Standard Test Methods for Mechanical Testing of Steel Products—Metric[1]

This standard is issued under the fixed designation A1058; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 These test methods cover mechanical tests described in ASTM, EN,[2] ISO,[3] and JIS[4] standards that utilize the SI system of units. The test methods in each system are not exact equivalents. Each standards system (ASTM, EN, ISO, and JIS) shall be used independently of the other. Combining requirements from any two or more systems may result in nonconformance with the purchase order.

1.2 These test methods cover procedures for the mechanical testing of steels, stainless steels, and related alloys. The various mechanical tests herein described are used to determine properties required in the product specifications. Variations in testing methods are to be avoided, and standard methods of testing are to be followed to obtain reproducible and comparable results. In those cases in which the testing requirements for certain products are unique or at variance with these general procedures, the product specification testing requirements shall control.

1.3 Only one of the testing procedure tracks shall be followed: ASTM, EN, ISO, or JIS. When a test method or practice is not available in one of the tracks then an appropriate test method or practice from an alternative track shall be used. The respective tests are listed in the column shown in Table 1.

NOTE 1—The test methods in each system are not exact equivalents.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 Attention is directed to Practice ISO 17025 when there may be a need for information on criteria for evaluation of testing laboratories.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[5]

A833 Practice for Indentation Hardness of Metallic Materials by Comparison Hardness Testers
A956 Test Method for Leeb Hardness Testing of Steel Products
A1038 Test Method for Portable Hardness Testing by the Ultrasonic Contact Impedance Method
E8/E8M Test Methods for Tension Testing of Metallic Materials
E10 Test Method for Brinell Hardness of Metallic Materials
E18 Test Methods for Rockwell Hardness of Metallic Materials
E23 Test Methods for Notched Bar Impact Testing of Metallic Materials
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E110 Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers
E190 Test Method for Guided Bend Test for Ductility of Welds
E290 Test Methods for Bend Testing of Material for Ductility

2.2 *Other Documents:*

ASME Boiler and Pressure Vessel Code Section VIII, Division I[6]
ISO 148-1 Metallic Materials—Charpy Pendulum Impact Test—Part 1: Test Method[7]
ISO 148-2 Metallic Materials—Charpy Pendulum Impact

[1] These test methods are under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and are the direct responsibility of Subcommittee A01.13 on Mechanical and Chemical Testing and Processing Methods of Steel Products and Processes.

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[2] Available from British Standards Institute (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., http://www.bsi-global.com.

[3] Available from International Organization for Standardization, 1 rue de Varembé, Case postale, CH-1211, Genève 20, Switzerland, http://www.iso.org.

[4] Available from Japanese Standards Association, 4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440, Japan, http://www.jsa.or.jp.

[5] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[6] Available from American Society of Mechanical Engineers, ASME International, Three Park Avenue, New York, NY 10016-5990, USA, http://www.asme.org.

[7] These standards are also designed EN ISO: this identifies the adoption of ISO standards by EN. "EN ISO" is part of the designation.

***A Summary of Changes section appears at the end of this standard**

TABLE 1 Tests and Applicable Standards

Test	Sections	ASTM	EN	ISO	JIS
Tension	5 to 12	E8/E8M	10002-1	6892-1	Z 2241
Bend	13	E190 E290	7438[A]	7438	Z 2248
Bend (tube)	13	...	10232	8491	...
Hardness	14				
Brinell	15	E10	6506-1[A]	6506-1	Z 2243
Rockwell	16	E18	6508-1[A]	6508-1	Z 2245
Portable	17	A833 E110 A1038	...	...	...
Impact	18 to 26	E23	148-1[A]	148-1	Z 2242
Keywords	27	...	...	...	...

[A] These standards are designated EN ISO; this identifies the adoption of ISO standards by EN. "EN ISO" is part of the designation.

Test—Part 2: Verification of Test Machines[7]

ISO 2566-1 Steel—Conversion of Elongation Values—Part 1: Carbon and Low Alloy Steels[7]

ISO 2566-2 Steel—Conversion of Elongation Values—Part 2: Austenitic Steels[7]

ISO 6506-1 Metallic Materials—Brinell Hardness Test—Part 1: Test Method[7]

ISO 6508-1 Metallic Materials—Rockwell Hardness Test—Part 1: Test Method (Scales A, B, C, D, E, F, G, H, K, N, T)[7]

ISO 6892-1 Metallic Materials—Tensile Testing at Ambient Temperature[7]

ISO 7438 Metallic Materials—Bend Test[7]

ISO 8491 Metallic Materials—Tube (in Full Section)—Bend Test[7]

ISO 17025 General Requirements for the Competence of Testing and Calibration Laboratories[7]

JIS B 7722 Charpy Pendulum Impact Test—Verification of Testing Machines

JIS Z 2201 Test Pieces for Tensile Test for Metallic Materials

JIS Z 2241 Method of Tensile Test for Metallic Materials

JIS Z 2242 Method of Charpy Pendulum Impact Test for Metallic Materials

JIS Z 2243 Brinell Hardness Test—Test Method

JIS Z 2245 Rockwell Hardness Test—Test Method

JIS Z 2248 Method of Bend Test for Metallic Materials

3. General Precautions

3.1 The ASTM track is the default track; if other than the ASTM track is used that track shall be reported.

3.2 Certain methods of fabrication, such as bending, forming, and welding, or operations involving heating, may affect the properties of the material under test. Therefore, the product specifications cover the stage of manufacture at which mechanical testing is to be performed. The properties shown by testing prior to fabrication may not necessarily be representative of the product after it has been completely fabricated.

