent of NDE.

8.4.3 Conclusion

A graded approach to % of NDE and method of NDE applies in ASME VIII and EN 13445. In both cases the weld joint efficiency factor used in design reflects the extent of NDE. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

8.5 Allowance for in-process examination.

8.5.1 ASME VIII DIV.1

In-process examination (visual check of every step of the welding preparation and welding process in place of NDE) is not addressed in VIII Div.1.

8.5.2 EN 13445

In-process examination is not addressed in EN 13445-5.

8.5.3 Conclusion

In-process examination is not addressed in ASME VIII or EN 13445. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

8.6 Weld acceptance criteria

8.6.1 ASME VIII DIV.1

UW-51 (b) Indications revealed by radiography within a weld that exceed the following criteria are unacceptable and therefore are defects. Defects shall be repaired as provided in UW-38, and the repaired area shall be reexamined. In lieu of reexamination by radiography, the repaired weld may be ultrasonically examined in accordance with Mandatory Appendix 12 at the Manufacturer's option. For material thicknesses in excess of 1 in. (25 mm), the concurrence of the user shall be obtained. This ultrasonic examination shall be noted under Remarks on the Manufacturer's Data Report Form:
(1) any indication characterized as a crack or zone of incomplete fusion or penetration;

(2) any other elongated indication on the radiograph which has length greater than:
(-a) 1/4 in. (6 mm) for t up to 3/4 in. (19 mm)
(-b) 1/3t for t from 3/4 in. (19 mm) to 2.1/4 in. (57 mm)
(-c) 3/4 in. (19 mm) for t over 2.1/4 in. (57 mm)

(3) any group of aligned indications that have an aggregate length greater than t in a length of 12t, except when the distance between the successive imperfections exceeds 6L where L is the length of the longest imperfection in the group;

(4) rounded indications in excess of that specified by the acceptance standards given in Mandatory Appendix 4.

8.6.2 EN 13445

In EN13445-5 Para.6.6.4 refers to EN ISO 17635 Annex A for acceptance levels for the NDE of welds. EN ISO 17635 Annex A refers to ISO 10675-1 and ISO 10675-2 for acceptance levels as a function of (a) the

type of NDE (VT, PT, MT, ET, RT film, RT digital, UT, UT TOFD, and UT PAUT); and (b) the Quality Level (B, C, or D).

The list of indications with acceptance/rejection criteria in ISO 10675-1 (steel, stainless, steel, Ni alloys) is more comprehensive than ASME VIII, and includes: cracks; porosity and gas pores; elongated cavities; crater pipe; slag inclusions, flux inclusions, and oxide inclusions; metallic inclusions; copper inclusions; lack of fusion; lack of penetration; crater cracks; undercut, continuous and intermittent; shrinkage groove; excess penetration; stray arc; spatter; root concavity; poor restart; incompletely filled groove, sagging; linear misalignment. The acceptance levels are subdivided into three acceptance levels (1 (highest), 2, 3 (lowest)).

8.6.3 Conclusion
EN 13445 is more comprehensive than ASME VIII in regard to the weld indications to be evaluated, and provides a graded approach to the acceptance/rejection criteria.

8.7 Progressive examinations
8.7.1 ASME VIII Div.1
UW-38 REPAIR OF WELD DEFECTS - Defects, such as cracks, pinholes, and incomplete fusion, detected visually or by the hydrostatic or pneumatic test or by the examinations prescribed in UW-11 shall be removed by mechanical means or by thermal gouging processes, after which the joint shall be rewelded [see UW-40(e)].

8.7.2 EN 13445
EN 13445-5 Para.6.6.6 if a defect is found, two further random samples are selected. If one of the two welds is defective, then 100% of the welds must be examined.

8.7.3 Conclusion
EN 13445 is more explicit regarding progressive NDE when flaws are identified.

8.8 Extent and percent of examinations of mechanical joints
8.8.1 ASME VIII DIV.1
INSPECTION AND TESTS UG-90 (1) The Inspector shall make all inspections specifically required of him plus such other inspections as he believes are necessary to enable him to certify that all vessels which he authorizes to be stamped with the Certification Mark have been designed and constructed in accordance with the requirements of this Division … (-k) making a visual inspection of the vessel to confirm that there are no material or dimensional defects (see UG-95, UG-96, and UG-97).

The examination of mechanical joints (bolted flange joints, swaged joints, clamped joints, etc.) is not addressed in ASME VIII.

8.8.2 EN 13445
The examination of mechanical joints (bolted flange joints, swaged joints, clamped joints, etc.) is not addressed in EN 13445.

8.8.3 Conclusion
ASME VIII and EN 13445 are silent in regard to the quality control of the assembly of mechanical joints.

The owner-user of ASME VIII or EN 13445 pressure vessels must have a procedure and quality controls in place to assemble or re-assemble mechanical joints (non-welded joints such as bolted, swaged, or clamped joints) within a pressure vessel or between the pressure vessel and the connected piping and tubing systems. The two Codes, ASME VIII and EN 13445 are equivalent regarding their lack of guidance on the assembly of mechanical joints.

9 Testing

The key attributes for testing are:

9.1 Pressure testing requirements.

9.1.1 ASME VIII DIV.1

UG-20 (f)(2) The completed vessel shall be hydrostatically tested per UG-99(b) or UG-99(c) or 27-4. Alternatively, the completed vessel may be pneumatically tested in accordance with 35-6.

UG-90 the manufacturer is responsible for:

(16) making the required hydrostatic or pneumatic test and having the required inspection performed during such test (see UG-99, UG-100, UG-101, and UW-50); …

The requirements for hydrostatic testing are addressed in UG-99 and for pneumatic testing in UG-100.

