COMPARISON OF ASME SPECIFICATIONS AND EUROPEAN STANDARDS FOR MECHANICAL TESTING OF STEELS FOR PRESSURE EQUIPMENT

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December 16, 2005

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EXECUTIVE SUMMARY

A study was conducted under the ASME Standards Technology, LLC (ASME ST-LLC) to compare ASME and European specifications for mechanical testing of steels for pressure equipment. The study has concluded that there are no technical differences between the two systems, the ASTM/ASME requirements and the EN requirements for material testing, that would support a position that one or the other system of requirements is more or less conservative than the other. The systems are slightly different, but, when used in conjunction with their respective construction codes, the European Pressure Equipment Directive (PED) and the ASME Boiler & Pressure Vessel Codes, they assure the production of safe pressure equipment.

There are three significant differences worthy of separate note. These are the EN requirement for elevated temperature proof testing, the EN requirement for a minimum absorbed energy impact test value for all pressure equipment materials, and the ASME requirement for lateral expansion values for some materials and some equipment to be reported from impact tests, in addition to the absorbed energy.

The difference between the EN requirement for elevated temperature proof testing (equivalent to a requirement for elevated temperature yield strength testing) vs. the ASME approach employing trend curves for both elevated temperature yield strength and elevated temperature tensile strength, is discussed in detail in the report. In the EN system, the maximum design stresses to be used in construction appear in the material specifications and are based on the measured proof stress as a function of temperature. The material manufacture is required to assure that the proof stress values adequately support the design allowable stresses. In the ASME system, the construction code establishes the design allowable stresses, based on data analyzed under the auspices of ASME. The material manufacturer certifies only that the material meets the room-temperature properties listed in the specification. The material manufacturer is not in a position to assure that the design allowable stresses are suitable, because he is not a party to their development, other than that the material manufacturer often provides representative data as a function of temperature to the ASME committee. ASME may analyze that data (to develop maximum allowable stresses) either alone, or in conjunction with data obtained from other sources. The insistence by European authorities on material having elevated temperature proof test data that assures the validity of the allowable stresses has often prevented the use of ASME materials in PED construction. However, even though the guaranteed proof stress values in EN material specifications may be somewhat lower (more conservative) than the yield strength values used as part of the basis for allowable stresses in the ASME construction codes, many studies have shown that vessels designed to the PED code are thinner and lighter (less conservative) than corresponding vessels constructed to the ASME Code. Nonetheless, experience shows that both systems lead to the manufacture of vessels with adequate protection against plastic collapse, and having equivalent safety records.

As mentioned in the matrix report, the EN codes require a minimum 27 J (20 ft. lb.) absorbed energy for all pressure equipment. The ASME code for boilers (which always operate at elevated temperature), Section I, does not contain an explicit impact testing requirement. In fact, as explained in the report, there are instances in which an absolute requirement for an absorbed energy minimum can lead to degradation of the principle function of boiler materials, that of retaining pressure at elevated temperatures. The ASME codes for pressure vessels, however, contain extensive requirements for impact testing, since these vessels often operate at ambient temperatures and cooler. The impact testing requirements vary with material, heat treatment condition, and thickness, as explained in the report. Neither set of requirements can be directly compared against the other. However, both sets of rules provide reasonable protection against brittle fracture.

Finally, in addition to the requirements for meeting minimum absorbed energy requirements for certain materials, the ASME pressure vessel codes also impose additional requirements involving the a minimum mils of lateral expansion (MLE) of specimens used in the impact test (which, in the European system is used only to determine absorbed energy). Some experts feel that MLE is a better indication of notch toughness (and thus of resistance to brittle fracture) than absorbed energy, at least for high-strength steels. While this position may not be universally accepted, MLE requirements for some materials have been incorporated into the ASME pressure vessel codes.

