Designation: A193/A193M – 22a

Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications[1]

This standard is issued under the fixed designation A193/A193M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This specification[2] covers alloy and stainless steel bolting materials and bolting components for pressure vessels, valves, flanges, and fittings for high temperature or high pressure service, or other special purpose applications. See Specification A962/A962M for the definition of bolting. Bars and wire shall be hot-wrought and may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be carbide solution treated or carbide solution treated and strain-hardened. When strain hardened austenitic stainless steel is ordered, the purchaser should take special care to ensure that Appendix X1 is thoroughly understood.

1.2 Several grades are covered, including ferritic steels and austenitic stainless steels designated B5, B8, and so forth. Selection will depend upon design, service conditions, mechanical properties, and high temperature characteristics.

1.3 The following referenced general requirements are indispensable for application of this specification: Specification A962/A962M.

NOTE 1—The committee formulating this specification has included several steel types that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent.

NOTE 2—For grades of alloy-steel bolting suitable for use at the lower range of high temperature applications, reference should be made to Specification A354.

NOTE 3—For grades of alloy-steel bolting suitable for use in low temperature applications, reference should be made to Specification A320/A320M.

1.4 Nuts for use with bolting are covered in Section 13.

1.5 Supplementary Requirements are provided for use at the option of the purchaser. The supplementary requirements shall apply only when specified in the purchase order or contract.

1.6 This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable *M* specification designation (SI units), the inch-pound units shall apply.

1.7 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A153/A153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A194/A194M Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

A320/A320M Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service

A354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

A788/A788M Specification for Steel Forgings, General Requirements

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-193 in Section II of that Code.

[3] 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.

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

A962/A962M Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range
B633 Specification for Electrodeposited Coatings of Zinc on Iron and Steel
B695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
B696 Specification for Coatings of Cadmium Mechanically Deposited
B766 Specification for Electrodeposited Coatings of Cadmium
E18 Test Methods for Rockwell Hardness of Metallic Materials
E21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials
E112 Test Methods for Determining Average Grain Size
E139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
E150 Recommended Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times (Withdrawn 1984)[4]
E151 Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures with Rapid Heating and Conventional or Rapid Strain Rates (Withdrawn 1984)[4]
E292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials
E328 Test Methods for Stress Relaxation for Materials and Structures
E566 Practice for Electromagnetic (Eddy Current/Magnetic Induction) Sorting of Ferrous Metals
E709 Guide for Magnetic Particle Testing
F606/F606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
F1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
F1941/F1941M Specification for Electrodeposited Coatings on Mechanical Fasteners, Inch and Metric
F2329/F2329M Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

2.2 *ASME Standards:*[5]
B18.2.1 Square and Hex Bolts and Screws
B18.2.3.3M Metric Heavy Hex Screws
B18.3 Hexagon Socket and Spline Socket Screws
B18.3.1M Metric Socket Head Cap Screws

2.3 *AIAG Standard:*[6]
AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

3. General Requirements and Ordering Information

3.1 The inquiry and orders shall include the following, as required, to describe the desired bolting material or bolting components adequately:

3.1.1 Heat-treated condition (that is carbide solution treated (Class 1), carbide solution treated after finishing (Class 1A), and carbide solution treated and strain-hardened (Classes 2, 2B and 2C), for the austenitic stainless steels; Classes 1B and 1C apply to the carbide solution-treated nitrogen-bearing stainless steels; Class 1D applies to bolting material that is carbide solution treated by cooling rapidly from the rolling temperature),

3.1.2 Description of items required (that is, bars, bolts, screws, or studs),

3.1.3 Nuts, if required by purchaser, in accordance with 13.1,

3.1.4 Supplementary requirements, if any, and

3.1.5 Special requirements, in accordance with 6.1.5.1, 6.2.6, 8.1, and 13.1.

3.2 *Coatings*—Coatings are prohibited unless specified by the purchaser (See Supplementary Requirements S13 and S14). When coated bolting components are ordered the purchaser should take special care to ensure that Appendix X2 is thoroughly understood.

4. Common Requirements

4.1 Bolting materials and bolting components supplied to this specification shall conform to the requirements of Specification A962/A962M. These requirements include test methods, finish, thread dimensions, macroetch (alloy steels only), marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A962/A962M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A962/A962M, this specification shall prevail.

5. Manufacture (Process)

5.1 *Melting*—See Specification A962/A962M for requirements.

5.2 *Quality*—See Specification A962/A962M for requirements.

6. Heat Treatment

6.1 *Ferritic Steels:*

6.1.1 Ferritic steels shall be allowed to cool to a temperature below the cooling transformation range immediately after rolling or forging. Bolting materials shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a *quenching charge*), quenched

[4] The last approved version of this historical standard is referenced on www.astm.org.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[6] Available from Automotive Industry Action Group (AIAG), 26200 Lahser Rd., Suite 200, Southfield, MI 48033, http://www.aiag.org.

TABLE 1 Chemical Requirements (Composition, percent)[A]

Grade	Description and UNS Designation	Class	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Cooper	Niobium[F]	Titanium	Vanadium	Aluminum	Nitrogen
Ferritic Steels																
B5	5 % Chromium		0.10 min	1.00	0.040	0.030	1.00	4.0–6.0	. . .	0.40–0.65	. . .	. . .	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.01	0.03	0.005	0.005	0.05	0.10	. . .	0.05	. . .	. . .	. . .	. . .	. . .	. . .
B6, B6X	12 % Chromium (410), S41000		0.08–0.15	1.00	0.040	0.030	1.00	11.5–13.5	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.01 over	0.03	0.005	0.005	0.05	0.15	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
B7, B7M	Chromium-Molybdenum[C]		0.38–0.48[D]	0.75–1.00	0.035	0.040	0.15–0.35	0.80–1.10	. . .	0.15–0.25	. . .	. . .	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.02	0.04	0.005	0.005	0.02	0.05	. . .	0.02	. . .	. . .	. . .	. . .	. . .	. . .
B16	Chromium-Molybdenum-Vanadium		0.36–0.47	0.45–0.70	0.035	0.040	0.15–0.35	0.80–1.15	. . .	0.50–0.65	. . .	. . .	. . .	0.25–0.35	0.015[E]	. . .
Product Analysis Variation[B]			0.02	0.03	0.005	0.005	0.02	0.05	. . .	0.03	. . .	. . .	. . .	0.03	. . .	. . .
Austenitic Steels																
Grade	Description and UNS Designation	Classes	Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Copper	Niobium[F]	Titanium	Vanadium	Aluminum	Nitrogen
B8, B8A	304, S30400	1, 1A, 1D, 2	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	. . .	. . .	. . .	. . .	. . .	. . .	. . .
B8C, B8CA	347, S34700	1, 1A, 1D, 2	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	10 × C to 1.10	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	. . .	. . .	0.05 under	. . .	. . .	. . .	. . .
B8M, B8MA, B8M2, B8M3	316, S31600	1, 1A, 1D, 2	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	0.10	. . .	. . .	. . .	. . .	. . .	. . .

TABLE 1 *Continued*

B8P, B8PA	S30500	1, 1A, 1D, 2	0.12	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	. . .	. . .	. . .	. . .	. . .	. . .	. . .
B8N, B8NA	304N, S30451	1A, 1B, 1D, 2	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	. . .	. . .	. . .	0.10–0.16
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	. . .	. . .	. . .	. . .	. . .	. . .	0.01
B8MN, B8MNA	316N, S31651	1A, 1B, 1D, 2	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	0.10–0.16
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	0.10	. . .	. . .	. . .	. . .	. . .	0.01
B8MLCuN, B8MLCuNA	S31254	1A, 1B, 1D, 2	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.50–1.00	. . .	. . .	. . .	. . .	0.18–0.25
Product Analysis Variation[B]			0.005	0.03	0.005	0.002	0.05	0.20	0.15	0.10	. . .	. . .	. . .	. . .	. . .	0.02
B8T, B8TA	321, S32100	1, 1A, 2	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	. . .	5 × (C + N) to 0.70	. . .	. . .	0.10
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	. . .	. . .	. . .	0.05 under	. . .	. . .	. . .
B8R, B8RA	S20910	1C, 1D	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	. . .	0.10–0.30	. . .	0.10–0.30	. . .	0.20–0.40
Product Analysis Variation[B]			0.01	0.05	0.005	0.005	0.05	0.25	0.15	0.10	. . .	0.05	. . .	0.02	. . .	0.02
B8S, B8SA	S21800	1C, 1D	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	. . .	. . .	. . .	. . .	. . .	. . .	0.08–0.18
Product Analysis Variation[B]			0.01	0.06	0.005	0.005	0.15	0.20	0.10	. . .	. . .	. . .	. . .	. . .	. . .	0.01
B8LN, B8LNA	S30453	1, 1A, 1D	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	. . .	. . .	. . .	0.10–0.16
Product Analysis Variation[B]			0.005	0.04	0.010	0.005	0.05	0.20	0.15	. . .	. . .	. . .	. . .	. . .	. . .	0.01