3.3 Improper machining or preparation of test specimens may give erroneous results. Care should be exercised to assure good workmanship in machining. Improperly machined specimens should be discarded and other specimens substituted.

3.4 Flaws in the specimen may also affect results. If any test specimen develops flaws, the retest provision of the applicable product specification shall govern.

3.5 If any test specimen fails because of mechanical reasons such as failure of testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

4. Orientation of Test Specimens

4.1 The terms "longitudinal test" and "transverse test" are used only in material specifications for wrought products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:

4.1.1 *Longitudinal Test,* unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is parallel to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a longitudinal tension test specimen is in the direction of the greatest extension, and the axis of the fold of a longitudinal bend test specimen is at right angles to the direction of greatest extension.

4.1.2 *Transverse Test,* unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is at right angles to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a transverse tension test specimen is at right angles to the greatest extension, and the axis of the fold of a transverse bend test specimen is parallel to the greatest extension.

4.2 The terms "radial test" and "tangential test" are used in material specifications for some wrought circular products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:

4.2.1 *Radial Test,* unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to the axis of the product and coincident with one of the radii of a circle drawn with a point on the axis of the product as a center.

4.2.2 *Tangential Test,* unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to a plane containing the axis of the product and tangent to a circle drawn with a point on the axis of the product as a center.

TENSION TEST

5. Description

5.1 The tension test related to the mechanical testing of steel products subjects a machined or full-section specimen of the material under examination to a measured load sufficient to cause rupture. The resulting properties sought are defined in Test Methods E8/E8M, ISO 6892-1, or JIS Z 2241 as applicable.

5.2 In general, the testing equipment and methods are given in Test Methods E8/E8M, ISO 6892-1 and JIS Z 2241. However, there are certain exceptions to these practices; these exceptions are covered in this standard.

6. Testing Apparatus and Operations

6.1 *Loading Systems*—There are two general types of loading systems, mechanical (screw power) and hydraulic. These differ chiefly in the variability of the rate of load application. The older screw power machines are limited to a small number of fixed free running crosshead speeds. Some modern screw power machines, and all hydraulic machines permit stepless variation throughout the range of speeds.

6.2 The tension testing machine shall be maintained in good operating condition, used only in the proper loading range, and calibrated periodically in accordance with the latest revision of the appropriate practices.

NOTE 2—Many machines are equipped with stress-strain recorders for autographic plotting of stress-strain curves. It should be noted that some recorders have a load measuring component entirely separate from the load indicator of the testing machine. Such recorders are calibrated separately.

6.3 *Loading*—It is the function of the gripping or holding device of the testing machine to transmit the load from the heads of the machine to the specimen under test. The essential requirement is that the load shall be transmitted axially. This implies that the centers of the action of the grips shall be in alignment, insofar as practicable, with the axis of the specimen at the beginning and during the test and that bending and twisting be held to a minimum.

6.4 *Speed of Testing*—The speed of testing shall not be greater than that at which load and strain readings can be made accurately. In production testing, speed of testing is commonly expressed *(1)* in terms of free running crosshead speed (rate of movement of the crosshead of the testing machine when not under load), or *(2)* in terms of rate of separation of the two heads of the testing machine under load, or *(3)* in terms of rate of stressing the specimen, or *(4)* in terms of rate of straining the specimen. The following limitations on the speed of testing are recommended as adequate for most steel products:

NOTE 3—Tension tests using closed-loop machines (with feedback control of rate) should not be performed using load control, as this mode of testing will result in acceleration of the crosshead upon yielding and elevation of the measured yield strength.

6.4.1 Any convenient speed of testing may be used up to one half the specified yield point or yield strength. When this point is reached, the free-running rate of separation of the crossheads shall be adjusted so as not to exceed 0.025 mm per second per 25 mm of reduced section, or the distance between the grips for test specimens not having reduced sections. This speed shall be maintained through the yield point or yield strength. In determining the tensile strength, the free-running rate of separation of the heads shall not exceed 13 mm per min per 25 mm of reduced section, or the distance between the grips for test specimens not having reduced sections. In any event, the minimum speed of testing shall not be less than 1⁄10 the specified maximum rates for determining yield point or yield strength and tensile strength.

6.4.2 It shall be permissible to set the speed of the testing machine by adjusting the free running crosshead speed to the above specified values, inasmuch as the rate of separation of heads under load at these machine settings is less than the specified values of free running crosshead speed.

6.4.3 As an alternative, if the machine is equipped with a device to indicate the rate of loading, the speed of the machine from half the specified yield point or yield strength through the yield point or yield strength may be adjusted so that the rate of stressing does not exceed 11 MPa per second. However, the minimum rate of stressing shall not be less than 1 MPa per second.

7. Test Specimen Parameters

7.1 *Selection*—Test coupons shall be selected in accordance with the applicable product specifications.

7.2 *Size and Tolerances*—Test specimen dimensions and tolerances shall comply with the requirements of the relevant standards.

7.3 *Procurement of Test Specimens*—Specimens shall be prepared from portions of the material. They are usually machined so as to have a reduced cross section at mid-length in order to obtain uniform distribution of the stress over the cross section and to localize the zone of fracture. Care shall be taken to remove by machining all distorted, cold-worked, or heat-affected areas from the edges of the section used in evaluating the test.

7.4 *Aging of Test Specimens*—Unless otherwise specified, it shall be permissible to age tension test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water, heating in oil or in an oven.

7.5 *Measurement of Dimensions of Test Specimens*—Test specimens shall be measured in accordance with the requirements of 7.5.1 and 7.5.2 for ASTM or the appropriate paragraphs of ISO 6892-1, or JIS Z 2241 as applicable.