COMPARISON OF EUROPEAN STANDARDS[1] AND ASME SPECIFICATIONS[2] FOR MECHANICAL TESTING OF STEELS FOR PRESSURE EQUIPMENT

Test Parameter	European Standards (EN Standards)	ASME and/or ASTM Specifications	Areas of Difference	Net Effect
Tensile Testing at Room Temperature	EN 10002-1, tensile testing at ambient temperature	ASME SA-370 (ASTM A 370/A 370M)	**Yield Strength:** In ASME material specifications, the yield strength generally is determined by the 0.2% offset method. The yield strength listed in the EN specifications is the upper yield strength, R_eH. **Strain Rate:** ASME SA-370 specification is identical with ASTM A 370. For determination of yield strength, ASME SA-370 specifies a strain rate in the reduced section not more than 0.001 in./in./sec. and not less than 0.1 times the maximum rate when the stress exceeds one half of the specified yield point or yield strength. As an alternative, the rate of stressing shall not exceed 100 ksi/min. (11.5 MPa/sec), or be less than 10 ksi/min (1.15 MPa/sec). For determination of the upper yield strength, ReH, EN 10002-1 specifies a minimum stress rate of 6 MPa/sec and a maximum stress rate of 60 MPa/sec, which are somewhat higher than the ASTM and ASME permissible strain rates. **Tensile Strength:** For determination of tensile strength, ASME SA-370 specifies a strain rate in the reduced section shall not more than 0.008 in./in.sec., and not less than 0.1 times the maximum strain rate. For determination of tensile strength, also EN 10002-1 specifies a maximum strain rate of 0.008/sec throughout the test; therefore the determination of tensile strength is not an issue. **Tension Test Specimen:** Both ASME SA-370 and EN 10002-1 permit the use of various types of tension test specimen, depending on product form, thickness, and shape. Commonly used test specimens	There is no technical significance to the differences in tensile testing at room temperature. Whether one uses the 0.2% offset method to determine yield strength, or the 0.5 % of total load method, or the 1% proof stress method, is totally arbitrary. The higher the percentage used, the higher will be the resulting yield strength or proof test numbers. Whether use of the higher percentage method is less conservative depends on how the results are used, not on the method.

Test Parameter	European Standards (EN Standards)	ASME and/or ASTM Specifications	Areas of Difference	Net Effect
			in the ASME and ASTM materials specifications are the 2 in. (50 mm) gage length round, 0.5 in (12.5 mm) dia., test specimen. Commonly used test specimens in the EN specifications are the 5.65√So gage length test specimen (where So = original cross-sectional area). However, the issue of differing tensile test specimen is not a factor in determining tensile properties as the stress at which a specimen begins to yield or at which it ruptures is a ratio of the actual cross sectional area of the specimen at that moment to the applied load. It is a property of the material, not of the geometry of the specimen. **Gage Length:** Gage lengths for elongation and tensile testing are different in the ASME and in the EN material specifications. Elongation is affected by the ratio of the length of the specimen to its cross section, so the difference between the 4:1 ASME (ASTM) tension specimen and the 5:1 ISO tension specimen might affect elongation values. However, ASME doesn't use elongation values in any of the Code requirements; therefore, this is not an issue that affects the use of the material.	
Elevated Temperature Tensile testing	EN10002-5, tensile testing at elevated temperature	ASME SA-370	**EN Material Specifications:** The EN specifications list the 0.2% proof strength values, Rp0.2, at temperatures above the room temperature, up to the temperature where time dependent properties govern. Verification of the 0.2% proof strength, 1.0% proof strength, and/or tensile strength at elevated temperature for austenitic steels is subject to agreement. The same type of test pieces are used as for room temperature testing. **ASME Boiler & Pressure Vessel Code:** The ASME Boiler & Pressure Vessel Code does not require elevated temperature tension tests. However, ASME does require sufficient data for all new materials (materials that have not yet been approved for ASME Code construction) at 40º C (100º F) intervals above the room temperature up to 40º C (100º F) above the maximum use temperature to establish "trend curves". These "trend curves" are used for establishing	There is a fundamental difference between the minimum yield/tensile strength values in the EN material specifications and the yield and tensile strength values published in Tables U and Y-1 of ASME Section II, Part D. The values in the EN material specifications are guaranteed minimum values, and they are guaranteed by the material manufacturer, to support the design allowable stresses in the PED. The values in the ASME Code are NOT guaranteed minimum values. The footnotes in tables U and Y-1 of ASME Section II, Part D (II-D), are very explicit in this regard. They are values that are appropriate for use in design according to the ASME construction codes that reference these values. The process for developing the Table U and Y-1 values depends on a ratio trend curve according to the principles put forward by Dr. G. V. Smith some decades ago. Room

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			the tensile strength and yield strength values that are used to determine the allowable design stresses at elevated temperatures. This data shall be provided from at least three heats of material meeting all of the requirements of a specification for at least one product form for which adoption is required for ASME Code construction.	and elevated temperature tensile data (according to the requirements of Appendix 5 of II-D) are provided to the ASME Boiler & Pressure Vessel Committee. For each heat for which data is provided, a ratio of the elevated temperature strength value to the room temperature strength value is calculated. The ratio values are plotted as a function of temperature. The logic behind this process is that for each heat tested, the plotted curves of the ratios vs. temperature have the same shape, or trend. A best-fit curve representing the mean behavior of the alloy as a function of temperature is developed using statistical methods. The ratioing technique normalizes out differences between strong and weak heats; that is, between heats that have high room temperature strengths and those that have lower room temperature strengths. To develop the yield strength values in Table Y-1, for example, the ratio values from the best-fit curve, the yield strength ratio trend curve, at fixed temperature intervals, are multiplied by the minimum specified room-temperature yield strength for the material as stated in the material specification. Obviously, since the ratio trend curve reflects the mean of the individual ratios, and if the data base was large enough, then if a material producer manufactures a heat of material for which the yield strength just meets the minimum specified room temperature yield strength in the specification, there is about a 50% probability that the yield strength at some elevated temperature for that heat might be below the value listed for that temperature in Table Y-1. However, such a situation has no effect on the validity of the allowable stresses or of the yield strength values (in Table Y-1) themselves, nor on the acceptability of the material for use in ASME construction. There are also other rules that come into play: no elevated temperature value can exceed the minimum specified room temperature value, and the values must trend monotonically downward with increasing temperature (in other words, no value at a higher temperature can be higher than a value at a lower temperature). The process for developing the tensile strength values in