9.1.2 EN 13445

EN 13445-5 Para.10.2.3 calls the hydrotest the “the standard proof test”. Pneumatic testing is permitted under certain conditions.

EN 13445 permits a statistical test for serially produced vessels, under several conditions.

9.1.3 Conclusion

ASME VIII and EN 13445 require a pressure or pneumatic test be conducted on the completed vessel. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

9.2 Test method, duration, pressure, procedure.

9.2.1 ASME VIII DIV.1

UG-99 The hydrotest pressure is $1.3 \times MAWP \times (S_{amb}/S_{hot})$

(g) Following the application of the hydrostatic test pressure, an inspection shall be made of all joints and connections. This inspection shall be made at a pressure not less than the test pressure divided by 1.3. Except for leakage that might occur at temporary test closures for those openings intended for welded connections, leakage is not allowed at the time of the required visual inspection. Leakage from temporary seals shall be directed away so as to avoid masking leaks from other joints.

UG-100 The **pneumatic** test pressure is $1.1 \times MAWP \times (S_{amb}/S_{hot})$.

The visual inspection of the vessel at the required test pressure divided by 1.1 may be waived, provided:
*(1) a suitable **gas leak test** is applied;*

(2) substitution of the gas leak test is by agreement reached between Manufacturer and Inspector;

Test duration is not stated, but all joints must be inspected for leakage.

9.2.2 EN 13445

The hydrotest pressure Para.10.2.3.3 is $1.25 \times P_{design} \times (S_{amb}/S_{hot})$ or 1.45 P, whichever is larger. For Group 4 vessels the hydrostatic test pressure is larger (EN 13445-5 Para.10.2.3.3.2).

The pneumatic testing pressure Para.10.2.4.3.4 is $1.1 \times P_{design} \times (S_{amb}/S_{hot})$ or 1.45 P whichever is larger.

Test duration is not stated, but all joints must be inspected for leakage.

9.2.3 Conclusion

EN 13445-5 test pressures are higher than ASME VIII.

9.3 Acceptance criteria for pressure test.

9.3.1 ASME VIII DIV.1

UG-99 No leaks are permitted during a hydrotest.

Not explicitly stated in UG-100 pneumatic testing.

9.3.2 EN 13445

EN 13445-5 acceptance criteria is that no “leaks are permitted” and no plastic yielding.

9.3.3 Conclusion

The pressure test criterion of “no leaks” is the same for ASME VIII and EN 13445. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

9.4 Externally pressured components.

9.4.1 ASME VIII DIV.1

UG-99 (f) Single-wall vessels and individual pressure chambers of combination units designed for vacuum only (MAWP less than or equal to zero) shall be subjected to either
(1) an internal hydrostatic pressure test in accordance with UG-99, or a pneumatic pressure test in accordance with UG-100. The applied test pressure shall be not less than 1.3 times the specified external design pressure; or
(2) a vacuum test conducted at the lowest value of specified absolute internal design pressure. In conjunction with the vacuum test, a leak test shall be performed following a written procedure complying with the applicable technical requirements of Section V, Article 10 for the leak test method and technique specified by the user. Leak testing personnel shall be qualified and certified as required by Section V, Article 1, T-120(e).

9.4.2 EN 13445

EN 13445-5 the test pressure must be 1.25 times the external pressure.

9.4.3 Conclusion

The difference in test pressure for negative pressure vessels (1.30 vs. 1.25) is small and does not affect the safe performance of the vessel. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

9.5 Sensitive leak testing allowance.

9.5.1 ASME VIII DIV.1

See 9.2.1, ASME VIII UG-99(f)(2) permits a leak test for negative pressure vessels. A gas leak test is permitted as an alternative to the hydrotest by agreement between the manufacturer and the Authorized Inspector UG-99(g)(2).

9.5.2 EN 13445

In Para.10.2.3.7 the leak test is only permitted to be carried out before the pressure tests.

9.5.3 Conclusion

EN 13445-5 permits a leak test only prior to a hydrotest, and not as an alternative to the hydrotest, and is therefore stricter than ASME VIII which permits a leak test as an alternative to a hydrotest.

9.6 Allowance to repair leaks.

9.6.1 ASME VIII DIV.1

UG-99 Except for leakage that might occur at temporary test closures for those openings intended for welded connections, leakage is not allowed at the time of the required visual inspection.

9.6.2 EN 13445

Not addressed in EN 13445-5.

9.6.3 Conclusion

Both Codes are silent regarding stoppage of the leak of the vessel itself. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

9.7 In-shop testing, subassembly testing, and installed testing.

9.7.1 ASME VIII DIV.1

The test may be a shop test or an installed field test, prior to U stamping.

UG-99 (a) A hydrostatic test shall be conducted on all vessels after
(1) all fabrication has been completed, except for operations that could not be performed prior to the test, such as weld end preparation [see U-1(e)(1)(-a)], and cosmetic grinding on the base material that does not reduce the actual thickness below the design thickness; and
(2) all examinations have been performed, except those required after the test.

9.7.2 EN 13445

EN 13445-5- Para.10.2.3.2.2 proof testing must be performed “after all fabrication has been completed”.

9.7.3 Conclusion

In ASME VIII and EN 13445 the pressure test is required after all fabrication has been completed. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

9.8 Testing of jacketed vessels and piping.

9.8.1 ASME VIII DIV.1

MANDATORY APPENDIX 9
JACKETED VESSELS refers to UG-19 and Appendix 9 for inspection.

UG-100 (2) Dependent Pressure Chambers. When pressure chambers of combination units have their common elements designed for the maximum differential pressure that can possibly occur during startup, operation, and shutdown, and the differential pressure is less than the higher pressure in the adjacent chambers, the common elements shall be subjected to a hydrostatic test pressure of at least 1.3 times the differential pressure to be marked on the unit times the LSR as in (b) above for the common elements.