7.5.1 *Rectangular Tension Test*—These forms of specimens are shown in Test Methods E8/E8M. To determine the cross-sectional area, the center width dimension shall be measured to the nearest 0.15 mm for the 200-mm gauge length specimen and 0.025 mm for the 50-mm gauge length specimen. The center thickness dimension shall be measured to the nearest 0.025 mm for both specimens.

7.5.2 *Round Tension Test Specimens*—These forms of specimens are shown in Test Methods E8/E8M. To determine the cross-sectional area, the diameter shall be measured at the center of the gauge length to the nearest 0.025 mm.

7.6 *General*—Test specimens shall be either substantially full size or machined, as prescribed in the product specifications for the material being tested.

7.6.1 It is desirable to have the cross-sectional area of the specimen smallest at the center of the gauge length to ensure fracture within the gauge length. This is provided for by the taper in the gauge length permitted for each of the specimens described in the following sections.

7.6.2 For low ductility materials it is desirable to have fillets of large radius at the ends of the gauge length.

8. Plate-Type Specimen

8.1 The standard plate-type test specimen is shown in Test Methods E8/E8M, ISO 6892-1, or JIS Z 2241. This specimen is used for testing metallic materials in the form of plate, structural and bar-size shapes, and flat material having a nominal thickness of 5 mm or over. When product specifications so permit, other types of specimens may be used.

9. Sheet-Type Specimen

9.1 The standard sheet-type test specimen is shown in Test Methods E8/E8M, ISO 6892-1, or JIS Z 2241. This specimen is used for testing metallic materials in the form of sheet, plate, flat wire, strip, band, and hoop ranging in nominal thickness from 0.13 to 19 mm. When product specifications so permit, other types of specimens may be used, as specified in Test Methods E8/E8M.

10. Round Specimens

10.1 The standard diameter round test specimen as shown in Test Methods E8/E8M, ISO 6892-1, or JIS Z 2241 is frequently used for testing metallic materials.

10.2 Small size specimens proportional to standard specimens may be used when it is necessary to test material from which the standard specimens cannot be prepared. When small size specimens are used, the gauge length for measurement of elongation shall be five times the diameter of the specimen.

10.3 The type of specimen ends outside of the gauge length shall accommodate the shape of the product tested, and shall properly fit the holders or grips of the testing machine so that axial loads are applied with a minimum of load eccentricity and slippage.

11. Gauge Marks

11.1 Test specimens shall be marked in accordance with the requirements of the relevant standards.

12. Determination of Tensile Properties

12.1 The determination and description of the tensile properties shall be in accordance with the requirements of the relevant standards.

12.2 Elongation values may be converted from (i) 4d gauge length to a 5d gauge length, or (ii) 5d gage length to a 4d gage length by use of the multiplication factors shown in Table 2. If this conversion is used, the supplier must show the calculation on the certification.

12.2.1 *Example 1*—Conversion of Carbon and low alloy steel elongation derived from 4d gauge length to a 5d gauge length elongation value:

$$23\ \% \times 0.916 = 21\ \%$$

TABLE 2 Conversion Factors for 4d and 5d Gauge Lengths (ISO 2566-1 and ISO 2566-2)

Conversion from	4d to 5d	5d to 4d
Carbon and low alloy steels	0.916	1.093
Austenitic steels	0.972	1.029

12.2.2 *Example 2*—Conversion of Austenitic steel elongation derived from 5d gauge length to a 4d gauge length elongation value:

$$23\ \% \times 1.029 = 24\ \%$$

12.3 *Reduction of Area*—Fit the ends of the fractured specimen together and measure the mean diameter or the width and thickness at the smallest cross section to the same accuracy as the original dimensions. The difference between the area thus found and the area of the original cross section expressed as a percentage of the original area is the reduction of area.

BEND TEST

13. Description

13.1 The bend test is one method for evaluating ductility, but it cannot be considered as a quantitative means of predicting service performance in all bending operations. The severity of the bend test is primarily a function of the angle of bend and inside diameter to which the specimen is bent, and of the cross section of the specimen. These conditions are varied according to location and orientation of the test specimen and the chemical composition, tensile properties, hardness, type, and quality of the steel specified. Test Method E190, Test Methods E290, EN ISO 7438, EN 10232 (tube), ISO 7438, or ISO 8491 (tube) and JIS Z 2248 may be consulted for methods of performing the test.

13.2 Unless otherwise specified, it shall be permissible to age bend test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water or by heating in oil or in an oven.

13.3 Bend the test specimen at room temperature to an inside diameter, as designated by the applicable product specifications, to the extent specified. The speed of bending is ordinarily not an important factor.

HARDNESS TEST

14. General

14.1 A hardness test is a means of determining resistance to penetration and is occasionally employed to obtain a quick approximation of tensile strength. Table 3, Table 4, Table 5, and Table 6 are for the conversion of hardness measurements from one scale to another or to approximate tensile strength. These conversion values have been obtained from computer-generated curves and are presented to the nearest 0.1 point to permit accurate reproduction of those curves. Since all converted hardness values must be considered approximate, however, all converted Rockwell hardness numbers shall be rounded to the nearest whole number.

14.2 *Hardness Testing:*

14.2.1 If the product specification permits alternative hardness testing to determine conformance to a specified hardness requirement, the conversions listed in Table 3, Table 4, Table 5, and Table 6 shall be used.