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				Table U is similar, but is somewhat more complicated, primarily for historical reasons. The ASME process avoids the need for material manufacturers to either collect or guarantee elevated temperature strength values on production material. The process was developed at a time when there was substantial participation by material producers in the ASME code process, and they objected to having to collect such data. Since the ASME process is a consensus process (rather than one determined by a government agency), a method was developed to avoid the necessity of collecting such data except when a new material is proposed for inclusion in the Code. It is not possible to require domestic materials producers to guarantee the validity of the ASME allowable stresses or other design values, particularly as they usually have no contractual relationship with the end user a vessel, boiler, or nuclear component owner). While the trend curve approach usually leads to values in Table Y-1 that are higher than those in the EN material specifications, the trend curve approach is neither better nor worse than the European model; it is just different. The values in ASME II-D Tables U and Y-1 ought to be considered appropriate for use in designing to the PED. What differences exist in any particular values will be on no measurable or discernable consequence with regard to the safety, i.e., with regard to potential plastic collapse, of the products built to either the ASME Codes or to the PED. In other words, the design margins will be somewhat different, but plastic collapse failures will not occur with either process. Those who might argue otherwise have a different agenda: their purpose is to limit competition and to provide manufacturers in their own country or region a commercial advantage. Such behavior might have a laudable social goal (helping to insure higher employment or profits at home), but to aver that it has a supportable technical basis is disingenuous

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Hardness testing	EN ISO 6506-1, 2 & 3 Brinell hardness test	ASTM E 10 & ASME SA-370	**General:** Hardness testing for products supplied to ASME material specifications is only performed when required by the product specification or when specified by the purchaser. There is significant variation in this requirement among product forms. Plate specifications usually have both minimum and maximum tensile strength requirements. Since the maximum hardness serves a similar purpose to a maximum tensile strength, hardness testing is not usually required by plate specifications. Other product forms, such as tubing and pipe, normally require only a minimum tensile strength. In material specifications for these product forms, hardness testing is usually mandatory. Other product forms, particularly those for which many small parts are made from a heat of steel, such as fittings, may have a capability hardness requirement. Hardness testing is not required, but a purchaser who finds one or more parts that don't meet the capability requirement can reject the parts. **Test methods and hardness determination:** ASME SA-370 references Test Method E 10 for detailed requirements of the Brinell hardness test. The methods for Brinell hardness testing and hardness determination are essentially the same in EN ISO 6506-1 as in ASTM E 10. EN ISO 6506-1, Annex C, gives Brinell hardness numbers for force-diameter ratios of 30, 15, 10, 5, 2.5, and 1, whereas ASTM E10 and SA-370 give hardness numbers for 3000, 1500, and 500 kgf loads. The hardness numbers for the 3000, 1500, and 500 kgf loads correspond to those for diameter-force ratios of 30, 15, and 5 in EN ISO 6506-1.	Hardness maximum limits and maximum tensile strength serve essentially the same technical purpose. They can provide some guidance concerning the difficulty a manufacturer might expect in forming operations; and they provide some guidance on the susceptibility of the material to environmentally-assisted cracking, such as hydrogen attack. Neither maximum hardness nor maximum tensile strength is used directly in ASME Construction Code rules. Harness testing is subject to wide scatter in results, due to testing variables and test material condition and preparation for testing. There are no significant technical consequences resulting from the differences between the test methods in the EN and ASTM/ASME hardness testing methods.
Hardness testing	EN ISO 6507-1, 2 & 3 Vickers hardness test	ASTM E 92	Detailed procedures for Vickers hardness testing are given in ASTM E 92. (ASME SA-370 does not include procedures for Vickers hardness testing). Both ASTM E 92 and EN ISO 6507-1 include essentially the same formula and the same procedures hardness for determining Vickers hardness, except that the applied force is given in kgf in E, and in Newtons (N) in EN ISO 6507-1; therefore, also the constants	

