SAE International

SURFACE VEHICLE STANDARD

SAE J1199 FEB2013

Issued 1978-02
Stabilized 2013-02

Superseding J1199 MAR2001

Mechanical and Material Requirements for Metric Externally Threaded Steel Fasteners

RATIONALE

Current requirements for Mechanical and Quality Requirements for Metric Externally Threaded Steel Fasteners are contained in ISO 898-1 Mechanical properties of fasteners made of carbon steel and alloy steel - Bolts, screws, and studs. SAE J1199 contains useful information and may have current users. However, several of the references have been cancelled or superseded.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE Fasteners Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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1. Scope

1.1 This SAE Standard covers the mechanical and material requirements for eight property classes of steel, externally threaded metric fasteners in sizes M1.6 through M36, inclusive, and suitable for use in automotive and related applications.

1.2 Products included are bolts, screws, studs, U-bolts, preassembled screw and washer assemblies (sems), and products manufactured the same as sems except without washer.

1.3 Products not covered are tapping screws, thread-rolling screws, and self-drilling screws. Mechanical and material requirements for these products are covered in other SAE documents.

1.4 The term stud as referred to herein, applies to a cylindrical rod of moderate length, threaded on either one or both ends or throughout its entire length. It does not apply to headed, collared, or similar products which are more closely characterized by requirements shown herein for bolts.

1.5 For specification purposes, this document treats U-bolts as studs. Thus, wherever the word studs appears, U-bolts is also implied. U-bolts covered by this document are those used primarily in the suspension and related areas of vehicles. (Designers should recognize that the U configuration may not sustain a load equivalent to two bolts or studs of the same size and grade; thus actual load-carrying capacity of U-bolts should be determined by saddle load tests.)

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J121M—Decarburization in Hardened and Tempered Metric Threaded Fasteners
SAE J123—Surface Discontinuities on Bolts, Screws, and Studs in Fatigue Applications
SAE J429—Mechanical and Material Requirements for Externally Threaded Fasteners
SAE J1061—Surface Discontinuities on General Application Bolts, Screws, and Studs

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 307—Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile
ASTM A 354—Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
ASTM A 449—Specification for Quenched and Tempered Steel Bolts and Studs
ASTM F 606M—Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

2.1.3 ASME PUBLICATION—Available from ASME, 345 East 47 Street, New York, NY 10017-2330.

ASME B18.2.1

3. Designations

3.1 Property classes are designated by numbers where increasing numbers generally represent increasing tensile strengths. The designation symbol consists of two parts:

a. The first numeral of a two-digit symbol or the first two numerals of a three-digit symbol approximates 1/100 of the minimum tensile strength in MPa.
b. The last numeral approximates 1/10 of the ratio expressed as a percentage between minimum yield stress and minimum tensile stress.

3.2 For specification purposes (on engineering drawings, purchase orders, etc.) all property class designations are used in combination with a single basic specification number as follows:

SAE J1199 (4.6)
SAE J1199 (4.8)
SAE J1199 (5.8)
SAE J1199 (8.8)
SAE J1199 (9.8)
SAE J1199 (10.9)

3.3 Property Classes

3.3.1 Machine screws are normally available only in classes 4.8 and 9.8; other bolts, screws, and studs are available in all classes within the specified product size limitations given in Tables 1A and 1B.

3.3.2 Screw and washer assemblies (sems) are covered by classes 4.8 and 9.8 and allowable deviations from normal 9.8 requirements are stated in footnotes throughout the document.

3.3.3 At the option of the manufacturer, class 5.8 may be supplied with either class 4.6 or 4.8 is ordered, and class 4.8 may be supplied when class 4.6 is ordered.

3.4 Conversion Guidance

3.4.1 For guidance purposes only, to assist designers in selecting a property class:

a. Class 4.6 is approximately equivalent to SAE J429, Grade 1 and ASTM A 307, Grade A.
b. Class 5.8 is approximately equivalent to SAE J429, Grade 2.
c. Class 8.8 is approximately equivalent to SAE J429, Grade 5, and ASTM A 449.
d. Class 9.8 has properties approximately 9% stronger than SAE J429, Grade 5, and ASTM A 449.
e. Class 10.9 is approximately equivalent to SAE J429, Grade 8, and ASTM A 354, Grade BD.