TABLE 3 Approximate Hardness Conversion Numbers for Nonaustenitic Steels[A] (Rockwell C to Other Hardness Numbers)

Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness			Approximate Tensile Strength, ksi (MPa)
					15N Scale, 15-kgf Load, Diamond Penetrator	30N Scale 30-kgf Load, Diamond Penetrator	45N Scale, 45-kgf Load, Diamond Penetrator	
68	940	. . .	920	85.6	93.2	84.4	75.4	. . .
67	900	. . .	895	85.0	92.9	83.6	74.2	. . .
66	865	. . .	870	84.5	92.5	82.8	73.3	. . .
65	832	739	846	83.9	92.2	81.9	72.0	. . .
64	800	722	822	83.4	91.8	81.1	71.0	. . .
63	772	706	799	82.8	91.4	80.1	69.9	. . .
62	746	688	776	82.3	91.1	79.3	68.8	. . .
61	720	670	754	81.8	90.7	78.4	67.7	. . .
60	697	654	732	81.2	90.2	77.5	66.6	. . .
59	674	634	710	80.7	89.8	76.6	65.5	351 (2420)
58	653	615	690	80.1	89.3	75.7	64.3	338 (2330)
57	633	595	670	79.6	88.9	74.8	63.2	325 (2240)
56	613	577	650	79.0	88.3	73.9	62.0	313 (2160)
55	595	560	630	78.5	87.9	73.0	60.9	301 (2070)
54	577	543	612	78.0	87.4	72.0	59.8	292 (2010)
53	560	525	594	77.4	86.9	71.2	58.6	283 (1950)
52	544	512	576	76.8	86.4	70.2	57.4	273 (1880)
51	528	496	558	76.3	85.9	69.4	56.1	264 (1820)
50	513	482	542	75.9	85.5	68.5	55.0	255 (1760)
49	498	468	526	75.2	85.0	67.6	53.8	246 (1700)
48	484	455	510	74.7	84.5	66.7	52.5	238 (1640)
47	471	442	495	74.1	83.9	65.8	51.4	229 (1580)
46	458	432	480	73.6	83.5	64.8	50.3	221 (1520)
45	446	421	466	73.1	83.0	64.0	49.0	215 (1480)
44	434	409	452	72.5	82.5	63.1	47.8	208 (1430)
43	423	400	438	72.0	82.0	62.2	46.7	201 (1390)
42	412	390	426	71.5	81.5	61.3	45.5	194 (1340)
41	402	381	414	70.9	80.9	60.4	44.3	188 (1300)
40	392	371	402	70.4	80.4	59.5	43.1	182 (1250)
39	382	362	391	69.9	79.9	58.6	41.9	177 (1220)
38	372	353	380	69.4	79.4	57.7	40.8	171 (1180)
37	363	344	370	68.9	78.8	56.8	39.6	166 (1140)
36	354	336	360	68.4	78.3	55.9	38.4	161 (1110)
35	345	327	351	67.9	77.7	55.0	37.2	156 (1080)
34	336	319	342	67.4	77.2	54.2	36.1	152 (1050)
33	327	311	334	66.8	76.6	53.3	34.9	149 (1030)
32	318	301	326	66.3	76.1	52.1	33.7	146 (1010)
31	310	294	318	65.8	75.6	51.3	32.5	141 (970)
30	302	286	311	65.3	75.0	50.4	31.3	138 (950)
29	294	279	304	64.6	74.5	49.5	30.1	135 (930)
28	286	271	297	64.3	73.9	48.6	28.9	131 (900)
27	279	264	290	63.8	73.3	47.7	27.8	128 (880)
26	272	258	284	63.3	72.8	46.8	26.7	125 (860)
25	266	253	278	62.8	72.2	45.9	25.5	123 (850)
24	260	247	272	62.4	71.6	45.0	24.3	119 (820)
23	254	243	266	62.0	71.0	44.0	23.1	117 (810)
22	248	237	261	61.5	70.5	43.2	22.0	115 (790)
21	243	231	256	61.0	69.9	42.3	20.7	112 (770)
20	238	226	251	60.5	69.4	41.5	19.6	110 (760)

[A] This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. The data in this table should not be used to establish a relationship between hardness values and tensile strength of hard drawn wire. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

14.2.2 When recording converted hardness numbers, the measured hardness and test scale shall be indicated in parentheses, for example: 353 HBW (38 HRC). This means that a hardness value of 38 was obtained using the Rockwell C scale and converted to a Brinell hardness of 353.

15. Brinell Test

15.1 The Brinell Test shall be carried out in accordance with the requirements of Test Method E10, ISO 6506-1, or JIS Z 2243.

TABLE 4 Approximate Hardness Conversion Numbers for Nonaustenitic Steels[A] (Rockwell B to Other Hardness Numbers)