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			in these formulas differ by a factor 9.80665. However, EN ISO 6507-1 includes some additional tables. For example, Table 3 gives the applied force F (in Newton's) for HV 5 to HV hardness tests, for low-force hardness tests HV 0.2 to HV 3), and for micro-hardness tests (HV 0.01 to HV 0.1). ASTM E 92, paragraph 5.1.1 states that the minimum thickness of the test specimen shall be such that there is no bulge or other indication of the effect of the force on the backside of the test specimen. The graph in EN ISO 6507-1, Fig. A.1 shows the minimum thickness of the test piece in relation to the test force and to the various hardness measurements (HV 0.2 to HV 100).	
Hardness testing	EN ISO 6508-1, 2 & 3 Rockwell hardness test	ASTM E 18 & ASME SA-370	**Test Methods And Hardness Determination:** ASME SA-370 references Test Method E 18 for detailed requirements of the Rockwell hardness test. The methods for Rockwell hardness testing and hardness determination are essentially the same in EN ISO 6508-1 as in ASTM E 18.	
Impact testing	EN 10045-1	ASME SA-370	**Tup Radius**: EN 10045-1 specifies a 2 mm radius at the tip of the striker (the tup), and ASME SA-370 specifies an 8 mm radius. Studies were performed by the Pressure Vessel Research Committee (PVRC) on Charpy V-notch test specimens certified by the US NIST from 1 in. thick ASTM A 516 Gr. 70 plate (70 ksi minimum specified UTS and 38 ksi specified minimum YS) and from 1 in. thick ASTM A 517, Gr. F plate (115 ksi specified min. UTS and 100 ksi specified min. YS). Test specimens were taken from the 1/4T location of the plate and oriented in the longitudinal direction of the plates. The test results showed no significant differences in the results of the Charpy energy values obtained with the 2 mm and 8 mm striker radius. **Lateral Expansion And Percent Shear Appearance:** Some ASME Construction Codes specify acceptance criteria for certain materials (e.g., high strength Q &T low alloy steels and stainless steels, depending on minimum design temperature) based on lateral expansion (mils lateral	Since the EN methodology depends only on absorbed energy requirements, the ASME requirements that depend on both absorbed energy and also on values of lateral expansion (for some materials) are somewhat more conservative. However, impact test results offer only a guide to the susceptibility of a material to brittle fracture. Nonetheless, such tests are used for acceptance and rejection of materials for a particular application. Impact tests are much easier and quicker to perform that the more technically significant fracture toughness tests.

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			expansion, MLE) measured opposite the notch of the fractured Charpy V-notch specimen. ASME Section VIII, Divisions 1 and 2, require the 15 MLE minimum single value for carbon and low alloy steels with specified minimum UTS of 95 ksi (655 MPa) and greater, fur all UHT materials in Div. 1 and for all AQT materials in Div. 2, and for high alloy steels required to be impact tested by the Section VIII rules. Fig. UHT-6.1 (and Fig. AM-211.2) require greater values than 15 MLE for thicknesses greater than 1¼ in. (32 mm). There are no provisions in EN 10045-1 (or in EN 13445) for measurement of lateral expansion or fracture appearance (percent of shear fracture).	
Impact testing	EN 10045-2 EN 13445	ASTM E 23 ASME Section VIII, Division 1, Figure UG-84.1 and Figure UCS-66.1Curve D	**Verification Of Pendulum Testing Machines:** ASTM E 23 requires verification of pendulum impact test machines by testing of specimens with certified values to verify the accuracy the machines. It is not certain whether EN 10045-2 includes the same requirements. (The EN 10045-2 specification was not available for this review). Improperly calibrated impact test machines can have a significant effect on the test results. EN 13445 (the European pressure vessel standard) has separate impact test requirements for as welded and for stress relieved parts. It permits significantly higher design reference (use) temperatures for stress relieved parts than for as-welded parts. The minimum impact test value in EN 13445 is 27 J (20 ft-lb), whereas it is 15 ft-lbs in Division 1 (and Division 2), but it increases with thickness, as shown in Fig. UG-84.1. Figures B.4-1 through B.4-5 in EN 13445-2 (Materials) plots the design reference (use) temperature vs. impact test temperature for various material thicknesses. EN 13445-2 includes separate figures for materials with YS equal to and less than 310 MPa (45 ksi) and for materials with YS greater than 310 MPa. The impact test requirements for two materials are compared below, using the impact test exemption Curve D (MDMT) in Division 1 as the impact test temperature for the curves in EN 13445-2 to determine their design reference temperature for the same thicknesses:	However, so long as impact testing machines are calibrated on a regular schedule with a consistent method, the method of calibration of impact (or other property measuring machines) has no effect on the conservatism of the test results.