9.8.2 EN 13445

EN 13445-5- Para.10.2.3.2.2 jackets must be proof tested at 1.25 the design pressure.

9.8.3 Conclusion

The difference in test pressure for negative pressure vessels (1.30 vs. 1.25) is small and does not affect the safe performance of the vessel. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

9.9 Responsibility for functional testing.

9.9.1 ASME VIII DIV.1

Functional testing is the chemical and thermohydraulic testing of a pressure vessel to verify that it achieves its desired process and heat transfer functions. Functional testing is not addressed in ASME VIII.

9.9.2 EN 13445

Functional design and adequacy not addressed in EN 13445.

9.9.3 Conclusion

Neither ASME VIII nor EN 13445 address functional testing and functional performance. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

9.10 Cleaning, drying, isolating, storing after testing.

9.10.1 ASME VIII DIV.1

Cleaning, drying, isolating, storing after testing is not addressed in ASME VIII.

9.10.2 EN 13445

Cleaning, drying, isolating, storing after testing is not addressed in EN 13445.

9.10.3 Conclusion

Neither ASME VIII nor EN 13445 address cleaning, storing after testing. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

10 Over-Pressure Protection

The key attributes of over-pressure protection are:

10.1 Over-pressure by relief devices or system design.

10.1.1 ASME VIII DIV.1

OVERPRESSURE PROTECTION
In the 2021 Edition of Division 1, pressure relief device requirements were transferred from UG-125 through UG-140 to Section XIII, and the remaining Division 1 overpressure protection requirements were restructured within UG-150 through UG-156.

For information: ASME XIII 1.2 ORGANIZATION
(a) This Section is divided into 13 Parts.
(1) Part 1 contains the scope and general requirements of this Section.
(2) Part 2 contains the responsibilities for providing overpressure protection.
(3) Part 3 contains requirements for the design, materials, inspection, testing, welding, and marking of pressure relief valves.
(4) Part 4 contains requirements for the design, materials, inspection, testing, welding, and marking of rupture disk devices.
(5) Part 5 contains requirements for the design, materials, inspection, testing, welding, and marking of pin devices.
(6) Part 6 contains requirements for the design, materials, inspection, testing, welding, and marking of spring-actuated non-reclosing devices.
(7) Part 7 contains requirements for the design, materials, inspection, testing, welding, and marking of temperature and pressure relief valves.
(8) Part 8 contains requirements for the use and marking of devices in combination.
(9) Part 9 contains requirements for capacity and flow resistance certification certification of pressure relief devices.
(10) Part 10 contains requirements concerning the use of the Certification Mark.
(11) Part 11 contains requirements for open flow paths and vents.
(12) Part 12 contains requirements and guidelines for the installation of pressure relief devices; these requirements and guidelines address only the variables that affect the performance and pressure-relieving function

of the devices.
(13) Part 13 contains requirements for overpressure protection by system design.)

UG-151 RESPONSIBILITIES
(a) It is the user's or his designated agent's responsibility to determine the required relief rate, to size and select the device, and to design the relief system.

UG-152 DETERMINATION OF PRESSURE RELIEVING REQUIREMENTS
(a) It is the user's or his/her designated agent's responsibility to identify all potential overpressure scenarios and the method of overpressure protection used to mitigate each scenario.
(b) The aggregate capacity of the pressure relief devices connected to any vessel or system of vessels for the release of a liquid, air, steam, or other vapor shall be sufficient to carry off the maximum quantity that can be generated or supplied to the attached equipment without permitting a rise in pressure within the vessel of more than that specified in UG-153.
…
(e) Overpressure Protection by System Design
Overpressure protection by system design in accordance with Section XIII, Part 13 is permitted.
(1) For vessels with overpressure protection by system design where the pressure is self-limited at or below the vessel MAWP, (see Section XIII, 13.2), there shall be no credible overpressure scenario in which the pressure exceeds the maximum allowable working pressure (MAWP) of the pressurized equipment at the coincident temperature.
(2) For vessels with overpressure protection by system design where the pressure is not self-limited at or below the vessel MAWP, (see Section XIII, 13.3), there shall be no credible overpressure scenario in which the pressure exceeds 116% of the MAWP times the ratio of the allowable stress value at the temperature of the overpressure scenario to the allowable stress value at the vessel design temperature. The overpressure limit shall not exceed the vessel test pressure.

Therefore, ASME VIII permits over-pressure protection by relief devices or by system design.

10.1.2 EN 13445

PED (2014) 2.10*. Protection against exceeding the allowable limits of pressure equipment*

Where, under reasonably foreseeable conditions, the allowable limits could be exceeded, the pressure equipment shall be fitted with, or provision made for the fitting of, suitable protective devices, unless the equipment is intended to be protected by other protective devices within an assembly.

The suitable device or combination of such devices shall be determined on the basis of the particular characteristics of the equipment or assembly.

Suitable protective devices and combinations thereof ***comprise****:*

(a) safety accessories as defined in point 4 of Article 2,

(b) where appropriate, adequate monitoring devices such as indicators and/or alarms which enable adequate action to be taken either automatically or manually to keep the pressure equipment within the allowable limits.

Therefore, the PED (and EN 13445) permits over-pressure protection by relief devices or by system design.

EN 4126-9 addresses the credibility of over-pressure scenarios. In Para. 5.1.3 , under reasonably foreseeable service conditions, the internal pressure can exceed the maximum allowable pressure, the pressure equipment shall be protected by means of at least one safety device of adequate capacity and capability.