Rockwell B Scale, 100-kgf Load 1/16-in. (1.588-mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell F Scale, 60-kgf Load, 1/16-in. (1.588-mm) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
						15T Scale, 15-kgf Load, 1/16-in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1/16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1/16-in. (1.588-mm) Ball	
100	240	240	251	61.5	. . .	93.1	83.1	72.9	116 (800)
99	234	234	246	60.9	. . .	92.8	82.5	71.9	114 (785)
98	228	228	241	60.2	. . .	92.5	81.8	70.9	109 (750)
97	222	222	236	59.5	. . .	92.1	81.1	69.9	104 (715)
96	216	216	231	58.9	. . .	91.8	80.4	68.9	102 (705)
95	210	210	226	58.3	. . .	91.5	79.8	67.9	100 (690)
94	205	205	221	57.6	. . .	91.2	79.1	66.9	98 (675)
93	200	200	216	57.0	. . .	90.8	78.4	65.9	94 (650)
92	195	195	211	56.4	. . .	90.5	77.8	64.8	92 (635)
91	190	190	206	55.8	. . .	90.2	77.1	63.8	90 (620)
90	185	185	201	55.2	. . .	89.9	76.4	62.8	89 (615)
89	180	180	196	54.6	. . .	89.5	75.8	61.8	88 (605)
88	176	176	192	54.0	. . .	89.2	75.1	60.8	86 (590)
87	172	172	188	53.4	. . .	88.9	74.4	59.8	84 (580)
86	169	169	184	52.8	. . .	88.6	73.8	58.8	83 (570)
85	165	165	180	52.3	. . .	88.2	73.1	57.8	82 (565)
84	162	162	176	51.7	. . .	87.9	72.4	56.8	81 (560)
83	159	159	173	51.1	. . .	87.6	71.8	55.8	80 (550)
82	156	156	170	50.6	. . .	87.3	71.1	54.8	77 (530)
81	153	153	167	50.0	. . .	86.9	70.4	53.8	73 (505)
80	150	150	164	49.5	. . .	86.6	69.7	52.8	72 (495)
79	147	147	161	48.9	. . .	86.3	69.1	51.8	70 (485)
78	144	144	158	48.4	. . .	86.0	68.4	50.8	69 (475)
77	141	141	155	47.9	. . .	85.6	67.7	49.8	68 (470)
76	139	139	152	47.3	. . .	85.3	67.1	48.8	67 (460)
75	137	137	150	46.8	99.6	85.0	66.4	47.8	66 (455)
74	135	135	147	46.3	99.1	84.7	65.7	46.8	65 (450)
73	132	132	145	45.8	98.5	84.3	65.1	45.8	64 (440)
72	130	130	143	45.3	98.0	84.0	64.4	44.8	63 (435)
71	127	127	141	44.8	97.4	83.7	63.7	43.8	62 (425)
70	125	125	139	44.3	96.8	83.4	63.1	42.8	61 (420)
69	123	123	137	43.8	96.2	83.0	62.4	41.8	60 (415)
68	121	121	135	43.3	95.6	82.7	61.7	40.8	59 (405)
67	119	119	133	42.8	95.1	82.4	61.0	39.8	58 (400)
66	117	117	131	42.3	94.5	82.1	60.4	38.7	57 (395)
65	116	116	129	41.8	93.9	81.8	59.7	37.7	56 (385)
64	114	114	127	41.4	93.4	81.4	59.0	36.7	. . .
63	112	112	125	40.9	92.8	81.1	58.4	35.7	. . .
62	110	110	124	40.4	92.2	80.8	57.7	34.7	. . .
61	108	108	122	40.0	91.7	80.5	57.0	33.7	. . .
60	107	107	120	39.5	91.1	80.1	56.4	32.7	. . .
59	106	106	118	39.0	90.5	79.8	55.7	31.7	. . .
58	104	104	117	38.6	90.0	79.5	55.0	30.7	. . .
57	103	103	115	38.1	89.4	79.2	54.4	29.7	. . .
56	101	101	114	37.7	88.8	78.8	53.7	28.7	. . .
55	100	100	112	37.2	88.2	78.5	53.0	27.7	. . .
54	. . .	. . .	111	36.8	87.7	78.2	52.4	26.7	. . .
53	. . .	. . .	110	36.3	87.1	77.9	51.7	25.7	. . .
52	. . .	. . .	109	35.9	86.5	77.5	51.0	24.7	. . .
51	. . .	. . .	108	35.5	86.0	77.2	50.3	23.7	. . .
50	. . .	. . .	107	35.0	85.4	76.9	49.7	22.7	. . .
49	. . .	. . .	106	34.6	84.8	76.6	49.0	21.7	. . .
48	. . .	. . .	105	34.1	84.3	76.2	48.3	20.7	. . .
47	. . .	. . .	104	33.7	83.7	75.9	47.7	19.7	. . .
46	. . .	. . .	103	33.3	83.1	75.6	47.0	18.7	. . .
45	. . .	. . .	102	32.9	82.6	75.3	46.3	17.7	. . .
44	. . .	. . .	101	32.4	82.0	74.9	45.7	16.7	. . .
43	. . .	. . .	100	32.0	81.4	74.6	45.0	15.7	. . .
42	. . .	. . .	99	31.6	80.8	74.3	44.3	14.7	. . .
41	. . .	. . .	98	31.2	80.3	74.0	43.7	13.6	. . .
40	. . .	. . .	97	30.7	79.7	73.6	43.0	12.6	. . .
39	. . .	. . .	96	30.3	79.1	73.3	42.3	11.6	. . .
38	. . .	. . .	95	29.9	78.6	73.0	41.6	10.6	. . .
37	. . .	. . .	94	29.5	78.0	72.7	41.0	9.6	. . .
36	. . .	. . .	93	29.1	77.4	72.3	40.3	8.6	. . .
35	. . .	. . .	92	28.7	76.9	72.0	39.6	7.6	. . .
34	. . .	. . .	91	28.2	76.3	71.7	39.0	6.6	. . .
33	. . .	. . .	90	27.8	75.7	71.4	38.3	5.6	. . .

TABLE 4 *Continued*

Rockwell B Scale, 100-kgf Load 1⁄16-in. (1.588-mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell F Scale, 60-kgf Load, 1⁄16-in. (1.588-mm) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
						15T Scale, 15-kgf Load, 1⁄16-in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1⁄16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1⁄16-in. (1.588-mm) Ball	
32	. . .	. . .	89	27.4	75.2	71.0	37.6	4.6	. . .
31	. . .	. . .	88	27.0	74.6	70.7	37.0	3.6	. . .
30	. . .	. . .	87	26.6	74.0	70.4	36.3	2.6	. . .