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			SA-516, Gr. 70 normalized (Curve D): As welded: **t = 13 mm:** Fig. UCS-66.1, Curve D (15 ft-lb): MDMT = -48C. EN 13445, Fig. B.4-2 (27 J = 20 ft-lb): design- reference-temp. = -75C (with impact tests at -48C). **t = 25mm:** Fig. UCS-66.1, Curve D (15 ft-lb): MDMT = -35C. EN 13445, Fig. B.4-2 (20 ft-lb): des. ref. temp. = -36C (with impact tests at -35C). **t = 35 mm:** Fig. UCS-66.1, Curve D (15 ft-lb): MDMT = -28C. EN 13445, Fig. B.4-2 (20 ft-lb): des. ref. temp. = -20C (with impact tests at -28C). PWHT: **t = 50 mm:** Fig. UCS-66.1, Curve D (15 ft-lb): MDMT = -20C. EN 13445 (20 ft-lb), Fig. B.4-1: des. ref. temp. = -30C (with impact tests at -20C). **t = 60 mm:** Fig. UCS-66.1, Curve D (15 ft-lb): MDMT -17C. EN 13445, Fig. B.4-1 (20 ft-lb): des. ref. temp. = -15C (with impact tests at -17C). **SA-537, Cl. 1 (Curve D):** As welded: **t = 13 mm:** Fig. UCS-66.1, Curve D (15 ft-lb): MDMT = -48C. EN 13445, Fig. B.4-4 (20 ft-lb): des. ref. temp. = -64C (with impact tests at -48C). **t = 25mm:** Fig. UCS-66.1, Curve D (15 ft-lb): MDMT = -35C. EN 13445, Fig. B.4-4 (20 ft-lb): des. ref. temp. = -29C (with impact tests at -35C). **t = 35 mm:** Fig. UCS-66.1, Curve D (16 ft-lb): MDMT = -28C. EN 13445, Fig. B.4-4 (20 ft-lb): des. ref. temp. = -10C (with impact tests at -28C). PWHT: **t = 50 mm**: Fig. UCS-66.1, Curve D (19 ft-lb): MDMT = -20C. EN 13445 (20 ft-lb), Fig. B.4-3: des. ref. temp. = +1C (with	

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			impact tests at -20C). **t = 60 mm:** Fig. UCS-66.1, Curve D (22 ft-lb): MDMT = -17C. EN 13445, Fig. B.4-3 (20 ft-lb): des. ref. temp. = +14C (with impact tests at -17C). EN 13445-2 would permit the same figures for as-rolled SA-516, Gr. 70 as for normalized SA-516, Gr. 70, whereas Division 1 would use Curve B for as rolled SA-516, Gr. 70. Based on the above, it is difficult to compare the toughness requirements in the ASME and in the European pressure vessel codes. In EN 13445-2, the thickness has a more significant effect on impact test requirements. On the other hand they give a more beneficial effect to PWHT than our 30 F (i.e., when PWHT is not required by Code rules). However, ASME will have two sets of impact test exemption curves in the Division 2 rewrite, for as-welded and for PWHT construction.	
Drop weight testing to determine nil-ductility temperature		ASTM E 208	ASME Code specifies acceptance criteria for certain materials (e.g., high strength Q &T low alloy) based on drop weight testing in accordance with ASTM E 208 to determine the nil-ductility temperature. EN 13445 does not require drop weight testing to determine nil-ductility temperature; therefore, no review was made in this study of the EN specifications for drop weight testing.	
General technical requirements for steel and iron products	EN 10021	ASME general requirements specifications for various product forms (pressure vessel plates, forgings, etc.)	EN 10021 includes general technical requirements for all steel and iron products. The general technical requirements, such as those in EN 10021, are included in the ASME (and ASTM) general requirements specifications for specific product forms, such as: ASME SA-20, Specification for General Requirements for Steel Plates for Pressure Vessels, ASME SA-450, Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes,	Obviously, the ASME product specifications provide requirements that are more specific to the products for which they apply. However, the requirements either system can not themselves be said to be more or less conservative than the other.

Test Parameter	European Standards (EN Standards)	ASME and/or ASTM Specifications	Areas of Difference	Net Effect
			ASME SA-480, Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip, ASME SA-530, Specification for Seamless Carbon Steel Pipe for High-Temperature Service, ASME SA-703, Specification for Steel Castings, General Requirements, for Pressure-Containing parts, ASME SA-788, Specification for Steel Forgings, General Requirements, ASME SA-960, Specification for Common Requirements for Wrought Steel Piping Fittings, ASME SA-961, Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications, ASME SA-965, Specification for Steel Forgings, Austenitic, for Pressure and High-Temperature Parts, ASME SA-1016, Specification for General Requirements for Ferritic Alloy Steels, Austenitic Alloy Steel, and Stainless Steel Tubes. The general requirements specifications include the common requirements for the product specifications listed in the general requirements specifications and additional supplementary requirements that may be specified by the purchaser.	