TABLE 1A—MECHANICAL REQUIREMENTS FOR BOLTS, SCREWS, AND STUDS

Property Class	Nominal Dia	Full Size Bolts, Screws, and Studs Proof Load (Stress) MPa[1]	Full Size Bolts, Screws, and Studs Tensile Strength (Stress) Min MPa[1]	Machined Test Specimens of Bolts, Screws, and Studs (Sizes Larger than M24) Yield Strength (Stress) Min[2] MPa	Machined Test Specimens of Bolts, Screws, and Studs (Sizes Larger Than M24) Tensile Strength (Stress) Min MPa	Machined Test Specimens of Bolts, Screws, and Studs (Sizes Larger Than M24) Elongation Min %	Machined Test Specimens of Bolts, Screws, and Studs (Sizes Larger than M24) Reduction of Area Min %
4.6	M5 thru M36	225	400	240[3]	400	22	35
4.8	M1.6 thru M16	310	420	—	—	—	—
5.8	M5 thru M24[4]	380	520	—	—	—	—
8.8	M17 thru M36	600	830	660	830	12	35
9.8	M1.6 thru M16[5]	650	900	—	—	—	—
10.9	M6 thru M36	830	1040	940	1040	9	35

1. Proof load and tensile strength values for full size products of each property class are given in Table 5.
2. Yield strength is stress at which a permanent set of 0.2% of gage length occurs.
3. Yield point shall apply instead of yield strength at 0.2% offset for class 4.6 products.
4. Class 5.8 requirements apply to bolts and screws with lengths 150 mm and shorter, and to studs of all lengths.
5. For class 9.8 screw and washer assemblies (sems), base metal hardness may be 25–40 HRC (270–390 HV) and surface hardness shall not exceed 60 HR30N. This requirement applicable also to products manufactured same as sems except without washer, sizes M1.6 thru M12.

TABLE 1B—MECHANICAL REQUIREMENTS FOR BOLTS, SCREWS, AND STUDS

Property Class	Nominal Dia	Surface Hardness Rockwell 30N Max	Product Hardness Rockwell Min[1]	Product Hardness Rockwell Max	Product Hardness Vickers Min[1]	Product Hardness Vickers Max
4.6	M5 thru M36	—	B67	B87	120	180
4.8	M1.6 thru M16	—	B71	B87	130	180
5.8	M5 thru M24[2]	—	B82	B95	160	220
8.8	M17 thru M36	[3]	C23	C34	254	336
9.8	M1.6 thru M16[4]	[3]	C27	C36	279	354
10.9	M6 thru M36	[3]	C33	C39	327	382

1. Minimum hardness requirement is waived if minimum tensile strength is met.
2. Class 5.8 requirements apply to bolts and screws with lengths 150 mm and shorter, and to studs of all lengths.
3. Surface hardness shall not exceed base metal hardness by more than 2 points (Rockwell C equivalent), and in the case of class 10.9 shall also not exceed 59 HR30N.
4. For class 9.8 screw and washer assemblies (sems), base metal hardness may be 25–40 HRC (270-390 HV) and surface hardness shall not exceed 60 HR30N. This requirement applicable also to products manufactured same as sems except without washer, sizes M1.6 thru M12.

3.4.2 Note that class 8.8 is applicable to sizes above 16 mm, and class 9.8 is applicable to sizes 16 mm and smaller.

4. *Materials and Processes*

4.1 Steel Characteristics—Bolts, screws, and studs shall be made of steel conforming g to the description and chemical composition requirements specified in Table 2 for the applicable property class.

TABLE 2—CHEMICAL COMPOSITION REQUIREMENTS
PRODUCT ANALYSIS (% BY MASS)