[A] This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. The data in this table should not be used to establish a relationship between hardness values and tensile strength of hard drawn wire. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 5 Approximate Hardness Conversion Numbers for Austenitic Steels (Rockwell C to other Hardness Numbers)

Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
		15N Scale, 15-kgf Load, Diamond Penetrator	30N Scale, 30-kgf Load, Diamond Penetrator	45N Scale, 45-kgf Load, Diamond Penetrator
48	74.4	84.1	66.2	52.1
47	73.9	83.6	65.3	50.9
46	73.4	83.1	64.5	49.8
45	72.9	82.6	63.6	48.7
44	72.4	82.1	62.7	47.5
43	71.9	81.6	61.8	46.4
42	71.4	81.0	61.0	45.2
41	70.9	80.5	60.1	44.1
40	70.4	80.0	59.2	43.0
39	69.9	79.5	58.4	41.8
38	69.3	79.0	57.5	40.7
37	68.8	78.5	56.6	39.6
36	68.3	78.0	55.7	38.4
35	67.8	77.5	54.9	37.3
34	67.3	77.0	54.0	36.1
33	66.8	76.5	53.1	35.0
32	66.3	75.9	52.3	33.9
31	65.8	75.4	51.4	32.7
30	65.3	74.9	50.5	31.6
29	64.8	74.4	49.6	30.4
28	64.3	73.9	48.8	29.3
27	63.8	73.4	47.9	28.2
26	63.3	72.9	47.0	27.0
25	62.8	72.4	46.2	25.9
24	62.3	71.9	45.3	24.8
23	61.8	71.3	44.4	23.6
22	61.3	70.8	43.5	22.5
21	60.8	70.3	42.7	21.3
20	60.3	69.8	41.8	20.2

15.1.1 A range of hardness can properly be specified only for quenched and tempered or normalized and tempered material. For annealed material a maximum figure only should be specified. For normalized material a minimum or a maximum hardness may be specified by agreement. In general, no hardness requirements should be applied to untreated material.

15.1.2 Brinell hardness may be required when tensile properties are not specified.

15.2 *Test Specimen*—Brinell hardness tests are made on prepared areas and sufficient metal must be removed from the surface to eliminate decarburized metal and other surface irregularities. The thickness of the piece tested must be such that no bulge or other marking showing the effect of the load appears on the side of the piece opposite the indentation.

15.3 *Procedure:*

15.3.1 It is essential that the applicable product specifications state clearly the position at which Brinell hardness indentations are to be made and the number of such indentations required. The distance of the center of the indentation from the edge of the specimen or edge of another indentation must be at least two and one-half times the diameter of the indentation.

15.3.2 Measure two diameters of the indentation at right angles to the nearest 0.1 mm, estimate to the nearest 0.05 mm,

TABLE 6 Approximate Hardness Conversion Numbers for Austenitic Steels (Rockwell B to other Hardness Numbers)

Rockwell B Scale, 100-kgf Load, 1⁄16-in. (1.588-mm) Ball	Brinell Indentation Diameter, mm	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
				15T Scale, 15-kgf Load, 1⁄16-in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1⁄16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1⁄16-in. (1.588-mm) Ball
100	3.79	256	61.5	91.5	80.4	70.2
99	3.85	248	60.9	91.2	79.7	69.2
98	3.91	240	60.3	90.8	79.0	68.2
97	3.96	233	59.7	90.4	78.3	67.2
96	4.02	226	59.1	90.1	77.7	66.1
95	4.08	219	58.5	89.7	77.0	65.1
94	4.14	213	58.0	89.3	76.3	64.1
93	4.20	207	57.4	88.9	75.6	63.1
92	4.24	202	56.8	88.6	74.9	62.1
91	4.30	197	56.2	88.2	74.2	61.1
90	4.35	192	55.6	87.8	73.5	60.1
89	4.40	187	55.0	87.5	72.8	59.0
88	4.45	183	54.5	87.1	72.1	58.0
87	4.51	178	53.9	86.7	71.4	57.0
86	4.55	174	53.3	86.4	70.7	56.0
85	4.60	170	52.7	86.0	70.0	55.0
84	4.65	167	52.1	85.6	69.3	54.0
83	4.70	163	51.5	85.2	68.6	52.9
82	4.74	160	50.9	84.9	67.9	51.9
81	4.79	156	50.4	84.5	67.2	50.9
80	4.84	153	49.8	84.1	66.5	49.9

and average to the nearest 0.05 mm. If the two diameters differ by more than 0.1 mm, discard the readings and make a new indentation.

16. Rockwell Test

16.1 The Rockwell Test shall be carried out in accordance with the requirements of Test Methods E18, ISO 6508-1, or JIS Z 2245.

17. Portable Hardness Test

17.1 Although this standard generally prefers the use of fixed-location Brinell or Rockwell hardness test methods, it is not always possible to perform the hardness test using such equipment due to the part size, location, or other logistical reasons. In this event, hardness testing using portable equipment as described in Test Methods A956, A1038, and E110 shall be used with strict compliance for reporting the test results in accordance with the selected standard (see examples below). Standard Practice A833 may be used, although it might not always be suitable as a criterion for acceptance or rejection since Practice A833 does not contain a precision and bias statement.

17.1.1 *Practice A833*—The measured hardness number shall be reported in accordance with the standard methods and given the HBC designation followed by the comparative test bar hardness to indicate that it was determined by a portable comparative hardness tester, as in the following example:

17.1.1.1 *232 HBC/240* where 232 is the hardness test result using the portable comparative test method (HBC) and 240 is the Brinell hardness of the comparative test bar.