Test Parameter	European Standards (EN Standards)	ASME and/or ASTM Specifications	Areas of Difference	Net Effect
General requirements for flat steel products for pressure purposes	EN 10028-1	ASME SA-20 (Steel Plates for Pressure Vessels)	**Processing:** EN10028-1 permits “normalized rolling” in lieu of “normalizing”, which is not acceptable in ASME SA-20 (ASTM A 20). **Mechanical tests:** EN10028-1 requires the following mechanical tests for flat steel products: - Tensile tests at room temperature; - Tensile tests at elevated temperature to determine the 0.2 % proof strength (or the 1.0 % proof strength) and the tensile strength at the specified elevated temperature in accordance with EN 10002-5. If no temperature is specified, the test shall be at 300 ºC (572 ºF), except for austenitic ferritic steels of EN 10028-7 the tests shall be at 250 ºC (482 ºF). - Impact tests (except for austenitic steels). ASME SA-20 does not require impact tests, but includes requirements for impact testing when required by the individual product specification or when specified by the Purchaser (e.g., to comply with ASME Code requirements or any additional Purchaser requirements). **Test specimen location in a plate and the amount of test specimen:** EN10028-1 requires test specimen to be taken from the ¼ width at the end of the plate. ASME material specifications require the test specimen to be taken from a corner of the plate. EN10028-1 requires one tension tests from each test unit (rolled plate), including Q&T plates in EN 10028-6. ASME SA-20 requires tension test from each end of Q&T plate, including plates produced from coils and quenched and tempered. In addition, ASME requires the test specimen to be taken 1T from any heat treated edge.	Normalized rolling is cooling rapidly from a hot-rolling temperature that is within the normalizing (austenite-forming) temperature band of a ferritic steel. This process can produce less uniformity of microstructure and properties through the thickness of the plate product. The equivalence of this process is highly dependent on the process control imposed by the material manufacturer, so it is usually considered a less desirable process. In ASME construction, the need for impact testing is determined by the construction code rather than by the material specification. For boilers, which are usually operated at high temperatures at which brittle fracture is not a concern, Section I does not require impact testing. But, for pressure vessels that are often operated an ambient temperatures or colder, Section VIII, Divisions 1, 2, and 3 do require toughness testing. Both systems have their value. But, for some materials, a hardness test requirement often leads to additions of elements, at least in weld consumables, where such additions are permitted, that improve the impact test results. Examples are additions of Ni and Mn to filler metals for weldments of Grade 91 and similar alloys. These additions can deleteriously affect other properties, and in particular, the elevated-temperature creep-rupture strength of weldments in some high-strength ferritic steels. Test specimen location and orientation requirements do not lead to a significant technical benefit of one system over the other.

Test Parameter	European Standards (EN Standards)	ASME and/or ASTM Specifications	Areas of Difference	Net Effect
			EN10028-1 does not specify the orientation of the tension test specimen, but does require transverse Charpy V-notch impact tests. ASME SA-20 requires transverse tension tests.	
		ASME SA-480 (Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip)	**Number of Tests:** ASME SA-480 (ASTM A 480) requires a minimum of one tension test, one bend test (when required), and one hardness test on each 100 or less pieces of the same heat and nominal thickness, and heat treated within the same operating period, for plate, sheet and strip, produced in cut lengths. Tension tests may be in the longitudinal or transverse direction. **Strain Rate:** The testing speed between yield the strength and the fracture of the specimen shall be between 1/8 and ½ in./in./min. (0.002 and 0.008 mm/mm/sec.).	Differences in the number of tests required do not lead to significant differences in materials.
General requirements for open die steel forgings for pressure purposes	EN 10222-1		**Mechanical Tests:** EN10222-1 requires the following mechanical tests: Tensile tests at room temperature; Tensile tests at elevated temperature. For steels whose designation has "H" suffix (EN 10222-2) the manufacturer shall provide proof to the purchaser in accordance with ENV 22605-1 and ENV 22605-2 that the product consistently meets the specified elevated temperature properties. If there is not sufficient data to meet the requirements of ENV 22605-1 and ENV 22605-2, one test shall be made from each heat of steel to show that the material meets the elevated temperature properties listed in EN 10222-2. Impact tests (except for austenitic steels). **Number of Tests:** One test per each batch exceeding 6000 kg (13250 lb) for non-alloyed steel and austenitic steel forgings not exceeding individual weight of 1000 kg (2210 lb) and tensile strength, Rm $\leq$ 510 MPa (74 ksi). For all other forgings, one test per each batch exceeding 3000 kg (6620 lb) and the individual weight of each forging not exceeding 500 kg (1100 lb).	See the discussion on elevated temperature proof test vs. the ASME trend curve approach, above.