Property Class	Description and Chemical Compositions
4.6 and 4.8	Manufacturer's Option— Low or medium carbon steels (for all sizes), within following limits: C 0.55 max, P 0.048 max, S 0.058 max
5.8	Manufacturer's Option— Low or medium carbon steels (for all sizes), within following limits: C 0.13 to 0.55, P 0.048 max, S 0.058 max For studs only, sulfur content may be 0.33 max
8.8	Manufacturer's Option— Medium carbon steels (for all sizes), within following limits: C 0.28 to 0.55, P 0.048 max, S 0.058 max For studs only, sulfur content may be 0.13 max Medium carbon alloy steels (for sizes over M24), within following limits: C 0.28 to 0.55, P 0.040 max, S 0.045 max When Authorized by Purchaser— Low carbon martensite steels (for sizes thru M20), within following limits: C 0.15 to 0.27, Mn 0.74 to 1.46, P 0.038 max, S 0.048 max, B 0.0005 to 0.003(1) Medium carbon boron steels (for sizes through M24), within following limits: C 0.25 to 0.40, Mn 0.74 min, P 0.048 max, S 0.058 max, B 0.0005 to 0.003(1)
9.8	Medium carbon steels (for all sizes), within following limits: C 0.28 to 0.55, P 0.048 max, S 0.058 max For studs only, sulfur content may be 0.13 max For screw and washer assemblies (sems) and for products manufactured same as sems except without washer, sizes thru M12 only, carbon content may be 0.15 to 0.40. See note 2, Table 6. When Authorized by Purchaser— Low carbon martensite steels (for sizes thru M20), within following limits: C 0.15 to 0.27, Mn 0.74 to 1.46, P 0.038 max, S 0.048 max, B 0.0005 to 0.003(1) Medium carbon boron steels (for sizes thru M24), within following limits: C 0.25 to 0.40, Mn 0.74 min, P 0.048 max, S 0.058 max, B 0.0005 to 0.003(1)
10.9	Manufacturer's Option— Medium carbon alloy steels (for all sizes), within following limits: C 0.28 to 0.55, P 0.040 max, S 0.045 max Fine grain Hardenability—47 min HRC(2) SAE 1541 or SAE 1541H (for sizes thru M12) Fine grain When Authorized by Purchaser— Carbon steels (for sizes thru M20); Fine grain Low carbon martensite steels (for sizes thru M20), within the following limits: C 0.15 to 0.27, Mn 0.74 to 1.46, P 0.038 max, S 0.048 max, B 0.0005 to 0.003(1) Hardenability—40 min HRC(2) Medium carbon boron steels (for sizes thru M24), within following limits: C 0.25 to 0.40, Mn 0.74 min, P 0.048 max, S 0.058 max, B 0.0005 to 0.003(1) Hardenability—47 min HRC(2)

1. Products made from low carbon martensite steels and medium carbon boron steels shall be identified as specified in Table 6, note 1.
2. Steels shall have hardenability that is capable of producing the minimum hardness (Rockwell C) shown at the center of a transverse section one nominal diameter from the threaded end of bolt, screw, or stud (after quenching).

4.2 Heading Practice

4.2.1 Methods other than upsetting and/or extrusion are permitted only by special agreement between purchaser and manufacturer.

4.2.2 Class 4.6 may be hot or cold headed at option of the manufacturer.

4.2.3 Class 4.8, 5.8, 8.8, 9.8, and 10.9 bolts and screws in sizes up to M20 inclusive, and lengths up to 10 times the nominal product size or 150 mm, whichever is shorter, shall be cold headed, except that they may be hot headed by special agreement of the purchaser. Larger sizes and longer lengths may be cold or hot headed at option of the manufacturer.

4.3 Threading Practice—Class 4.8, 5.8, 8.8, 9.8, and 10.9 bolts and screws in sizes up to M20 inclusive, and lengths up to 150 mm inclusive, shall be roll threaded, except by special agreement. Threads of all sizes of class 4.6 bolts and screws and class 4.8, 5.8, 8.8, 9.8, and 10.9 bolts and screws in sizes over M20 and/or lengths longer than 150 mm, may be rolled, cut, or ground, at option of the manufacturer. Threads of all classes and sizes of studs may be rolled, cut, or ground at option of the manufacturer.

4.4 Heat Treatment Practice

4.4.1 Class 4.6 bolts and screws and class 4.6, 4.8, and 5.8 studs need not be heat treated. Class 4.8 and 5.8 bolts and screws shall be stress relieved if necessary to assure the soundness of the head to shank junction. When specified by the purchaser, class 5.8 bolts and screws shall be stress relieved at a minimum stress relief temperature of 470 °C. Where higher temperatures are necessary to relieve stresses in severely upset heads, mechanical requirements shall be agreed upon by manufacturer and purchaser.

4.4.2 Class 8.8 and 9.8 bolts, screws, and studs shall be heat treated, quenched in oil or water-base quenchant at the option of the manufacturer, and tempered at a minimum tempering temperature of 425 °C for class 8.8 and 410 °C for class 9.8. For class 9.8 screw and washer assemblies (sems), quenchants whose principal constituent is water shall NOT be used, and tempering temperature shall be no less than 340 °C. See also 4.4.5.

4.4.3 Medium carbon alloy steel class 10.9 bolts, screws, and studs shall be heat treated, oil quenched, and tempered at a minimum tempering temperature of 425 °C. Low-carbon martensite steel class 10.9 bolts, screws, and studs shall be heat treated, quenched in oil or water-base quenchant at the option of the manufacturer, and tempered at a minimum tempering temperature of 340 °C. See also 4.4.5.

4.4.4 Under no circumstances should heat treatment or carbon restoration be accomplished in the presence of nitrogen compounds, such as carbonitriding or cyaniding.

4.4.5 Tempering Temperature Audit Test (for checking whether products have been tempered at specified temperature). Conduct hardness test (ASTM F 606M) on one or more bolts, screws, or studs; retemper the product(s) at a temperature 10 °C less than the specified minimum tempering temperature for 30 min; repeat product hardness test. The difference between the mean hardnesses (before and after retempering) shall be no greater than 2 points Rockwell C (approximately 20 Vicker points).

5. Mechanical and Physical Properties

5.1 Mechanical—Bolts, screws, and studs shall be tested in accordance with the mechanical testing requirements for the applicable type, property class, size, and length of product as specified in Tables 3A and 3B, and shall meet the mechanical requirements specified for that product in Tables 1A and 1B.

5.2 Decarburization—Unless otherwise specified, class 8.8 and 9.8 products shall conform to decarburization class 1/2H and Class 10.9 products shall conform to decarburization class 2/3H as specified in SAE J121M.

5.3 Surface Discontinuities

5.3.1 Bolts, screws, and studs of classes 8.8, 9.8, and 10.9 in sizes up to M24 inclusive, and lengths up to 150 mm inclusive, shall not have surface discontinuities exceeding the limits specified in SAE J1061.

Surface discontinuities for sizes and lengths of products not covered in the scope of SAE J1061 shall be within limits specified by purchaser.

5.3.2 When the engineering requirements of the application necessitate that surface discontinuities must be more closely controlled, the purchaser shall specify the applicable limits in the original inquiry and purchase order. For certain fasteners, this may be done by reference to SAE J123.

6. *Methods of Test*

6.1 General—Procedures for conducting the tests to determine the mechanical properties as specified in Tables 3A and 3B for the applicable product, property class, size, and length are given in ASTM F 606M. Tables 3A and 3B specifies the applicable test method to be followed when determining each mechanical property.

TABLE 3A—MECHANICAL TESTING REQUIREMENTS FOR BOLTS, SCREWS, AND STUDS

Product	Property Class	Specified Min Tensile Strength of Product (See Table 5) kN	Length of Product[1]	Product Hardness Max[2]	Product Hardness Min[2]	Surface Hardness [2][3]	Tests Conducted Using Full Size Products Proof Load[2]	Tests Conducted Using Full Size Products Wedge Tensile Strength[2][4]	Tests Conducted Using Full Size Products Axial Tensile Strength[2]
Short bolts and screws	all	all	less than 2-1/4D	•	•	•	—	—	—
Special head bolts and screws[5]	all	all	all	•	•	•	—	—	—
Hex bolts and screws[6][7]	all	450 and less	2-1/4D to 8D or 200 mm, whichever is greater	•	—	•	°	•	—
	all	450 and less	Over 8 D or 200 mm, whichever is greater thru and incl 300 mm	•	—	•	°	•	—
	all	450 and less	over 300 mm	•	—	•	°	A	—
	all	over 450	2-1/4D and longer	•	—	•	°	A	—
All other bolts and screws	all	450 and less	2-1/4D to 8D or 200 mm, whichever is greater	•	—	•	°	—	•
	all	450 and less	over 8D or 200 mm, whichever is greater	•	—	•	°	—	A
	all	over 450	2-1/4D and longer	•	—	•	°	—	A
Short studs	all	all	less than 2-1/4D	•	•	•	—	—	—
All other studs	all	450 and less	2-1/4D to 8D or 200 mm, whichever is greater	•	—	•	°	•	—
	all	450 and less	over 8D or 200 mm, whichever is greater	•	—	•	°	A	—
	all	over 450	2-1/4D and longer	•	—	•	°	A	—
Tests to be conducted in accordance with paragraph				See ASTM F 606M 3.1	See ASTM F 606M 3.1	See ASTM F 606M 3.1	See ASTM F 606M 3.2	See ASTM F 606M 3.5	See ASTM F 606M 3.4