17.1.2 *Practice A956:*

17.1.2.1 The measured hardness number shall be reported in accordance with the standard methods and appended with a Leeb impact device in parenthesis to indicate that it was determined by a portable hardness tester, as in the following example:

(1) 350 HLD where 350 is the hardness test result using the portable Leeb hardness test method with the HLD impact device.

17.1.2.2 When hardness values converted from the Leeb number are reported, the portable instrument used shall be reported in parentheses, for example:

(1) 350 HB (HLD) where the original hardness test was performed using the portable Leeb hardness test method with the HLD impact device and converted to the Brinell hardness value (HB).

17.1.3 *Test Method A1038*—The measured hardness number shall be reported in accordance with the standard methods and appended with UCI in parenthesis to indicate that it was determined by a portable hardness tester, as in the following example:

17.1.3.1 *446 HV (UCI) 10* where 446 is the hardness test result using the portable UCI test method under a force of 10 kgf.

17.1.4 *Test Method E110:* The measured hardness number shall be reported in accordance with the standard methods and appended with a /P to indicate that it was determined by a portable hardness tester, as follows:

17.1.4.1 *Rockwell Hardness Examples:*

(1) 40 HRC/P where 40 is the hardness test result using the Rockwell C portable test method.

(2) 72 HRBW/P where 72 is the hardness test result using the Rockwell B portable test method using a tungsten carbide ball indenter.

17.1.4.2 *Brinell Hardness Examples:*

(1) 220 HBW/P 10/3000 where 220 is the hardness test result using the Brinell portable test method with a ball of 10 mm diameter and with a test force of 3000 kgf (29.42 kN) applied for 10 s to 15 s.

(2) 350 HBW/P 5/750 where 350 is the hardness test result using the Brinell portable test method with a ball of 5 mm diameter and with a test force of 750 kgf (7.355 kN) applied for 10 s to 15 s.

CHARPY IMPACT TESTING

18. Description

18.1 The equipment, test specimen and testing procedures shall comply with the requirements of Test Methods E23, ISO 148-1, or JIS Z 2242.

19. Testing Machines

19.1 Charpy machines used for testing steel generally have capacities in the 300 to 400 J energy range. Sometimes machines of lesser capacity are used; however, the capacity of the machine should be substantially in excess of the absorbed energy of the specimens (see Test Methods E23). The linear velocity at the point of impact should be in the range of 4.9 to 5.8 m/s or in accordance with ISO 148-1, or JIS Z 2242.

20. Sampling and Number of Specimens

20.1 *Sampling:*

20.1.1 Test location and orientation should be addressed by the product specifications. If not, for wrought products, the test location shall be the same as that for the tensile specimen and the orientation shall be longitudinal with the notch perpendicular to the major surface of the product being tested.

20.1.2 *Number of Specimens:*

20.1.2.1 All specimens used for a Charpy impact test shall be taken from a single test coupon or test location.

20.1.2.2 When the specification calls for a minimum average test result, three specimens shall be tested.

20.1.2.3 When the specification requires determination of a transition temperature, eight to twelve specimens are usually needed.

20.2 *Type and Size:*

20.2.1 A standard full size Charpy V-notch specimen as shown in Test Methods E23, ISO 148-1, or JIS Z 2242 shall be used except as provided in the following sub-paragraphs.

20.2.2 If a standard full-size specimen cannot be prepared, the largest feasible standard subsize specimen shall be prepared. The specimens shall be machined so that the specimen does not include material nearer to the surface than 0.5 mm.

20.2.3 Tolerances for standard subsize specimens are shown in Test Methods E23, ISO 148-1, or JIS Z 2242.

20.3 *Notch Preparation*—The machining of the notch is critical, as it has been demonstrated that extremely minor variations in notch radius and profile, or tool marks at the bottom of the notch may result in erratic test data.

21. Calibration

21.1 *Accuracy and Sensitivity*—Calibrate and adjust Charpy impact machines in accordance with the requirements of the test methods used Test Methods E23, ISO 148-2, or JIS B 7722.

22. Conditioning—Temperature Control

22.1 When a specific test temperature is required by the specification or purchaser, control the temperature of the heating or cooling medium within ±2°F (1°C).

23. Procedure

23.1 *Individual Test Values:*

23.1.1 *Impact Energy*—Record the impact energy absorbed to the nearest J.

23.1.2 *Fracture Appearance:*

23.1.2.1 Determine the percentage of shear fracture area by any of the methods described in Test Methods E23, ISO 148-1, or JIS Z 2242.

23.1.2.2 Determine the individual fracture appearance values to the nearest 5 % shear fracture and record the value.

23.1.3 *Lateral Expansion:*

23.1.3.1 Methods of measurement and precautions are described in Test Methods E23.

23.1.3.2 Measure the individual lateral expansion values to the nearest 0.025 mm and record the values.

23.1.3.3 With the exception described as follows, any specimen that does not separate into two pieces when struck by a single blow may be reported as unbroken. If the specimen can be separated by force applied by bare hands, the specimen may be considered as having been separated by the blow.

24. Interpretation of Test Result

24.1 When the acceptance criterion of any impact test is specified to be a minimum average value at a given temperature, the test result shall be the average (arithmetic mean) of the individual test values of three specimens from one test location.

24.1.1 When a minimum average test result is specified:

24.1.1.1 The test result is acceptable when all of the below are met:

(1) The test result equals or exceeds the specified minimum average (given in the specification),

(2) The individual test value for not more than one specimen measures less than the specified minimum average, and

(3) The individual test value for any specimen measures not less than two-thirds of the specified minimum average.

24.1.1.2 If the acceptance requirements of 24.1.1.1 are not met, perform one retest of three additional specimens from the same test location. Each individual test value of the retested specimens shall be equal to or greater than the specified minimum average value.

24.2 *Test Specifying a Minimum Transition Temperature:*

24.2.1 *Definition of Transition Temperature*—For specification purposes, the transition temperature is the temperature at which the designated material test value equals or exceeds a specified minimum test value.

24.2.2 *Determination of Transition Temperature:*

TABLE 7 Charpy V-Notch Test Acceptance Criteria for Various Sub-Size Specimens described by Test Methods E23

Full Size 10 by 10 mm	¾ Size 10 by 7.5 mm	⅔ Size 10 by 6.7 mm	½ Size 10 by 5 mm	⅓ Size 10 by 3.3 mm	¼ Size 10 by 2.5 mm
J	J	J	J	J	J
54	41	37	27	18	14
48	35	31	24	16	12
41	30	27	20	14	11
34	26	23	16	11	8
27	20	18	14	10	7
22	16	15	11	7	5
20	15	14	11	7	5
18	14	12	8	5	4
16	12	11	8	5	4
14	11	10	7	4	3
10	7	7	5	3	3

24.2.2.1 Break one specimen at each of a series of temperatures above and below the anticipated transition temperature using the procedures in Section 23. Record each test temperature to the nearest 0.5°C.

24.2.2.2 Plot the individual test results (J or percent shear) as the ordinate versus the corresponding test temperature as the abscissa and construct a best-fit curve through the plotted data points.

24.2.2.3 If transition temperature is specified as the temperature at which a test value is achieved, determine the temperature at which the plotted curve intersects the specified test value by graphical interpolation (extrapolation is not permitted). Record this transition temperature to the nearest 3°C. If the tabulated test results clearly indicate a transition temperature lower than specified, it is not necessary to plot the data. Report the lowest test temperature for which test value exceeds the specified value.

24.2.2.4 Accept the test result if the determined transition temperature is equal to or lower than the specified value.

24.2.2.5 If the determined transition temperature is higher than the specified value, but not more than 12°C higher than the specified value, test sufficient samples in accordance with Section 25 to plot two additional curves. Accept the test results if the temperatures determined from both additional tests are equal to or lower than the specified value.

24.3 When subsize specimens are permitted or necessary, or both, modify the specified test requirement according to Table 7 or test temperature according to codes such as ASME Boiler and Pressure Vessel Code, Section VIII, Division I Table UG-84.2, or both. Greater energies or lower test temperatures may be agreed upon by purchaser and supplier.

25. Records

25.1 The test record should contain the following information as appropriate:

25.1.1 Full description of material tested (that is, specification number, grade, class or type, size, heat number).

25.1.2 Specimen orientation with respect to the material axis.

25.1.3 Specimen size.

25.1.4 Test temperature and individual test value for each specimen broken, including initial tests and retests.

25.1.5 Test results.

25.1.6 Transition temperature and criterion for its determination, including initial tests and retests.

26. Report

26.1 The specification should designate the information to be reported.

27. Keywords

27.1 bend test; Brinell hardness; Charpy impact test; elongation; hardness test; portable hardness; reduction of area; Rockwell hardness; tensile strength; tension test; yield strength

ANNEX

(Mandatory Information)

A1. ROUNDING OF TEST DATA

A1.1 Rounding

A1.1.1 An observed value or a calculated value shall be rounded off in accordance with the applicable product specification. In the absence of a specified procedure, the rounding-off method of Practice E29 shall be used.

A1.1.1.1 Values shall be rounded up or rounded down as determined by the rules of Practice E29.

A1.1.1.2 In the special case of rounding the number "5" when no additional numbers other than "0" follow the "5," rounding shall be done in the direction of the specification limits if following Practice E29 would cause rejection of material.

A1.1.2 Recommended levels for rounding reported values of test data are given in Table A1.1. These values are designed to provide uniformity in reporting and data storage, and should be used in all cases except where they conflict with specific requirements of a product specification.

NOTE A1.1—To minimize cumulative errors, whenever possible, values should be carried to at least one figure beyond that of the final (rounded) value during intervening calculations (such as calculation of stress from load and area measurements) with rounding occurring as the final operation. The precision may be less than that implied by the number of significant figures.

TABLE A1.1 Recommended Values for Rounding Test Data

Test Quantity	Test Data Range	Rounded Value[A]
Yield Point	Up to 500 MPa, excl	1 MPa
Yield Strength	500 to 1000 MPa, excl	5 MPa
Tensile Strength	1000 MPa and above	10 MPa
Elongation	0 to 10 %, excl	0.5 %
	10 % and above	1 %
Reduction of Area	0 to 10 %, excl	0.5 %
	10 % and above	1 %
Impact Energy	0 to 325 J	1 J
Brinell Hardness	all values	tabular value[B]
Rockwell Hardness	all scales	1 Rockwell Number

[A] Round test data to the nearest integral multiple of the values in this column. If the data value is exactly midway between two rounded values, round in accordance with A1.1.1.2.
[B] Round the mean diameter of the Brinell impression to the nearest 0.05 mm and report the corresponding Brinell hardness number read from the table without further rounding.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A1058 – 12b) that may impact the use of this standard. (Approved May 15, 2014)

(1) Revised 17.1.

(2) Revised 22.1.

Committee A01 has identified the location of selected changes to this standard since the last issue (A1058 – 12a) that may impact the use of this standard. (Approved Nov. 1, 2012)

(1) ISO and EN standards numbers updated, EN ISO designation removed in 2.2, 5.1, 5.2, 7.5, 8.1, 9.1, 10.1, 15.1, 16.1, 18.1, 19.1, 20.2.1, 20.2.3, 21.1, 23.1.2.1, Table 1.

(2) Note "B" added to 2.2.