10.1.3 Conclusion

ASME VIII and EN 13445 (PED) permit over-pressure protection by relief devices or by system design (interlocks, alarms, etc.). Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

10.2 Use of certified relief devices.

10.2.1 ASME VIII DIV.1

UG-154 PERMITTED PRESSURE RELIEF DEVICES AND METHODS
(a) Pressure Relief Valves
(1) Pressure relief valves bearing the ASME Certification Mark with the UV Designator in accordance with Section XIII may be used. Pressure relief valves shall be of the direct spring-loaded or pilot-operated type.
(2) Pressure relief valves certified for a steam discharging capacity under the provisions of Section I and bearing the ASME Certification Mark with the ***V Designator*** *for safety valves may be used on pressure vessels constructed to this Division. The rated capacity in terms of other fluids shall be determined by the method of conversion given in Section XIII, Mandatory Appendix IV. (See Section XIII, 9.2.3.)*
(b) Nonreclosing Pressure Relief Devices
(1) Rupture disks bearing the ASME Certification Mark with the UD Designator in accordance with Section XIII may be used as the sole pressure-relieving device for overpressure protection.

Non-reclosing relief devices are also addressed in ASME B&PV Code Section XIII, Parts 6 and 9.

Relief devices (relief valves, safety valves, and rupture discs) must have the ASME designator to be applied to an ASME VIII pressure vessel. The National Board has been designated by the ASME to provide the oversight to the certification process of pressure relief devices. The National Board's NB-18 document lists the manufacturers and their assemblers that are certified to provide new pressure relief devices per the ASME Code.

10.2.2 EN 13445

The ISO standard for pressure relief devices is ISO EN 4126, as specified in the "COMMISSION IMPLEMENTING DECISION (EU) 2019/1616 of 27 September 2019 on the harmonised standards for pressure equipment drafted in support of Directive 2014/68/EU of the European Parliament and of the Council". ISO EN 4126 comprises the following parts:

- ISO EN 4126-1 - Safety Valves (Spring Loaded)
- ISO EN 4126-2 - Bursting Disc Safety Devices
- ISO EN 4126-3 - Safety Valves and Bursting Disc Safety Devices in Combination
- ISO EN 4126-4 - Pilot Operated Safety Valves
- ISO EN 4126-5 - Controlled Safety Pressure Relief Systems (CSPRS)
- ISO EN 4126-6 - Application, Selection and Installation of Bursting Disc Safety Devices
- ISO EN 4126-7 - Common Data
- ISO EN 4126-9 - Application and Installation of Safety Devices Excluding Stand-Alone Bursting Discs
- ISO EN 4126-10 - Sizing of Safety Valves for Gas/Liquid Two-Phase Flow

The ISO capacity certification tests are similar to ASME for steam, gas and water. The coefficient of discharge method is used to compare tested flows at 10% or 1.45 psi (0.1 bar) overpressure, whichever is greater, to that of an ideal nozzle. There are multiple tests, anywhere from 4 tests to 9 tests as a minimum, and the ratio from each test must fall within plus or minus 5% of the average. These tests can be performed for a specific valve size or valve design family. Once a coefficient of discharge is established by test, the rated coefficient is reduced by 10% as it is with ASME.

The certification of equipment in compliance with the PED is through notified bodies, which are approved to carry out these certifications by the European authorities. Most of the pressure safety devices will have to be certified for the highest level, level IV, except for pressure safety devices that are designed solely for equipment that is itself is in a lower category.

A relief device that is certified in compliance with the PED will have to bear the "CE" (Conformité Européenne or European Conformity) mark on its nameplate.

The EN 4126 standards give one way, amongst many, to comply with some of the requirements of the PED. As long as the standards or codes used, such as ASME Section VIII, meet all the requirements of the PED to the satisfaction of the Notified Body, then valves can be supplied with a CE mark.

EN 4126-2 does not address bursting disc (rupture disc) set pressure tolerances. The owner-user must verify equivalency between ASME VIII/XIII and EN for the sizing and set pressure tolerance of rupture discs.

10.2.3 Conclusion

ASME VIII and EN 13445 (the PED) have a strict procedure to certify relief devices by a third party. Therefore, ASME VIII and EN 13445 are equivalent for this attribute. However, EN 4126-2 does not address bursting disc (rupture disc) set pressure tolerances.

Suggestion: The owner-user must verify the equivalency of sizing and set points of EN 13445 vessel rupture discs against ASME VIII/XIII.

10.3 Placement of Relief Device

10.3.1 ASME VIII DIV.1

UG-156 INSTALLATION
*(a) Pressure relief devices shall be constructed, located, and installed so that they are readily **accessible** for testing, inspection, replacement, and repair and so that they cannot be readily rendered **inoperative** (see Nonmandatory Appendix M).*
*(b) The pressure relief devices required in UG-150(b) and UG-150(c) need not be installed **directly** on a pressure vessel when either of the following conditions apply:*
(1) The source of pressure is external to the vessel and is under such positive control that the pressure in the vessel cannot exceed the maximum allowable working pressure at the operating temperature except as permitted in UG-153(a) (see UG-98), or under the conditions set forth in Nonmandatory Appendix M
*(2) There are **no intervening stop valves** between the vessel and the pressure relief device or devices, except as permitted under (g) …*

10.3.2 EN 13445

EN 4126-9 Para.8.2 *Installation of safety valves or the main valve of a CSPRS or a POSV; Para.8.2.1 General, Sufficient access and workspace, including height, shall be provided for the servicing and removal of safety devices.*

EN 4126-9 Para.8.2.2 *Location. If a vessel contains both liquid and gas/vapour, and gas/vapour is to be relieved, a safety device for use with gases shall be connected to the vessel in the gas space, or piping connected to this space, and located in a position chosen to minimize the entrainment of liquid when the valve discharges. Alternatively, if there is liquid to be relieved, a safety device for use with liquid shall be connected to the vessel or piping below the liquid level at a point chosen to prevent ingress of gas/vapour. If either phase is to be relieved, a safety device suitable for either phase should be installed.*

EN 4126-9 Para.6.1 *The inlet line shall be as short as practical in order to avoid the negative influence of dynamic effects and pressure losses.*

EN 4126-9 Para.8.4.2 *Isolation of safety device(s) from the equipment to be protected. Isolation of safety device(s) from the equipment to be protected is permitted if the source of pressure, which could lead to an unsafe condition, is simultaneously isolated from the equipment to be protected. Safety devices*

undergoing maintenance should be from operating equipment. Operating equipment should continue to be fully protected against potential sources of overpressure.

10.3.3 Conclusion

ASME VIII and EN 4126 address the placement of the relief device on the vessel in the same manner. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

10.4 Certification of the relief device.

10.4.1 ASME VIII DIV.1

ASME XIII Part 9 contains requirements for capacity and flow resistance certification certification of pressure relief devices.

In the US, ASME has designated the National Board as responsible to oversee the capacity certification of safety-relief valves. Capacity certification is achieved by rigorous testing of the valves, as specified in ASME performance test code PTC-25.

The NB mark signifies that a pressure relief device has been certified by the National Board. The NB mark is used jointly with ASME stamps to assure that pressure relief devices have gone through design review, rating factor testing, and production sample testing. Following the successful completion of a quality system review, organizations may become accredited to apply this mark to pressure relief devices.

10.4.2 EN 13445

The PED2014/68/EU requires pressure relief valves destined for Europe have a CE mark indicating that the valve meets all aspects of the respective directive. According to the PED Para.2.4 the relief valve is a safety accessory and is to be certified as Category IV (highest), with some exceptions.

10.4.3 Conclusion

ASME VIII and EN 13445 (the PED) require safety-relief valves to be certified by test andverified by a third party (National Board in the case of ASME, the Notified Body in the case of the PED). Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

10.5 Hydraulic sizing of the relief device.

10.5.1 ASME VIII DIV.1

The formulas for the sizing of safety (gas) and relief (liquid) valves are specified in ASME VIII (UG-125 through 140) and ASME XIII. In the US it is common practice to supplement the ASME VIII and XIII sizing formulas with the following references:

- API 520 Sizing, “Selection, and Installation of Pressure-relieving Devices Part I - Sizing and Selection”; API 521 “Pressure-relieving and Depressuring Systems”
- CGA (compressed gas association) CGA S-1.1 “Pressure Relief Device Standards-Part 1-Cylinders for Compressed Gases”; CGA S-1.2 “Pressure Relief Device Standards-Part 2-Portable Containers for Compressed Gases”; CGA S-1.3 “Pressure Relief Device Standards-Part 3-Stationary Storage Containers for Compressed Gases”.
- AIChE American Institute of Chemical Engineers “Guidelines for Pressure Relief and Effluent Handling Systems” by the Center for Chemical Process Safety of AIChE.

10.5.2 EN 13445

Valve sizing formulas are provided in

- EN 4126-7 Common data
- EN 13648 Cryogenic vessels - Safety devices for protection against excessive pressure - Part 1: Safety valves for cryogenic service

10.5.3 Conclusion

ASME VIII and EN 13445 rely on the designer to select and size relief devices for each application. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

10.6 Allowance for non-reclosing relief device.

10.6.1 ASME VIII DIV.1

UG-154 PERMITTED PRESSURE RELIEF DEVICES
AND METHODS
(b) Nonreclosing Pressure Relief Devices
(1) Rupture disks bearing the ASME Certification
Mark with the UD Designator in accordance with Section
XIII may be used as the sole pressure-relieving device for
overpressure protection.

10.6.2 EN 13445

EN 4126-2 Bursting Disc Safety Devices addresses the use of rupture discs.

10.6.3 Conclusion

ASME VIII and EN 13445 (through EN 4126-2) permit the use of rupture discs for over-pressure protection, with the cautions associated with non-reclosing discharge. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

11 Inspections and Certifications

The key attributes of inspections and certifications are:

11.1 Requirement for formal quality control and quality assurance programs.

11.1.1 ASME VIII DIV.1

MANDATORY APPENDIX 10 QUALITY CONTROL SYSTEM
10-1 GENERAL
The Manufacturer or Assembler shall have and maintain a quality control system which will establish that all Code requirements, including material, design, fabrication, examination (by the Manufacturer or Assembler), and for vessels and vessel parts, inspection (by the Authorized Inspector), will be met.

11.1.2 EN 13445

As explained in CR 13445-7 report "Guidance on the use of the conformity procedures", the manufacturer has the choice of applying their own approved Quality Assurance program (ISO 9001), or submit to the Notified Body review, prior to affixing the CE mark to the vessel. This choice is based on an elaborate graded approach.

The manufacturer quality program is to be certified by a Notified Body.

A Notified Body for the European PED, reviews and certify all elements and procedures to achieve the CE certification. The Notified Bodysupports the manufacturer through the whole process to fulfill the applicable requirements. In some cases, the Notified Body is also accredited by ASME as an AIA.

11.1.3 Conclusion

ASME VIII requires the involvement of the Authorized Inspector in all cases. PED / EN 13445 requires the involvement of the Notified Body. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

11.2 Protocol for certification.

11.2.1 ASME VIII DIV.1

UG-117 CERTIFICATES OF AUTHORIZATION AND CERTIFICATION MARKS

(a) A Certificate of Authorization to use the Certification Mark with the U, UM, or PRT VIII-1 Designator shown in Figure UG-116 will be granted by the Society pursuant to the provisions of the following paragraphs. Stamps for applying the Certification Mark shall be obtained from the Society.