Test Parameter	European Standards (EN Standards)	ASME and/or ASTM Specifications	Areas of Difference	Net Effect
			Test specimen location and orientation: All samples shall be t/4 below the heat treated surface and t/2 from the end. The direction of the test specimen shall be transverse to the grain flow, except for forged bars with diameter < 160 mm (6.3 in.), in which case the shall be parallel to the grain flow.	
		ASME SA-788 (Steel Forgings)	**Mechanical tests:** The sampling, tension testing, impact testing, and hardness testing shall conform to the requirements of the product specification. Tension tests are performed at room temperature. **Number of Tests:** The number of tests is specified in the product specification and may vary in the different forging specifications. Generally, a test is required from a forging from each heat and heat treatment charge; however, more tests are specified for larger and heavier forgings. **Test specimen location and orientation:** For heat treated forgings, all test specimens shall be from a location t/4 below the heat treated surface, where t is the maximum heat treated thickness. For quenched and tempered forgings, the test specimens shall be at a distance t from any second heat treated surface. The direction of the test specimen generally is not specified in the forging specifications. With prior purchaser approval, some forging specifications also permit test specimens from heat treated ferritic thick and complex forgings to be taken at a depth t, corresponding to the distance from the area of significant stress to the nearest heat treated surface and at least twice this distance (2t) from any second surface; however, the test depth shall not be nearer to one heat treated surface than ¾ in. (19 mm) and 1½ in. (38 mm) to the second heat treated surface.	Again, there is little technical consequence arising from any differences in these test requirements.

Test Parameter	European Standards (EN Standards)	ASME and/or ASTM Specifications	Areas of Difference	Net Effect
			Impact tests: ASME-SA 788 does not require impact tests, but includes requirements for impact testing when required by the individual product specification or when specified by the purchaser. Impact test specimen are taken from locations adjacent to tension test specimen. **Test methods:** All tests shall be conducted in accordance with ASTM A 370.	
		ASME SA-961 (Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications)	**Mechanical tests:** The sampling, tension testing, impact testing, and hardness testing shall conform to the requirements of the product specification. Tension tests are performed at room temperature. **Number of tests:** Sampling for tension testing shall comply with the product specification. The number of tests is specified in the product specification and may vary in the different forging specifications. **Test specimen location and orientation:** Test specimen location and orientation are specified in SA 961. (These requirements are essentially the same as for forgings supplied to the general requirements of SA 788). **Impact tests:** ASME-SA 961 does not specify impact tests. Impact testing must be performed when required by the product specification or when specified by the purchaser. Impact test specimen are taken from locations adjacent to tension test specimen. **Test methods:** All tests shall be conducted in accordance with ASTM A 370.	

Test Parameter	European Standards (EN Standards)	ASME and/or ASTM Specifications	Areas of Difference	Net Effect
Types of inspection Documents	EN 10204		EN 10204 lists the following inspection documents, to be supplied by the material manufacturer to the Purchaser: **Type 2.1**, Statement of Compliance with the order. **Type 2.2**, Statement of Compliance with the order, with typical data. **Type 3.1**, Statement of Compliance with the order with the results of all required tests. Validated by the manufacturer's authorized inspection representative, independent of the manufacturing department.	While domestic material manufacturers all have their own quality assurance or quality control organizations, they do not have "authorized inspection representatives," which are usually taken to mean independent third-party or government inspection agencies. Whether purchasers have there on inspectors present in a material manufacturer's facility is a contractual issue, not an ASME or material specification issue. Compliance conflicts between material producers and purchasers are subject to the uniform Commercial Code and other laws such as those governing fraud.
Types of inspection Documents		ASME General Requirements Specifications (SA-20, SA-480, SA-530, SA-788, SA-961, etc.)	**Type 3.2**, Statement of Compliance with the order with the results of all required tests. Validated by the manufacturer's authorized inspection representative, independent of the manufacturing department, and by the Purchaser's authorized inspection representative or the inspector designated by the official regulations. The type of certification to be supplied by the material manufacturer is generally specified in the general requirements specifications for the various product forms (SA-20, SA-480, SA-530, SA-788, SA-961, etc.). ASME and (ASTM) has two types of certification: **Certificate of Compliance (COC)** – It contains the information specified in the product specification and in the purchase order. It may contain typical production data but need not contain test data from the actual production material. The Purchaser may also request the manufacturer to issue a Test Report in lieu of the COC. **Manufacturer's Test Report (MTR)** – The manufacturer (or processor, as applicable) shall report the results of all tests required by the material specification, applicable supplementary requirements, and the purchase order. For example, the general requirements specifications SA-20 and A-788 require Manufacturer's Test Reports for plates and	While it may surprise some, the presence or absence of any particular document has no effect on the quality of the material involved. That is determined by the chemistry, heat treatment, and control of the material manufacturing variables to which the material was subject. Be that as it may, more and more ASME material specifications have added mandatory MTR requirements.

Test Parameter	European Standards (EN Standards)	ASME and/or ASTM Specifications	Areas of Difference	Net Effect
			forgings supplied to product specifications referenced in these general requirements specifications. The general requirements specifications A 450 and A 961 permit COCs, unless the Purchaser requests an MTR.	