TABLE 1 *Continued*

B8MLN, B8MLNA	S31653	1, 1A, 1D	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	0.10–0.16
Product Analysis Variation[B]			0.005	0.04	0.010	0.005	0.05	0.20	0.15	0.10	. . .	. . .	. . .	. . .	. . .	0.01
B8CLN, B8CLNA	347LN, S34751	1, 1A, 1D	0.005–0.020	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	. . .	. . .	0.20–0.50; 15 × carbon content, min	. . .	. . .	. . .	0.06–0.10
Product Analysis Variation[B]			0.002 under, 0.005 over	0.04	0.01	0.005	0.05	0.20	0.15	. . .	. . .	0.05	. . .	. . .	. . .	0.01
B8CLNCuB B8CLNCuBA	S34752[G]	1,1A,1D	0.005-0.02	2.00	0.035	0.010	0.60	17.0-19.0	10.0-13.0	0.20-1.20	2.50-3.50	0.20–0.50; 15 × carbon content, min	. . .	. . .	. . .	0.06-0.12
Product Analysis Variation			0.002 under, 0.005 over	0.04	0.01	0.005	0.05	0.20	0.15		0.15	0.05	. . .	. . .	. . .	0.01
B8ML4CuN, B8ML4CuNA	S31730	1, 1A, 1D	0.030	2.00	0.040	0.010	1.00	17.0–19.0	15.0–16.5	3.0–4.0	4.0–5.0	. . .	. . .	. . .	. . .	0.045
Product Analysis Variation[B]			0.005	0.04	0.005	0.002	0.05	0.20	0.15	0.10	0.15	. . .	. . .	. . .	. . .	0.01

[A] Values are maximums unless a range or a minimum is indicated. Where ellipses appear in this table, there is no requirement and the element need not be determined or reported. The intentional addition of Bi, Se, Te, and Pb is not permitted.
[B] Product Analysis—Individual determinations sometimes vary from the specified limits as shown in the tables. The several determinations of any individual element in a heat may not vary both above and below the specified range. Product variation limits are over for maximums, over or under for ranges, and under for minimums, unless otherwise indicated.
[C] Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.
[D] For bar sizes over 3½ in. [90 mm], inclusive, the carbon content may be 0.50 % max. For the B7M grade, a minimum carbon of 0.28 % is permitted, provided that the required tensile properties are met in the section sizes involved, the use of AISI 4130 or 4130H is allowed.
[E] Total of soluble and insoluble.
[F] Columbium and Niobium are alternate names for element 41 in the Periodic Table of the Elements.
[G] For S34752 – Boron content shall be 0.001-0.005 for both heat and product analysis.

in a liquid medium under substantially uniform conditions for each quenching charge, and tempered. The minimum tempering temperature shall be as specified in Tables 2 and 3.

TABLE 2 Mechanical Requirements — Inch Products

Grade	Diameter, in.	Minimum Tempering Temperature, °F	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
			Ferritic Steels				
B5							
4 to 6 % chromium	up to 4, incl	1100	100	80	16	50	. . .
B6							
13 % chromium	up to 4, incl	1100	110	85	15	50	. . .
B6X							
13 % chromium	up to 4, incl	1100	90	70	16	50	26 HRC
B7							
Chromium-molybdenum	2½ and under	1100	125	105	16	50	321 HBW or 35 HRC
	over 2½ to 4	1100	115	95	16	50	321 HBW or 35 HRC
	over 4 to 7	1100	100	75	18	50	321 HBW or 35 HRC
B7M[A] Chromium-molybdenum	4 and under	1150	100	80	18	50	235 HBW or 99 HRB
	over 4 to 7	1150	100	75	18	50	235 HBW or 99 HRB
B16							
Chromium-molybdenum-vanadium	2½ and under	1200	125	105	18	50	321 HBW or 35 HRC
	over 2½ to 4	1200	110	95	17	45	321 HBW or 35 HRC
	over 4 to 8	1200	100	85	16	45	321 HBW or 35 HRC