ASME surveys applicants, their ASME VIII-compliant QA program and the implementation of the program through a prototype fabrication. If the applicant is successful, the ASME survey team recommends they obtain a certificate of authorization from ASME to fabricate vessels to ASME VIII (U mark for ASME VIII Div.1; U2 mark for ASME VIII Div.2; U3 mark for ASME VIII Div.3).

11.2.2 EN 13445

To be authorized to fabricate PED-compliant pressure vessels, the manufacturer must:

- Apply for obtaining the CE Marking for the pressure equipment

- Determine the PED Category (hazard level) of the pressure equipment from “sound engineering practice” (SEP, lowest hazard) then Categories I through IV (highest hazard). The PED category is based on diagrams that capture:
    - Type of component
    - Fluid Group (1 or 2)
    - Fluid state (gas or liquid)
    - Design temperature and pressure
    - Volume of vessel or nominal size of pipe
- Chose the conformity assessment procedure for the Category
    - Cat. I self-certification, no Notified Body
    - Cat. II through IV involve the Notified Body to different extents
- Determine the ESRs
    - Hazards analysis
    - Design calculations
    - Fabrication
    - Materials
    - Testing
- Compile the Technical Construction File
    - Manufacturing
    - Design
- Submit the preliminary design and technical documentation to a Notified Body representative for approval
- Fabricate, examine, and test in the presence of Notified Body representative
- Receive the PED Certificate of Conformity from the Notified Body representative
- Complete an EU declaration of conformity (to emphasize that conformity is the responsibility of the manufacturer and not the Notified Body)
- Affixes the CE marking, followed by the identification number of the Notified Body

In the case of serial production, for the maintenance of the certification, there are surveillance visits of the fabricator.

11.2.3 Conclusion

The PED protocol for certification and stamping (affixing the mark) to a pressure vessel is more complicated than the ASME VIII protocol. But both are complete and logical protocols that involve third parties at the right steps. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

11.3 Requirement for an independent inspector.

11.3.1 ASME VIII DIV.1

The oversight of ASME VIII Code activities (procurement of materials, design, fabrication of the vessel or relief device) is provided by an Authorized Inspector, which is an employee of an ASME-authorized AIA. The AIA and the Inspector are qualified and certified in accordance with ASME QAI-1 “Qualifications of Authorized Inspection”.

UG-91 THE INSPECTOR
(a) All references to Inspectors throughout this Division
mean the Authorized Inspector as defined in this paragraph.
All inspections required by this Division of Section
VIII shall be:

(1) by an Inspector regularly employed by an ASME accredited Authorized Inspection Agency, as defined in ASME QAI-1, except that
(2) inspections may be by the regularly employed user's Inspector in the case of a User-Manufacturer that manufactures pressure vessels exclusively for its own use and not for resale [see UG-116(a)(1)].
Except as permitted in (2) above, the Inspector shall not be in the employ of the Manufacturer. All Inspectors shall have been qualified in accordance with ASME QAI-1.
(b) In addition to the duties specified, the Inspector has the duty to monitor the Manufacturer's Quality Control System as required in Mandatory Appendix 10.

11.3.2 EN 13445

A Notified Body (conformity assessment body) is an organization designated by an EU country to assess the conformity of certain products before being placed on the market. The EU member state appoints the body and "notifies" the EU Commission. These bodies carry out tasks related to conformity assessment procedures set out in the applicable legislation, when a third party is required. Once the competence and independence of a Notified Body is verified by the EU Commission, it is notified by the European Commission. The European Commission publishes a list of such notified bodies (https://webgate.ec.europa.eu/single-market-compliance-space/#/notified-bodies).

The competence of the Notified Body is subject to verification carried out at regular intervals and following the practice established by the accreditation organizations, in accordance with EN ISO/IEC 17000 Conformity assessment - Vocabulary and general principles (referenced in https://single-market-economy.ec.europa.eu/single-market/goods/building-blocks/notified-bodies_en)

11.3.3 Conclusion

ASME and the EU have robust processes to designate third parties to oversee the manufacturer's compliance with their respective Codes ASME VIII and EN 13445. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

11.4 Responsibilities of the Authorized Inspector.

11.4.1 ASME VIII DIV.1

UG-90
(1) The Inspector shall make all inspections specifically required of him plus such other inspections as he believes are necessary to enable him to certify that all vessels which he authorizes to be stamped with the Certification Mark have been designed and constructed in accordance with the requirements of this Division. Some, but not all, of the required inspections and verifications, which are defined in the applicable rules, are summarized as follows: …

11.4.2 EN 13445

The equivalent of the ASME VIII Authorized Inspector is the EU Notified Body, described above. The Notified Body has several responsibilities in verifying the PED compliance of a vessel at various stages (modules). These responsibilities cover:

- Conformity assessment (PED, Article 10)
- Module A1: internal manufacturing checks with monitoring of the final assessment
- Module B: EC type-examination
- Module B1: EC design-examination
- Module C: conformity to type
- Module F: product verification
- Module G: EC unit verification
- Approve the procedures for the permanent joining (PED, Annex I, 3.1.2)
- Approve the personnel undertaking the permanent joining (PED, Annex I, 3.1.2)

11.4.3 Conclusion

The role of the ASME AI is clearly defined in ASME VIII UG (general requirements). The role of the Notified Body is clearly defined in the PED, and consists of independently reviewing the materials, design, and fabrication records to verify that the Codes and standards have been followed. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

11.5 Qualifications and Independence of the Authorized Inspector.

11.5.1 ASME VIII DIV.1

UG-91 THE INSPECTOR
(a) All references to Inspectors throughout this Division mean the Authorized Inspector as defined in this paragraph. All inspections required by this Division of Section VIII shall be:
(1) by an Inspector regularly employed by an ASME accredited Authorized Inspection Agency, as defined in ASME QAI-1, except that
(2) inspections may be by the regularly employed user's Inspector in the case of a User-Manufacturer that manufactures pressure vessels exclusively for its own use and not for resale [see UG-116(a)(1)].
Except as permitted in (2) above, the Inspector shall not be in the employ of the Manufacturer. All Inspectors shall have been qualified in accordance with ASME QAI-1.
(b) In addition to the duties specified, the Inspector has the duty to monitor the Manufacturer's Quality Control System as required in Mandatory Appendix 10.

