Mechanical and Material Requirements for Metric Externally Threaded Steel Fasteners—SAE J1199

SAE Standard
Approved February 1978

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LAND SEA AIR SPACE

PREPRINT

MECHANICAL AND MATERIAL REQUIREMENTS FOR METRIC EXTERNALLY THREADED STEEL FASTENERS—SAE J1199

SAE Standard

Report of Iron and Steel Technical Committee approved February 1978.

1. Scope

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

1.2 Products included are bolts, screws, studs, U-bolts, pre-assembled 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 standard treats U-bolts as studs. Thus, wherever the word *studs* appears, *U-bolts* is also implied. U-bolts covered by this standard 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. Designations

2.1 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.

2.2 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 (9.8)
SAE J1199 (4.8)	SAE J1199 (10.9)
SAE J1199 (5.8)	SAE J1199 (12.8)
SAE J1199 (8.8)	SAE J1199 (12.9)

2.3 Property Classes

2.3.1 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 Table 1.

2.3.2 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 standard.

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

2.4 Conversion Guidance

2.4.1 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 A307, 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 A449.

(d) Class 9.8 has properties approximately 9% stronger than SAE J429, Grade 5, and ASTM A449.

(e) Class 10.9 is approximately equivalent to SAE J429, Grade 8, and ASTM A354, Grade BD.

(f) Class 12.9 has properties approximately equivalent to ASTM A574.

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

3. Materials and Processes

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

3.2 Heading Practice

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

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

3.2.3 Class 4.8, 5.8, 8.8, 9.8, 10.9, and 12.9 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.

3.3 Threading Practice—Class 4.8, 5.8, 8.8, 9.8, 10.9, and 12.9 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, 10.9, and 12.9 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.

3.4 Heat Treatment Practice

3.4.1 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.

3.4.2 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 Section 3.4.6.

3.4.3 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 Section 3.4.6.

3.4.4 Class 12.9 bolts, screws, and studs shall be heat treated, oil quenched, and tempered at a minimum tempering temperature of 380°C. See also Section 3.4.6.

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

3.4.6 Tempering Temperature Audit Test (for checking whether products have been tempered at specified temperature). Conduct hardness test (SAE J1216, Section 3.1) 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).

4. Mechanical and Physical Properties

4.1 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 Table 3, and shall meet the mechanical requirements specified for that product in Table 1.

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

		Full Size Bolts, Screws, and Studs		Machined Test Specimens of Bolts, Screws, and Studs (Sizes larger than M24)				Surface Hardness	Product Hardness			
									Rockwell		Vickers	
Property Class	Nominal Dia	Proof Load (Stress) MPa (4)	Tensile Strength (Stress) Min MPa (4)	Yield Strength (Stress) Min(1) MPa	Tensile Strength (Stress) Min MPa	Elongation Min %	Reduction of Area Min %	Rockwell 30N Max	Min (8)	Max	Min (8)	Max
4.6	M5 thru M36	225	400	240(2)	400	22	35	—	B67	B87	120	180
4.8	M1.6 thru M16	310	420	—	—	—	—	—	B71	B87	130	180
5.8	M5 thru M24(3)	380	520	—	—	—	—	—	B82	B95	160	220
8.8	M17 thru M36	600	830	660	830	12	35	(6)	C23	C34	254	336
9.8	M1.6 thru M16(5)	650	900	—	—	—	—	(6)	C27	C36	279	354
10.9	M6 thru M36	830	1040	940	1040	9	35	(6)	C33	C39	327	382
12.8	See Appendix											
12.9(7)	M1.6 thru M36	970	1220	1100	1220	8	35	(6)	C38	C44	372	434

NOTES: (1) Yield strength is stress at which a permanent set of 0.2% of gage length occurs.

(2) Yield point shall apply instead of yield strength at 0.2% offset for class 4.6 products.

(3) Class 5.8 requirements apply to bolts and screws with lengths 150 mm and shorter, and to studs of all lengths.

(4) Proof load and tensile strength values for full size products of each property class are given in Table 5.

(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.

(6) Surface hardness shall not exceed base metal hardness by more than 2 points (Rockwell C equivalent), and in the case of classes 10.9 and 12.9 shall also not exceed 59 HR30N and 63 HR30N, respectively.

(7) Caution is advised when considering the use of class 12.9 bolts and screws. Capability of the bolt manufacturer, as well as the anticipated in-use environment, should be considered. High strength products such as class 12.9, require rigid control of heat treating operations and careful monitoring of as-quenched hardness, surface discontinuities, depth of partial decarburization, and freedom from carburization. Some environments may cause stress corrosion cracking of non-plated as well as electroplated products.

(8) Minimum hardness requirement is waived if minimum tensile strength is met.

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TABLE 2—CHEMICAL COMPOSITION REQUIREMENTS

Product Analysis (% by mass)

Property Classes 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

Property Class 5.8

Manufacturer's option—

Low or medium carbon steels (for all sizes), within following limits:

C 0.13—0.55, P 0.048 max, S 0.058 max

For studs only, sulfur content may be 0.33 max

Property Class 8.8

Manufacturer's option—

Medium carbon steels (for all sizes), within following limits:

C 0.28—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—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—0.27, Mn 0.74—1.46, P 0.038 max, S 0.048 max, B 0.0005—0.003 (See Note 1 below)

Medium carbon boron steels (for sizes thru M24), within following limits:

C 0.25—0.40, Mn 0.74 min, P 0.048 max, S 0.058 max, B 0.0005—0.003 (See Note 1 below)

Property Class 9.8

Medium carbon steels (for all sizes), within following limits:

C 0.28—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—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—0.27, Mn 0.74—1.46, P 0.038 max, S 0.048 max, B 0.0005—0.003 (See Note 1 below)

Medium carbon boron steels (for sizes thru M24), within following limits:

C 0.25—0.40, Mn 0.74 min, P 0.048 max, S 0.058 max, B 0.0005—0.003 (See Note 1 below)

Property Class 10.9

Manufacturer's option—

Medium carbon alloy steels (for all sizes), within following limits:

C 0.28—0.55, P 0.040 max, S 0.045 max

Fine grain

Hardenability—47 min HRC (See Note 2 below)

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 following limits:

C 0.15—0.27, Mn 0.74—1.46, P 0.038 max, S 0.048 max, B 0.0005—0.003 (See Note 1 below)

Hardenability—40 min HRC (See Note 2 below)

Medium carbon boron steels (for sizes th. M24), within following limits:

C 0.25—0.40, Mn 0.74 min, P 0.048 max, S 0.058 max, B 0.0005—0.003 (See Note 1 below)

Hardenability—47 min HRC (See Note 2 below)

Property Class 12.9

Alloy steels (for all sizes), within following limits:

C 0.31—0.65, P 0.045 max, S 0.045 max

One or more of the alloying elements chromium, nickel, molybdenum, or vandium shall be present in sufficient quantity to insure that the specified strength properties are met after quenching and tempering.

Fine grain

Hardenability—47 min HRC (See Note 2 below)

NOTES: (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).