Grade, Diameter, in.	Heat Treatment[B]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, B8CLN, all diameters	carbide solution treated	75	30	30	50	223 HBW or 96 HRB[C]
Classes 1 and 1D; B8, B8CLNCuB, all diameters	carbide solution treated	75	30	35	50	223 HBW or 96 HRB[C]
Classes 1 and 1D: B8ML4CuN, all diameters	carbide solution treated	70	25	35	50	90 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated	75	30	30	50	223 HBW or 96HRB[C]
Class 1A: B8A, B8CA, B8CLNA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA, B8MLCuNA, all diameters	carbide solution treated in the finished condition	75	30	30	50	192 HBW or 90 HRB
Class 1A: B8ML4CuNA, all diameters	carbide solution treated	70	25	35	50	90 HRB
Classes 1B and 1D: B8N, B8MN, B8MLCuN, all diameters	carbide solution treated	80	35	30	40	223 HBW or 96 HRB[C]
Classes 1C and 1D: B8R, all diameters	carbide solution treated	100	55	35	55	271 HBW or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	100	55	35	55	271 HBW or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	95	50	35	55	271 HBW or 28 HRC
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	95	50	35	55	271 HBW or 28 HRC
Class 2: B8, B8C, B8P, B8T, B8N,[D] ¾ and under	carbide solution treated and strain hardened	125	100	12	35	321 HBW or 35 HRC
over ¾ to 1, incl		115	80	15	35	321 HBW or 35 HRC

TABLE 2 *Continued*

Grade, Diameter, in.	Heat Treatment[B]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
over 1 to 1¼, incl		105	65	20	35	321 HBW or 35 HRC
over 1¼ to 1½, incl		100	50	28	45	321 HBW or 35 HRC
Class 2: B8M, B8MN, B8MLCuN[D] ¾ and under	carbide solution treated and strain hardened	110	95	15	45	321 HBW or 35 HRC
over ¾ to 1 incl		100	80	20	45	321 HBW or 35 HRC
Over 1 to 1¼, incl		95	65	25	45	321 HBW or 35 HRC
over 1¼ to 1½, incl		90	50	30	45	321 HBW or 35 HRC
Class 2B: B8, B8M2[D] 2 and under	carbide solution treated and strain hardened	95	75	25	40	321 HBW or 35 HRC
over 2 to 2½ incl		90	65	30	40	321 HBW or 35 HRC
over 2½ to 3 incl		80	55	30	40	321 HBW or 35 HRC
Class 2C: B8M3[D] 2 and under	carbide solution treated and strain hardened	85	65	30	60	321 HBW or 35 HRC
over 2		85	60	30	60	321 HBW or 35 HRC

[A] To meet the tensile requirements, the Brinell hardness shall be over 200 HBW (93 HRB).
[B] Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over ¾ in. in diameter.
[C] For sizes ¾ in. in diameter and smaller, a maximum hardness of 241 HBW (100 HRB) is permitted.
[D] For diameters 1½ and over, center (core) properties may be lower than indicated by test reports which are based on values determined at ½ radius.

TABLE 3 Mechanical Requirements—Metric Products

Class	Diameter, [mm]	Minimum Tempering Temperature, °C	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
		Ferritic Steels					
B5 4 to 6 % chromium	up to M100, incl	593	690	550	16	50	. . .
B6 13 % chromium	up to M100, incl	593	760	585	15	50	. . .
B6X 13 % chromium	up to M100, incl	593	620	485	16	50	26 HRC
B7 Chromium-molybdenum	M64 and under	593	860	720	16	50	321 HBW or 35 HRC
	over M64 to M100	593	795	655	16	50	321 HBW or 35 HRC
	over M100 to M180	593	690	515	18	50	321 HBW or 35 HRC
B7M[A] Chromium-molybdenum	M100 and under	620	690	550	18	50	235 HBW or 99 HRB
	over M100 to M180	620	690	515	18	50	235 HBW or 99 HRB
B16 Chromium-molybdenum-vanadium	M64 and under	650	860	725	18	50	321 HBW or 35 HRC
	over M64 to M100	650	760	655	17	45	321 HBW or 35 HRC
	over M100 to M200	650	690	585	16	45	321 HBW or 35 HRC