1. D equals nominal diameter of product. For purposes of Table 3 requirements, "length of product" is the nominal length including point chamfer as defined in ASME B18.2.1, and all special point products shall be measured from the bearing surface to the crest of the last complete thread form.
2. • denotes a mandatory test. For each product, all mandatory tests (•) shall be performed. In addition, either all tests denoted A (which apply to full size products) or all tests denoted B (which apply to machined test specimens) shall be performed; except optional B tests are not applicable to products M24 and smaller. ° denotes tests to be performed when specifically required in the original inquiry and purchase order. In case arbitration is necessary, both A tests and ° tests shall be performed. Dashes (—) indicate tests which are not required.
3. Surface hardness and decarburization requirements apply only to property classes 8.8, 9.8, and 10.9.
4. Tensile test wedge angles are specified in Table 4.
5. Special head bolts and screws are those with special configurations or with drilled heads which are weaker than the threaded section.
6. Includes flange, washer, and other hex head configurations which are not weaker than the threaded section.
7. Includes class 9.8 sems and 9.8 products manufactured same as sems except without washer (sizes M1.6 thru M12). For purposes of determining applicability of tensile testing, length of sems is the distance measured from the underside of bearing plane of the unflattened washer to the last full thread of the screw.

TABLE 3B—MECHANICAL TESTING REQUIREMENTS FOR BOLTS, SCREWS, AND STUDS

Product	Property Class	Specified Min Tensile Strength of Product (See Table 5) kN	Length of Product[1]	Tests Conducted Using Machined Test Specimens Yield Strength[2]	Tests Conducted Using Machined Test Specimens Tensile Strength[2]	Tests Conducted Using Machined Test Specimens Elongation[2]	Tests Conducted Using Machined Test Specimens Reduction of Area[2]	Decarburization in Threaded Section[2][3]
Short bolts and screws	all	all	less than 2-1/4D	—	—	—	—	°
Special head bolts and screws[4]	all	all	all	—	—	—	—	°
Hex bolts and screws[5][6]	all	450 and less	2-1/4D to 8D or 200 mm, whichever is greater	—	—	—	—	°
	all	450 and less	Over 8D or 200 mm, whichever is greater thru and incl 300 mm	—	—	—	—	°
	all	450 and less	over 300 mm	B	B	B	B	°
	all	over 450	2-1/4D and longer	B	B	B	B	°
All other bolts and screws	all	450 and less	2-1/4D to 8D or 200 mm, whichever is greater	—	—	—	—	°
	all	450 and less	over 8D or 200 mm, whichever is greater	B	B	B	B	°
	all	over 450	2-1/4D and longer	B	B	B	B	°
Short studs	all	all	less than 2-1/4D	—	—	—	—	°
All other studs	all	450 and less	2-1/4D to 8D or 200 mm, whichever is greater	—	—	—	—	°
	all	450 and less	over 8D or 200 mm, whichever is greater	B	B	B	B	°
	all	over 450	2-1/4D and longer	B	B	B	B	°
Tests to be conducted in				See ASTM F 606M	See ASTM F 606M	See ASTM F 606M	See ASTM F 606M	See SAE J121M
accordance with paragraph				3.6	3.6	3.6	3.6	See SAE J121M

1. D equals nominal diameter of product. For purposes of Table 3 requirements, "length of product" is the nominal length including point chamfer as defined in ASME B18.2.1, and all special point products shall be measured from the bearing surface to the crest of the last complete thread form.
2. • denotes a mandatory test. For each product, all mandatory tests (•) shall be performed. In addition, either all tests denoted A (which apply to full size products) or all tests denoted B (which apply to machined test specimens) shall be performed; except optional B tests are not applicable to products M24 and smaller. ° denotes tests to be performed when specifically required in the original inquiry and purchase order. In case arbitration is necessary, both A tests and ° tests shall be performed. Dashes (—) indicate tests which are not required.
3. Surface hardness and decarburization requirements apply only to property classes 8.8, 9.8, and 10.9.
4. Special head bolts and screws are those with special configurations or with drilled heads which are weaker than the threaded section.
5. Includes flange, washer, and other hex head configurations which are not weaker than the threaded section.
6. Includes class 9.8 sems and 9.8 products manufactured same as sems except without washer (sizes M1.6 thru M12). For purposes of determining applicability of tensile testing, length of sems is the distance measured from the underside of bearing plane of the unflattened washer to the last full thread of the screw.

TABLE 4—TENSILE TEST WEDGE ANGLES

Product	Property Class	Nominal Dia.	Wedge Angle Deg
Hex and hex washer head machine screws	4.8, 9.8	thru M10	6
Hex bolts and screws threaded 1D and closer to underside of head	8.8, 9.8, 10.9	thru M20	6
		over M20 to M36	4
Hex flange and hex washer head bolts and screws	4.6, 4.8, 5.8, 8.8, 9.8, 10.9	thru M36	6
All other hex bolts and screws	4.6, 4.8, 5.8, 8.8, 9.8, 10.9	thru M24	10
		over M24 to M36	6
Studs	all	thru M20	6
		over M20 to M36	4