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

Product	Property Class	Specified Min Tensile Strength of Product (See Table 5) kN	Length of Product (2)	Product Hardness Max	Product Hardness Min	Surface Hardness (4) Max	Tests Conducted Using Full Size Products: Proof Load	Wedge Tensile Strength (5)	Axial Tensile Strength	Tests Conducted Using Machined Test Specimens: Yield Strength	Tensile Strength	Elongation	Reduction of Area	Decarburization in Threaded Section (4)
Short bolts and screws	all	all	less than 2 1/4D	•	•	•	–	–	–	–	–	–	–	○
Special head bolts and screws (3)	all	all	all	•	•	•	–	–	–	–	–	–	–	○
Hex bolts and screws (6) (7)	all	450 and less	2 1/4D to 8D or 200 mm, whichever is greater	•	–	•	○	•	–	–	–	–	–	○
			over 8D or 200 mm, whichever is greater thru and incl 300 mm	•	–	•	○	•	–	–	–	–	–	•
			over 300 mm	•	–	•	○	A	–	B	B	B	B	○
		over 450	2 1/4D and longer	•	–	•	○	A	–	B	B	B	B	○
All other bolts and screws	all	450 and less	2 1/4D to 8D or 200 mm, whichever is greater	•	–	•	○	–	•	–	–	–	–	○
			over 8D or 200 mm, whichever is greater	•	–	•	○	–	A	B	B	B	B	○
		over 450	2 1/4 D and longer	•	–	•	○	–	A	B	B	B	B	○
Short studs	all	all	less than 2 1/4 D	•	•	•	–	–	–	–	–	–	–	○
All other studs	all	450 and less	2 1/4D to 8D or 200 mm, whichever is greater	•	–	•	○	•	–	–	–	–	–	○
			over 8D or 200 mm, whichever is greater	•	–	•	○	A	–	B	B	B	B	○
		over 450	2 1/4D and longer	•	–	•	○	A	–	B	B	B	B	○
Tests to be conducted in accordance with paragraph				See SAE J1216										See SAE J121
				3.1		3.2	3.3	3.6	3.5	3.7				

NOTES: (1) • 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, A tests shall be performed. Dashes (–) indicate tests which are not required.

(2) 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 SAE J105, and all special point products shall be measured from the bearing surface to the crest of the last complete thread form.

(3) Special head bolts and screws are those with special configurations or with drilled heads which are weaker than the threaded section.

(4) Surface hardness and decarburization requirements apply only to property classes 8.8, 9.8, 10.9, and 12.9.

(5) Tensile test wedge angles are specified in Table 4.

(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 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 2D and closer to underside of head	12.9	thru M20	4
		over M20 to M36	4
All other hex bolts and screws	12.9	thru M20	6
		over M20 to M36	4
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

4.2 Decarburization—Unless otherwise specified, class 8.8, 9.8, and 10.9 products shall conform to decarburization class 1/2H, and class 12.9 products shall conform to decarburization class 3/4H as specified in SAE J121. In addition for class 12.9, no gross decarburization is permitted on product threads.

4.3 Surface Discontinuities

4.3.1 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.

4.3.2 When the engineering requirements of the application necessitate that surface discontinuities must be more closely controlled, such as for class 12.9 products, 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.

5. Methods of Test

5.1 General—Procedures for conducting the tests to determine the mechanical properties as specified in Table 3 for the applicable product, property class, size, and length are given in SAE J1216. Table 3 specifies the applicable test method to be followed when determining each mechanical property.

6. Marking

6.1 Bolts and Screws—Slotted and cross-recessed screws of all sizes and other screws and bolts of sizes smaller than M5 need not be marked. All other bolts and screws of sizes M5 and larger shall be marked permanently and clearly to identify the property class and the manufacturer. The property class symbols shall be as given in Table 6; the symbol for the manufacturer's identification shall be at his option. Markings shall be located on the top of the head of bolts and screws, and may be either raised or depressed at option of the manufacturer. Alternatively, for hex head products, the markings may be indented on the side of the head.

Property class marking shall conform to the following:

Bolt or Screw Size mm	Height of Symbol mm
5 thru 6	1.5 min
8 thru 10	2.3 min
12 and 14	3.2 min
16 and larger	4.0 min

Metric bolts and screws shall not be marked with radial line symbols.

6.2 Studs—All studs of sizes M5 and larger shall be marked permanently and clearly to identify the property class. The symbols used shall be as given in Table 6. Markings shall be located on the extreme end of the stud, and may be raised or depressed at the option of the manufacturer. For studs with an interference fit thread, the markings shall be located at the nut end. Studs of sizes smaller than M12 may be marked using the property class symbols given in Table 6.