11.5.2 EN 13445

PED Article 24 specifies the requirements relating to notified bodies (NB) and recognized third-party organizations.

- The NB is established under national law of a Member State.
- The NB is a third-party body independent of the organization it assesses. The NB is impartial.

- The NB is technically knowledgeable and experienced.
- The NB has appropriate policies and procedures in place.
- The NB must observe professional secrecy with regard to all information obtained in carrying its tasks.

11.5.3 Conclusion

The expertise and independence of the Authorized Inspector and agency, and the NB (Notified Body inspector and agency) are clearly specified in ASME VIII and PED. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

11.6 Allowance for self-certification of inspections.

11.6.1 ASME VIII DIV.1

There is no exception to using an Authorized Inspector when constructing an ASME VIII pressure vessel.

11.6.2 EN 13445

The manufacturer bears sole responsibility for declaring conformity with all requirements. The manufacturer does not need a license to affix the CE marking to your product, however, the manufacturer must:

- ensure conformity with all relevant EU-wide requirements
- determine whether you can assess your product by yourself or if you have to involve a notified body
- put together a technical dossier documenting conformity: find out about technical documentation
- draft and sign an EU declaration of conformity

Once your product bears the CE marking — if the competent national authority requests — you must provide them with all the information and supporting documentation concerning CE marking.

In the PED, there is a graded approach to (a) the involvement of the Notified Body, and (b) the CE mark.

- First, the equipment is type of fluid (gas, vapor, liquid).
- Second, determine the Group of the fluid:
    - Group 1 designates media as hazardous. Group 1 hazardous media are all media that are either explosive, extremely flammable, highly flammable, flammable, very toxic, toxic, or oxidizing.
    - Group 2 covers all other media. Note media that can be dangerous, but not hazardous (i.e. steam) is categorized as Group 2 due to this.
- Third, determine the energy content of the fluid, i.e., its volume and pressure, on the basis of a series of pressure-volume charts showing the boundaries between Categories.
- Fourth, having the three parameters above, determine the Category of the component, from I (lowest consequence) to IV (highest consequence). There is also a Category below Category I (lowest pressure-volume) where “sound engineering practice” (referred to as the SEP Category) is sufficient to design and fabricate the component, but the SEP component cannot be CE stamped.

The conformity of a Category SEP (sound engineering practice) vessel, below Category I, can be undertaken by the manufacturer as a self-declaration route without the involvement of a Notified Body.

11.6.3 Conclusion

ASME VIII requires the involvement of the Authorized Inspector for ASME VIII vessels. EN 13445 permits self-declaration of conformity by the manufacturer, without Notified Body oversight, but only for Category SEP (sound engineering practice) vessels.

Suggestion: If the vessel is (a) not CE stamped, or (b) classified as Category SEP (sound engineering practice) vessels, the user must review the application of the PED directive to confirm that the vessel was correctly categorized as SEP, before the vessel is installed.

11.7 Qualifications and audits of material supplier.

11.7.1 ASME VIII DIV.1

Material suppliers do not have to be accredited by ASME. The manufacturer is required to verify the specification compliance of the material.

11.7.2 EN 13445

Material suppliers do not have to be accredited by a Notified Body. The manufacturer is required to verify the specification compliance of the material.

11.7.3 Conclusion

The lack of material supplier qualification, and therefore the responsibility of the manufacturer (material buyer), is the same in both Codes. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

11.8 Qualifications and audits of designer.

11.8.1 ASME VIII DIV.1

Mandatory Appendix 47 Requirements for Pressure Vessel Designers

(c) Designer. The Designer shall meet either of the following:
(1) The Designer shall have completed an accredited engineering technician or associates degree, requiring the equivalent of at least 2 yr of study, plus have a minimum of 6 yr of experience in the design of pressure vessels.
(2) The Designer shall have a minimum of 10 yr of experience in the design of pressure vessels.
(d) As an alternative to the requirements in (a), (b), or (c), the Manufacturer may follow the requirements of ASME Section VIII, Division 2, Part 2.

11.8.2 EN 13445

PED does not have designer qualification requirements. It does state that the design calculations are to be submitted to the Notified Body: *PED Para.3.1. The manufacturer shall lodge an application for assessment of his quality system with the notified body of his choice, for the pressure equipment concerned. The application shall include: … results of design calculations made.*

EN 13445 Appendix B Para.B.1.3 and C.1 require an independent body if the vessel is designed by analysis or designed for creep.

11.8.3 Conclusion

Unlike ASME VIII, EN 13445 does not impose minimum qualification requirements on the designer. However, the Notified Body is responsible for review of the design calculations, whereas the focus of the ASME Authorized Inspector is typically on fabrication; while design relies on the expertise of the designer and his/her colleague checker. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

11.9 Qualifications and audits of fabricator.

11.9.1 ASME VIII DIV.1

The applicant for an ASME certificate (such as "U" to construct Section VIII unfired pressure vessels), prepares the Quality Assurance program, contracts an Authorized Inspection Agency, and submits an application to ASME for a review/survey. The review/survey includes all aspects of construction, including witnessing of the fabrication of a (simple) pressure vessel (material procurement, design, welding, NDE, pressure test, etc.). The survey team then recommends that the applicant receive the ASME certificate (the stamp) for the scope that was surveyed.

11.9.2 EN 13445

Unlike ASME VIII, the fabricator of CE-stamped vessels does not hold a certificate of authorization. Instead, the reliance for Code compliance lies on surveys, audits, and approvals by the Notified Body. The Manufacturer does take responsibility through the Declaration of Conformity.

11.9.3 Conclusion

The compliance of the ASME vessel relies on the reviews by the Authorized Inspector, and the ASME certification of the fabricator. The compliance of the PED vessel relies on the reviews by the Notified Body and the manufacturer Declaration of Conformity. Where the Notified Bodies perform their review the ASME and the PED approaches is similar. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

11.10 Responsibilities of the Owner, the designer, the fabricator.

11.10.1 ASME VIII DIV.1

NONMANDATORY APPENDIX NN

GUIDANCE TO THE RESPONSIBILITIES OF THE USER AND DESIGNATED AGENT

Appendix NN provides tables of responsibilities, and the sections within the body of the Code where the responsibilities are called-out.

11.10.2 EN 13445

EN 13445-1 Para.3.7, EN 13445-4 Para.4.1, and EN 13445-5 Para.7.1 lists the responsibilities of the manufacturer.

The responsibilities of the Notified Body are specified in the PED.

11.10.3 Conclusion

Responsibilities are clear in ASME VIII and EN 13445/PED. Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

11.11 Authorized inspectors and notified body responsibilities and independence.

11.11.1 ASME VIII DIV.1

The ASME QAI-1 Standard provides requirements for the qualification and duties of individuals performing authorized inspections as required in the ASME Boiler and Pressure Vessel Code. The Standard also establishes the requirements for an organization to be an accredited Authorized Inspection Agency or Qualified Inspection Organization. The individuals performing authorized inspections under the employment of an accredited organization are Authorized Inspectors, Authorized Inspector Supervisors, Authorized Nuclear Inspectors, Authorized Nuclear Inspector Supervisors, Inspectors, and Supervisors. The qualification and duties of a Certified Individual is also addressed.

11.11.2 EN 13445

A Notified Body is an organization that an EU Member State or other countries designate to assess the conformity of certain products before they can be sold on the market. For the Pressure Equipment Directive (PED), a Notified Body certifies the conformity assessment of pressure equipment to ensure compliance with the PED. The PED provides a legal framework that allows pressure equipment to be sold and manufactured throughout the European Union without having to go through a local approval process in each member state.

11.11.3 Conclusion

ASME VIII (and QAI-1) and EN 13445 (and PED) have defined the responsibilities and independence of the Authorized Inspector (ASME III) and Notified Body (PED). Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

11.12 Fabrication records.

11.12.1 ASME VIII DIV.1

10-13 RECORDS RETENTION
(a) The Manufacturer or Assembler shall have a system for the maintenance of radiographs (see UW-51), Manufacturer's Data Reports (see UG-120), and Certificates of Compliance/Conformance (see UG-120) as required by this Division.
(b) The Manufacturer or Assembler shall maintain the documents outlined below for a period of ***at least 3 yr****:*
(1) Manufacturer's Partial Data Reports
(2) manufacturing drawings
(3) design calculations, including any applicable Proof Test Reports
(4) Material Test Reports and/or material certifications
(5) Pressure parts documentation and certifications
(6) Welding Procedure Specifications and Procedure Qualification Records

(7) Welder/Welding Operator Performance Qualification Records for only those welders/welding operators who welded on the vessel or part
(8) NDE interpretation reports
(9) repair procedure and records

(10) process control sheets
(11) heat treatment records and test results
(12) postweld heat treatment records
(13) nonconformances and dispositions
(14) pressure test records
(15) transfer forms [see UG-120(c)(1)(-e)]
(16) continuity records showing that the qualifications of welders, brazers, welding operators, and brazing operators have been maintained
(c) For Manufacturers of vessels bearing the UM Designator or vessels constructed under the provisions of UG-90(c)(2) rules, the records listed in (b) above, for six representative vessels per year, shall be maintained as follows:
(1) vessels bearing the UM Designator for a period of 1 yr
(2) vessels constructed under the provisions of UG-90(c)(2) rules for a period of 3 yr.

Para.UG-120 requires the Data Reports to be kept for a minimum of 3 years.

11.12.2 EN 13445
EN 13445-5 Para.12.3 requires all records to be maintained and made available for a period of 10 years.

11.12.3 Conclusion
For record retention, EN 13445 (10-year retention) is more restrictive than ASME VIII (3-year retention).

11.13 Stamping or other physical evidence of compliance.
11.13.1 ASME VIII DIV.1
The certification mark (stamp) is applied after the Authorized Inspector is satisfied that all the ASME VIII Code requirements have been met: materials, design, fabrication, examinations, tests, over-pressure protection.

U-2 General

(e) It is the duty of the Inspector to make all of the inspections specified by the rules of this Division, and to monitor the quality control and the examinations made by the Manufacturer. The Inspector shall make such other inspections as in his judgment are necessary to permit certification that the vessel has been designed and constructed in accordance with the minimum requirements of this Division. The Inspector has the duty of verifying that the applicable design calculations have been made and are on file at Manufacturer's plant at the time the Data Report is signed. Any questions concerning the calculations raised by the Inspector must be resolved. See UG-90(c)(1).

11.13.2 EN 13445

The CE stamp is affixed to the vessel once the Notified Body is satisfied that all the requirements of the PED and EN 13445 have been met.

11.13.3 Conclusion

ASME VIII and EN 13445 require a third-party concurrence to affix the U stamp (ASME VIII) or CE stamp (PED/EN 13445). Therefore, ASME VIII and EN 13445 are equivalent for this attribute.

12 Record or Revisions

Rev.	Date	Description
8/12/2024	8/12/2024	First issue