Notes:

[1]Reference: Bernard Creton, "Mechanical Testing Issues Related to Steels Used for Pressure Equipment", October 28, 2004.

[2]ASME adopts ASTM and international material specification specifications for ASME Code construction after the appropriate approvals by ASME Code committees. ASME material specifications include prefix S in the original specifications numbers. ASME also references the applicable ASTM standards and international standards in its specifications (e.g., A 20, E 23, E 208, etc.).

ANNEX A

List of European EN Standards for steels for pressure equipment:

EN 10028

EN 10028-1 (April 2003) - Flat products made of steels for pressure purposes - Part 1: General requirements

EN 10028-2 (December 2003) - Flat products made of steels for pressure purposes - Part 2: Non-alloy and alloy steels with specified elevated temperature properties

EN 10028-3 (December 2003) - Flat products made of steels for pressure purposes - Part 3: Weldable fine grain steels, normalized

EN 10028-4 (December 2003) - Flat products made of steels for pressure purposes - Part 4:Nickel alloy steels with specified low temperature properties

EN 10028-5 (December 2003) - Flat products made of steels for pressure purposes - Part 5: Weldable fine grain steels, thermomechanically rolled

EN 10028-6 (December 2003) - Flat products made of steels for pressure purposes - Part 6: Weldable fine grain steels, quenched and tempered

EN 10028-7 (March 2000) - Flat products made of steels for pressure purposes - Part 7: Stainless steels

EN 10213

EN 10213-1 (December 1995) - Technical delivery conditions for steel castings for pressure purposes. Part 1: General

EN 10213-2 (December 1995) – Technical delivery conditions for steel castings for pressure purposes. Part 2: Steel grades for use at room temperature and elevated temperatures

EN 10213-3 (December 1995) - Technical delivery conditions for steel castings for pressure purposes. Part 3: Steel grades for use at low temperatures

EN 10213-4 (December 1995) - Technical delivery conditions for steel castings for pressure purposes. Part 4: Austenitic and austenitic-ferritic steel grades

EN 10216

EN 10216-1 (May 2002) - Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 1: Non-alloy steel tubes with specified room temperature properties

EN 10216-2 (May 2002) - Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 2: Non-alloy and alloy steel tubes with specified elevated temperature properties

EN 10216-3 (May 2002) - Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 3: Alloy fine grain steel tubes

EN 10216-4 (May 2002) - Seamless steel tubes for pressure purposes - Technical delivery conditions - Part 4: Non-alloy and alloy steel tubes with specified low temperature properties

EN 10217

EN 10217-1(*May 2002*) - Welded steel tubes for pressure purposes - Technical delivery conditions - Part 1: Non-alloy steel tubes with specified room temperature properties

EN 10217-2 (May 2002) - Welded steel tubes for pressure purposes - Technical delivery conditions - Part 2: Electric welded non-alloy and alloy steel tubes with specified elevated temperature properties

EN 10217-3 (May 2002) - Welded steel tubes for pressure purposes - Technical delivery conditions - Part 3: Alloy fine grain steel tubes

EN 10217-4 **(**May 2002) - Welded steel tubes for pressure purposes - Technical delivery conditions - Part 4: Electric welded non-alloy steel tubes with specified low temperature properties

EN 10217-5 **(**May 2002) Welded steel tubes for pressure purposes - Technical delivery conditions - Part 5: Submerged arc welded non-alloy and alloy steel tubes with specified elevated temperature properties

EN 10217-6 (May 2002) Welded steel tubes for pressure purposes - Technical delivery conditions - Part 6: Submerged arc welded non-alloy steel tubes with specified low temperature properties

EN 10222

EN 10222-1 (January 1998) - Steel forgings for pressure purposes. Part 1: General requirements for open die forgings

EN 10222-2 (December 1999) - Steel forgings for pressure purposes - Part 2: Ferritic and martensitic steels with specified elevated temperature properties

EN 10222-3 (November 1998) - Steel forgings for pressure purposes. Part 3: Nickel steels with specified low temperature properties

EN 10222-4 (November 1998) - Steel forgings for pressure purposes. Part 4: Weldable fine grain steels with high proof strength

EN 10222-5 (December 1999) - Steel forgings for pressure purposes - Part 5: Martensitic, austenitic and austenitic-ferritic stainless steels

List of ASME and ASTM specifications for steels for pressure equipment included in this review:

ASME SA-20, Standard Specification for General Requirements for Steel Plates for Pressure Vessels.

ASME SA-370, Test Methods and Definitions for Mechanical Testing of Steel Products.

ASME SA-480, Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip.

ASME SA-788, Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts.

ASME SA-961, Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and parts for Piping Applications.

ASTM E 23, Test Methods for Notched Bar Impact Testing of Metallic Materials.

ASTM E 208, Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels.